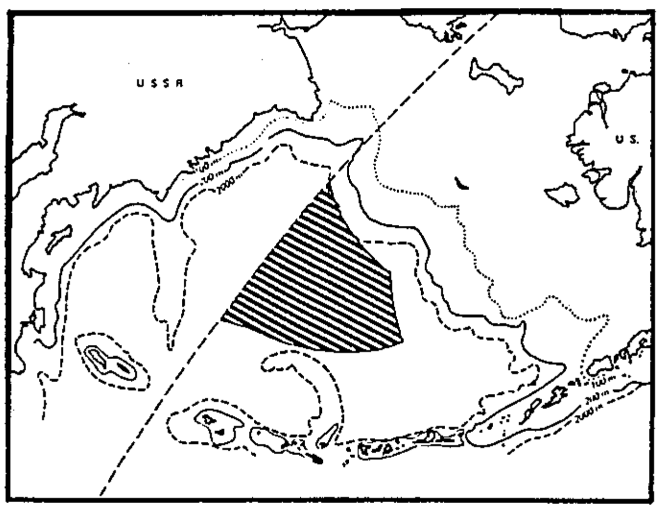
Compilation of Papers
Presented at the

INTERNATIONAL SYMPOSIUM ON BERING SEA FISHERIES

April 2-5, 1990
KHABAROVSK, U.S.S.R.



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Compilation of Papers Presented at the

INTERNATIONAL SYMPOSIUM ON BERING SEA FISHERIES

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INTERNATIONAL SYMPOSIUM ON BERING SEA FISHERIES
KHABAROVSK, U.S.S.R.
APRIL 2-5, 1990

(Remarks by Loh-Lee Low)

INTRODUCTION

This is a compilation of the papers presented at the second international symposium on Bering Sea Fisheries. The Proceedings of the symposium is being compiled by VNIRO (the All-Union Research Institute of Marine Fisheries and Oceanography), Moscow, U.S.S.R.

GENERAL INFORMATION

Symposium Title:	International Scientific Symposium on Bering Sea Fisheries	
Dates of the Symposium:	April 2-5, 1990	
Location:	Khabarovsk, U.S.S.R.	
Head of Delegation: and Delegation size	U.S.S.R.	(Studenetsky, Novikov; 40)
	U.S.	(Aron; 6)
	Japan	(Morimoto, Sasaki, 14)
	ROK	(Chong Kab Lae, Yeong Gong; 3)
	PRC	(Song ZhiWen; 3)
	Poland	(Karnizki; 4)
	Canada	(Shaw, 1)

U.S. Participants: (From AFSC) William Aron, Loh-Lee Low, Jimmie Traynor, Neal Williamson
(From ADF&G) Douglas Eggers
(From Univ. of Alaska) Ole A. Mathisen

ORGANIZATION OF THE SYMPOSIUM

The symposium was organized in five Panels with a session on Research Planning:

Panel 1 Oceanography	(Chair:	Rodionov, USSR)
	(Rapporteur:	Khen, USSR)
Panel 2 Reproduction and Early Life History	(Chair:	Bulatov, USSR)
	(Rapporteur:	Serebriakov, USSR)
Panel 3 Population Structure	(Chair:	Traynor, U.S.)
	(Rapporteur:	Eggers, U.S.)

Panel 4 Commercial Fisheries	(Chair:	Karnizki, Poland
	(Rapporteur:	Stepanenko, USSR)
Panel 5 Stock Assessment	(Chair:	Shaw, Canada and Sasaki, Japan)
	(Rapporteur:	Low, U.S.)

The papers presented are listed in the Agenda. There were more papers submitted than presented. All the papers submitted are anticipated to be published in the proceedings of the symposium.

PAPERS PRESENTED AT EACH PANEL

A summary of papers presented at each Panel was made by the Rapporteur and a rough draft has been circulated for comment. Each national section has been asked to review the draft and submit comments to VNIRO for compilation into the final Proceedings.

Most of the papers that are of special relevance to Bering Sea donut pollock issues were discussed in Panels 3 and 5.

Catch Statistics: The history of pollock catches (in thousands of metric tons) from 1980 to 1989 are listed below:

Donut Hole Zone							U.S.	U.S.S.R.
YR	PRC	JAPAN	ROK	PPR	USSR	Donut hole total	EEZ All nations	EEZ
80		2.4	12.5				958.3	
81		0.2	0				973.5	
82		1.2	2.9				955.9	
83		4.1	66.6				982.4	
84		100.9	80.3			181.2	1,098.8	756
85	1.6	136.5	82.4	115.8		336.3	1,178.8	662
86	3.2	698.0	155.7	163.2	41	1,061.1	1,189.4	838
87	4.1	802.6	241.9	230.3	158	1,436.9	1,253.5	688
88	17.4	749.2	268.6	298.7	135	1,468.9	1,228.0	1,253
89	-	647.1	302.0	268.6	-	-	-	-

P.R.C. - People's Republic of China.
R.O.K. - Republic of Korea.
P.P.R. - Polish People's Republic.
EEZ - Exclusive Economic Zone.

Stock Structure: Papers on stock structure presented in Panels 3 and 5 portrayed that there are three major stocks of pollock in the Bering Sea: a western Bering Sea stock, an Aleutian Basin stock, and an eastern Bering Sea stock. There was no evidence of a unique self-sustaining stock in the donut hole area.

The most comprehensive diagram of stock migration pattern was presented in a paper by Dr. Fadeyev from the U.S.S.R. (see Figure 1 of this summary). The migratory pattern suggests that most of the pollock that are found in the Aleutian Basin resulted from spawning in the U.S. EEZ (Bogoslof and eastern Bering Sea shelf-slope areas) and reared on the eastern Bering Sea shelf as juveniles (until age 5).

Stock assessment, conditions of the stocks, and allowable catch levels: There were three major papers presented on stock assessments that estimated stock biomass and allowable catch levels. The first paper was by Mito (Japan) who conducted a cohort analysis of the three major stocks. The second paper was by Horbowy and Janusz (Poland) who presented a cohort analysis of the Aleutian Basin stock. The third paper was by Low (U.S.) who suggested allowable catch levels of pollock resources for the Bering Sea.

The Japanese paper suggested that the allowable catch for 1990 for the entire Bering Sea should be about 4.29-6.31 million metric tons. The Polish paper suggested that the exploitable biomass for the Aleutian Basin stock was about 15.3 million metric tons in 1989 and that the present rate of harvest in the donut hole (about 1.3 million mt) is very low. The U.S. paper reported on the conclusions reached by the Bering Sea Fisheries Advisory Body (BSFAB) that suggested the appropriate harvest level for 1990 at 2.63 million mt.

The differences in estimates (in million metric tons) for 1990 can best be illustrated for the three stocks presented in the papers as:

	Biomass Estimates (MMT)			Allowable Harvest (MMT)		
	Japanese	Polish	U.S.	Japanese	Polish	U.S.
EBS stock	9.5	-	6.5	1.71	-	1.6
Aleutian Basin	20.8	15.3	2.0	2.16	-	0.5
WBS stock	-	-	1.5	0.43	-	0.4

There are substantial differences in the numbers above, especially for the biomass of the Aleutian Basin stock (15-21 million mt from the Japanese and Polish papers and 2 million mt from the U.S. paper). There was considerable debate at the symposium of these estimates and the participants agreed that a technical workshop on stock assessment would have to be conducted later to resolve the differences.

Despite these differences, the symposium brought together much expertise, new data, and many papers on marine resources in the Bering Sea that would not have been made available otherwise. Therefore, the symposium was a very constructive forum for bringing together major scientists to address Bering Sea donut pollock issues and to plan coordinated research.

RESEARCH PLANNING AND COORDINATION

The participants agreed to the following research and coordination:

1. Conduct a workshop on ageing techniques in Poland this year to standardize age determination methodology.

2. Agreed that all nations provide detailed catch-effort statistics according to a standard format. We also agreed that the U.S. will be the "clearing house" for the data base.

3. Conduct a workshop on biomass estimation and age-structured analysis in Seattle. This workshop will be used to examine all of the data and different combinations of cohort analyses will be performed to arrive at a closer understanding of pollock stock biomass and allowable harvests. This workshop would take place after data are derived from the ageing workshop.

4. Agreed that all the countries cooperate on surveys. Details of these surveys and national participation are to be worked out later.

5. Stressed that research must be conducted throughout the range of Bering Sea pollock stocks, which include the need to enter USSR waters to conduct research.

FUTURE SYMPOSIUM

This topic was not addressed, although there was informal desire and agreement to hold further symposia of a similar nature.

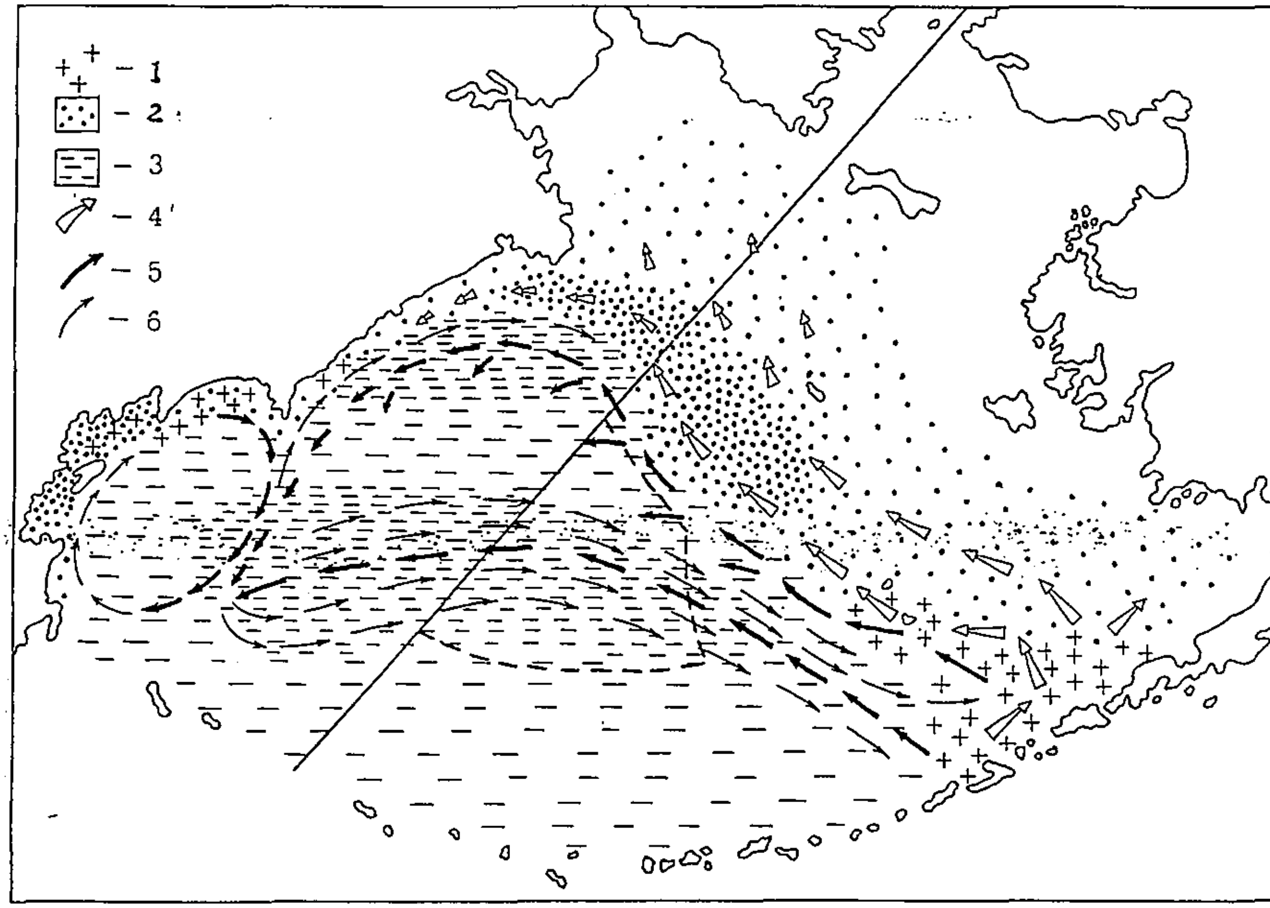

Figure 1. Representation of pollock stocks in the Bering Sea and their migration paths as presented in a paper by N. Fadeyev entitled "The walleye pollock migrations in the Bering Sea".

Notations:

1 indicates spawning locations
2 indicates distributions of juveniles ages 1 to 4
3 indicates distribution of adults ages 5 and above

4 indicates paths of eggs and larvel drift
5 indicates migration paths of juveniles ages 1 to 4
6 indicates migration of adults ages 5 and above

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INTERNATIONAL SYMPOSIUM ON BERING SEA FISHERIES

Khabarovsk, U.S.S.R.
April 2-5, 1990

LIST OF PARTICIPANTS

DELEGATION FROM PEOPLE'S REPUBLIC OF CHINA

1. Song Zhiwen - Deputy Director, Bureau of Fisheries Management and Fishing Port Superintendence, Ministry of Agriculture, Beijing
2. Tang Qi Sheng - Yellow Sea Fisheries Research Institute, Staff Scientist, Qingdao
3. Zhang Zu Liang - Shanghai Marine Fisheries Company, Deputy Manager, Shanghai

DELEGATION FROM CANADA

4. William Shaw - Pacific Biological Station

DELEGATION FROM JAPAN

5. Minoru Morimoto - Fisheries Agency of Japan (FAJ)
6. Joji Morishita - FAJ
7. Rikio Sato - FAJ
8. Takashi Sasaki - FAJ
9. Keiichi Mito - FAJ
10. Ko Fuyuki - Japan Fisheries Association
11. Ken Kobayashi - Japan Deep Sea Trawlers Association (JDSTA)
12. Tomosaburo Nakada - JDSTA
13. Motoyoshi Shitou - JDSTA
14. Mr. Yamamoto - National Federation of Medium Trawlers
15. Kaori Kawamoto - Interpreter
16. Itsuko Sakai - Intepreter
17. Jay Hastings - Counselor
18. Steven Johnson - Counselor

DELEGATION FROM REPUBLIC OF KOREA

19. Chong, Kab Lae - Director-General, National Fisheries Research & Development Agency (NFRDA)
20. Gong, Yeong - NFRDA
21. Hur, Young Hee - NFRDA
22. Kim, Yong Chul - Executive Director, Samhomulsan

DELEGATION FROM UNITED STATES OF AMERICA

23. William Aron	-	Science & Research Director, Alaska Fisheries Science Center (AFSC) National Marine Fisheries Service
24. Loh-Lee Low	-	AFSC
25. Jimmie Traynor	-	ASFC
26. Neal Williamson	-	AFSC
27. Douglas Eggers	-	Alaska Department of Fish and Game
28. Ole Mathisen	-	University of Alaska, Juneau

DELEGATION FROM THE U.S.S.R.

Steering Committee

29. V. K. Zilanov	-	Chairman, Deputy Minister of Fisheries
30. . . Morozov	-	Deputy Chairman, Vice-Governor of Khabarovsk Territory
31. V. V. Shergin	-	Deputy Chairman, Khabarovskrybprom Chief Engineer
32. S. A. Studenetsky	-	Deputy Chairman, VNIRO Director
33. N. P. Novikov	-	Deputy Chairman, TINRO Director
34. F. T. Stuk	-	Head of the Commercial Fisheries and International Relations Dept., Khabarovskrybprom
35. M. A. Stepanenko	-	TINRO Chief Scientist
36. M. Ya. Kazarnovsky	-	VNIRO International Relations Division Deputy Head
37. V. R. Ushakov	-	TINRO Amur Branch Deputy Director
38. V. P. Tumanov	-	TINRO International Relations Laboratory Head
39. T. A. Chernobylskaya	-	Khabarovskrybprom Administration Staff Head
40. L. I. Shepel	-	Secretary of the U.S.-U.S.S.R. Fisheries Commission
41. O. A. Bulatov	-	TINRO Deputy Director

TINRO

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43. A. I. Abakumov	-	Head of Laboratory
44. L. S. Kodolov	-	Department Head
45. Ye. I. Sobolevsky	-	Chief scientist
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47. K. A. Zgurovsky	-	Senior scientist
48. A. G. Slizkin	-	Senior scientist
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50. Y. N. Tuponogov	-	Staff scientist
51. M. G. Suchkova	-	Staff scientist

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59. A. A. Churikov	-	Senior scientist
60. S. N. Rodionov	-	Senior scientist
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63. A. M. Privalikhin	-	Staff scientist
64. N. K. Prusova	-	Interpreter

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68. . . Maksimenko	-	Senior scientist
69. A. F. Tolstyak	-	Staff scientist
70. V. I. Karpenko	-	Staff scientist
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72. G. M. Marayeva	-	Interpreter

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74. Jan Sprus	-	
75. Edward Purchla	-	
76. Jerzy Janusz	-	Sea Fisheries Institute

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AGENDA FOR THE SECOND INTERNATIONAL SYMPOSIUM ON BERING SEA FISHERIES

Khabarovsk, U.S.S.R.

April 2, Monday

10am - 12noon	Working meeting of the delegations' heads
6pm - 8pm	Welcome reception party

April 3, Tuesday

9am - 10am	Opening Ceremony

PANEL 1: Oceanography

10am - 10:30am	**G. Khen, S. Glebova.** Warming of the Bering and Okhotsk Seas in the last decade.
10:30am - 11am	**A. Krovnin, S. Rodinov.** Interannual variability of thermal conditions in the Bering Sea.
11am - 11:30am	**D. Schumacher, R. Reed.** Suggestion for a fishery oceanography coordinated investigation cruise for the Bering Sea.
11:30am - 12noon	Coffee break

PANEL 2: Reproduction and Early Life Stages

12noon - 12:30pm	**L. Halderson, O. Mathisen.** A study on pollock spawning and level of food supply.
12:30pm - 1pm	**Z. A. Voronina, A. M. Privalikhin.** Bering Sea pollock fecundity.
1pm - 3pm	Lunch break

PANEL 3: Population Studies

3pm - 3:30pm	**P. Dawson.** Information on the stock structure of Bering Sea pollock.
3:30 pm - 4pm	**A. Nitta, T. Sasaki.** Study on stock identification of walleye pollock based on morphometric data.
4pm - 4:30pm	Coffee break
4:30pm - 5pm	**Yong Hee Hur.** Comparison of meristic characteristics of Alaska pollock from

	seven geographical areas of the North Pacific.
5pm - 5:30pm	**T. Sasaki.** Preliminary report on the second research cruise by Kaiyo maru for fiscal 1989. Research on pollock stock in the international waters of the Bering Sea.
5:30pm - 6pm	**Ye. Ilyinsky** et al. The hypothesis of the existence of near-bottom and pelagic pollock.

April 4, Wednesday

PANEL 4: Some Data Regarding Fisheries Results

9am - 9:30am	**Yong Gong.** Status of the Korean trawl fishery for Alaska pollock in the Bering Sea in 1987-1988.
9:30am - 10am	**T. Yoshimura and T. Sasaki.** Outline of Japanese trawl fishery in the international waters of Bering Sea (1986-1989).
10am - 10:30am	**M. Kowalewska-Pahlke.** Biological information on walleye pollock based on Polish catches in the international waters of the Bering Sea in 1988.

PANEL 5: Stock Assessment

11 am - 11:30am	**O. Bulatov.** The fishery and state of stocks of the most important fish species.
11:30am - 12noon	Coffee break
12noon - 12:30pm	**Kei-ichi Mito.** Stock assessment of walleye pollock in the Bering Sea under assumption of three stocks.
12:30pm - 1pm	**J. Horbowy, J. Janusz.** Assessment of walleye pollock biomass in the Aleutian Basin based on cohort analysis and Polish fisheries data.
1pm - 3pm	Lunch break
3pm - 3:30pm	**N. Fadeyev.** The walleye pollock migrations in the Bering Sea.
3:30pm - 4pm	**B. G. Ivanov.** Shrimp stocks monitoring in the Western Bering Sea.
4pm - 4:30pm	Coffee break

4:30pm - 5pm	**Ye. Sobolevsky, Ye. Dulepova, V. Radchenko.** Structure and functioning of ichthyocoenosis of the Bering Sea epipelagial.
5pm - 5:30pm	**Loh-Lee Low.** Harvest levels for Bering Sea pollock.
5:30pm - 6pm	**R. Beamish.** An examination of age determination structure of walleye pollock from five stocks in the North-West Pacific.

April 5, Thursday

PANEL 5: Stock Assessment (continued)

9am - 9:30am	**N. Naumenko** et al. Year-to-year variations of stocks and community structure of Western Bering Sea pelagic fishes.
9:30am - 10am	**T. Sasaki.** Distribution, abundance, length composition and potential yield of Pacific cod in Gulf of Anadyrsky and waters off Cape Navarin and Cape Olyutorsky.
10am - 10:30am	**L. Grachyov.** Stock state and commercial use of salmon in the Western Bering Sea.
10:30am - 11am	**J. Traynor.** Preliminary results from surveys of walleye pollock in the Aleutian Basin in 1988 and 1989.
11am - 1pm	Open discussion on future research activities planning. Other business.
1pm - 3pm	Lunch break
3pm - 5pm	Main results and scientific ideas of the Symposium. Summary.
5pm - 6pm	Closing ceremony
6:30pm	Farewell party

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Draft Summary of Papers Presented at Khabarovsk Symposium on Bering Sea Fisheries

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Panel 1 Oceanography
Chairman - Dr Rodionov S.N.
Rapporteur - Dr.G.Khen

Brief results of the Panel discussions

The Panel discussed the most important tasks of commercial oceanography in the Bering sea. Much time was spent reviewing regular patterns of year-to-year variations in environmental conditions and characterizing the currents in the internatio-nal waters of the Bering sea.

At the Panel three papers were presented. Main ideas and results of the papers are given below.

Depending on the modern state of the problems connected to the Bering sea commercial objects' studies, the following primary tasks for the fisheries oceanography become clear in the present.

1. Studies of multi-annual variation regularities of the environmental conditions, and the problems of long-term forecasting.

2. The detalization of currents in the Bering Sea central part.

Presentations by Soviet scientists Drs. Khen and Glebova, and Krovnin and Rodionov, dealt with the regular patterns of large--scale variations of thermal conditions in the Bering Sea there exists the large-scale variation of thermic conditions.

After sharp cooling that took place in 1970s, warm regime was established 12-13 later, such a regime is still characteristic of the Bering Sea. The sea warming in 1980s can be explained by the peculiarities of the atmospheric processes development, but the duration of this period is rather surprising. If this warming is connected to atmospheric processes, then, according to Khen and Glebova in the nearest future the next sea cooling will take place.

The question of the exact time of the modern existing regime change is rather complicated,so the forecasts are so far preliminar If one takes into consideration the temporal scale of the quasistationary climatic processes (5-15 years),it is possible that the warm regime of the Bering sea is near its end. On the other hand, taking into consideration that the solar activity maximum will take place approximately in 1991, Drs. Krovnin and Rodionov suppose that the existing regime will continue into the said year. But if the high temperature background of the Bering Sea is connected to the global climate warming,then the 1980s process will continue. In this case,the consequences of the continuing warming will be unpredictable.In any case, it is proposed to study both variants.

So far, we have no facts of water temperature influence on the abundance of the Alaska pollock, the main commercial object, available.But the general tendency to increasing or decreasing of the walleye pollock year-classes' abundance in the process of cooling or warming is evident from the presentation by Drs. Krovnin and Rodionov. So we have some hope that the latest warm years' year-classes are more abundant than at least the year--classes of the cold 1970s.

The suggestions by Drs. Schumacher and Reed regarding the cooperative studies of the Bering Sea central deep-water part,including the USSR zone,in 1991, is worth discussing,in more detail. The problems of the fisheries oceanography in those areas especially concern the directions and speeds of currents,the strength of tidal currents over the Shirshov Ridge,and the water masses exchange via the straits.

If it is possible to carry out the specialized cooperative research, it will be possible to discuss the problems of the whole Bering Sea currents at one of the future Symposia at the Oceanography Panel.

Panel 2. Reproduction and Early Life History

Chairman - Bulatov O.A.

Rappopteur - Serebriakov V.P.

Two papers were presented in which main results of studies on pollock fecundity in the Bering Sea are given. The research was made at the most modern technical level. Brief review is given below.

The papers presented at the Panel were:

L.Haldørson and O.Mathisen "A study on pollock spawning and level of food supply".

E.Voronina, A.Privalikhin and M.Suchkova "Bering Sea pollock fecundity". The first paper is devoted to ~~distribution and~~ growth of larvae in ~~the Bering Sea~~, ~~In~~ small local ecosystems, ~~depending on the~~ development of primary production, ~~presence~~ of copepode nauplii and density of larvas, ~~distribution day by day starting fro the spawning time~~. Thus, it was somehow verification of Dr.Hjort's hypothesis about "~~crucial~~ period in the development of larvae". In the second paper the results of study on maturity and fecundity of pollock are given. It was found out that pollock spawn once a year and that in gonads upto 6-16% of undeveloped oocytes are ~~met~~. This fact should be taken into consideration when trying to determine individual fecundity. It was also found that there are differences in individual fecundity, of age groups during different years, and that during the last three years the population fecundity decreased 4 times.

Both paper demonstrated two different approaches to the problem of recruitment. In the first paper a ~~trial~~ was made to clarify what in the environment were the most important ~~factors~~ determining ~~year class strength~~. In the second how this value ~~can~~ determine the process of fecundity forming. This can be used for determination of spawning levels of population fecundity and according the threshold biomass of spawning stock. Determination of fecundity should be a standard procedure, the same as age determination. To study the process of copepod abundance ~~forming~~, it would be desirable to use satellite information about water temperature and currents during spawning and drift of pollock eggs and larvae.

Panel 3. Population study

Chairman: Dr.Traynor

Rapporteur: Dr.Eggers

Brief results of the Panel discussion.

Five papers were presented. Practical and theoretical items of Bering Sea pollock population study were reviewed. Methods of stocks division using morphometric data were shown, comparative analysis of meristic characteristics of pollock stocks in the North Pacific was given, hypothetic theory of pollock belonging to bottom or pelagic communities. Brief contents of the papers are given below.

Paper by Dawson.

Five different procedures including age composition, length at age, mitochondrial DNA studies, timing of spawning, and oceanography were used to examine stock structure of Bering Sea pollock. The combination of age composition, length at age and DNA studies indicate that pollock in the donut hole and in the US portion of the Aleutian Basin are members of the same stock. Recent surveys have found very few pollock spawning in the doughnut hole and at the same time found a large spawning population in the southeastern Aleutian Basin in the vicinity of Bogoslof Island. Because no juvenile or younger mature pollock have been found in the Aleutian Basinand because the prevailing direction and velocity of currents in the Bogoslof area would carry larvae onto the Eastern Bering Sea shelf, pollock in the doughnut or elsewhere in the eastern Aleutian Basin cannot be a self contained stock but are dependant on recruitment from outside the Aleutian Basin.

Paper by Nitta and Sasaki

Morphometric measurements through a truss network measurement system (TNM) were taken on pollock from three different areas, off Hachinohe in the northwestern Pacific, the international waters of the Bering sea, and the continental shelf of the eastern Bering Sea. The measurements were standardized to length and classified based on discrimant analysis. The classification accuracy was high for the three samples analysed.

Paper by Gong, Hur and Kim

Meristic measurements, including the number of rays of the three dorsal and two anal fins, the number of gillrakers on the first gill area, and the number of vertebrae were taken of pollock from seven areas of the North Pacific. The Asian areas including two areas around Hokkaido are two areas from the sea of Japan, the Bering sea areas included the central and southeastern Aleutian Basin and the eastern Bering Sea shelf. The mean numbers of vertebrae and gillrakers were significantly different between the Bering Sea and Asian area groups, however, these differences were not significant for areas within the asian group or for areas within the Bering Sea group.

Paper by Sasaki

Preliminary results of the second cruise by "Kaiyo Maru" that occurred 20 January - 16 February, 1990 in the International zone of the central Bering Sea, were presented. Pollock were observed in extremely low densities. 93,7% of the female pollock had mature overies, however, only 0,7% of the female pollock had hydrated oocytes, indicating that no active spawning was occurring at the time of the survey.

Paper by Ilyinsky et al.

Analysis of pollock catch and effort data for the western Bering Sea suggests that two distinctive groups of pollock occur there. The first group is a less abundant bottom oriented group restricted to the continental shelf. The second group is the more abundant and is oriented in mid-water. There are distinct differences in the size composition between the two groups, with the first being greater than 55cm and the second 40-45cm in length. The mid-water group appears to migrate between the shelf and the Aleutian and Komandorsky Basins. Because the bottom-oriented group has a much larger length at age, than the mid-water group, the two groups are thought to be separate stocks.

Panel 4. SOME DATA REGARDING FISHERIES RESULTS

Chairman. Dr.Karnicky

Rapporteur: Dr.Stepanenko

SUMMARY

In three papers presented at the panel some data and results of the commercial activities in the Bering Sea international waters by Korean and Polish fishing vessels were considered,as well as the R/V "Kaiyo Maru" investigations in 1988-1989.

The contents of the presented papers is given in brief below:

Dr.Yeoug Gong: The status of the Korean trawl fishery for Alaska pollock in the Bering Sea in 1987-1988. The Korean side presented the data on above,noting that the CPUE has considerably decreased even in this short period. The main commercial harvesting of Alaska pollock in the central part of the sea was carried out in October-January. There is substancial seasonal variation of the CPUE. It is minimal in August-September and maximal - in October-January.

There is also significant seasonal variation of Alaska pollock vertical distribution: in winter it inhabits greater depths,mainly 200-300m, in spring and summer it is distributed in the upper layer of 100-200m deep.

The Alaska pollock size composition increase is also noted recently in the central part of the sea. In the latest years the Korean trwalers started to employ the trwals with a considerably larger vertical opening than in the early decade,

Dr.T.Sasaki presented the results of the pelagic trawl survey carried out in the Aleutian Basin in the winter season of 1988/198 The comparison of the results of this survey with the same of the past showed that the CPUE has recently decreased. The main harvesting of Aleutian pollock takes place in October-January; basid the second period of the intensive commercial activity is observed in April-May,when the fishing fleet operates on the after--spawned Alaska pollock.

Despite the main commercial Alaska pollock harvesting taking place in the southern part of the Central Bering Sea ("Doughnut hole"area), there exists the considerable seasonal variation of the commercial activities' distribution. The japanese commercial fishing for Alaska pollock is practically sustained throughout the whole Central Bering Sea.

Dr.

Dr.Kowalewsha-Pahlke: Biological information on Alaska pollock based on Polish catches in the Bering Sea international waters in 1989. The total Alaska pollock harvest by Poland in 1989 in the Doughnut hole area amounted to 268.6 thousand tons. That year the main Alaska pollock concentrations were observed in the central and south-eastern part of the doughnut hole. The fish sized 39-63cm was observed in the catches. It was noted that in comparison to the previous years, the 1989 Alaska pollock was larger in size. The 1977 and 1978 year-classes were dominant. In September-October the 1981 and 1983 year-classes were observed in the catches. The studies of 1989 didnot reveal any substencial variation in the Alaska pollock biomass in the doughnut hole area.

At the same time, it was noted that the CPUE in 1989 was slightly less than in 1988. On the basis of that data, as well as of the age structure stability, the conclusion is drawn that the existing fishing does not influence the Alaska pollock stocks state. As in the doughnut hole area the constantly spawning Alaska pollock is observed, the supposition is made that at least some part of Alaska pollock spawns within this area.

PANEL 5. STOCK ASSESSMENT

CHAIRMAN: Dr.SHAW, Dr.SASAKI

RAPPORTEUR: Dr.Loh-Lee LOW

(This section was drafted but had not been typed for distribution at the symposium)

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Agreement Reached on Planning and Coordination of Research at International Symposium on Bering Sea Fisheries held at Khabarovsk, U.S.S.R.

April 5, 1990

Based upon the papers presented and discussed at the Symposium, the participants noted that there was further needs to conduct coordinated studies and workshops to resolve a variety of questions. The participants agreed that:

(1) A workshop on ageing methodology be convened in Poland later this year to standardize age determination techniques for pollock.

(2) All participating nations provide data on their commercial fisheries in the Bering Sea according to a format suggested by Japan. It was further agreed that Japan coordinate the receipt of these data and the U.S. would serve as "clearing house" for their computerization.

(3) A workshop on biomass estimation and age structure analysis be convened in Seattle after the ageing workshop.

(4) Research on pollock and oceanography should be coordinated and conducted throughout the Bering Sea. Details of such cruises and their coordination are to be pursued through correspondence.

In the course of further discussions, the following points were also made:

(1) Poland extended an invitation for participants to visit its plankton sorting and identification center to exchange views on methodology and procedures used for egg and larvae studies.

(2) Poland also urged that the classification criteria used for gonad maturity be standardized. The participants agreed that these exercises can be conducted via correspondence.

(3) All the nations that have research vessels conducting cruises on pollock resources expressed a willingness to accept participation by scientists of the other nations, subject of course, to normal practical constraints.

Draft Proposal for Standardizing Data Collection and Reporting

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COMPILER's NOTES

The following proposal to collect data from Bering Sea pollock fisheries was presented by the Fisheries Agency of Japan. The proposal was based upon a conclusion made at a Bering Sea pollock symposium held in Shimizu, Japan in the summer of 1989. The participants at that symposium were from Japan, Poland, and the Republic of Korea.

It was agreed at the Khabarovsk symposium that such a standardized data collection system will be useful and that national participants will submit comments about the data to be collected to the Fishery Agency of Japan.

It was also agreed that:

1. The Fisheries Agency of Japan will coordinate timely receipt of the data, and

2. The United States (the Alaska Fisheries Science Center in Seattle) will serve as the "clearing house" and computerize the data.

A DRAFT OF STANDARDIZED PROCEDURES FOR REPORTING CATCH AND EFFORT DATA OF THE BERING SEA POLLOCK FISHERY

FISHERIES AGENCY OF JAPAN

APRIL 1990

On the basis of the mutual understanding reached at the Scientific Meeting on International Cooperation for Pollock Research in the Bering Sea held at Shimizu, Japan in August, 1989, Japan has prepared a draft format for reporting catch and effort data as attached.

With regard to the standardized procedures for handling reported data submitted in accordance with the agreed format, Japan believes we need more discussions on such matters as;

(i) What are the necessary steps for handling the data ?
(ii) What are the necessary capacities to process the data ?
(iii) Who should be "the clearing house" ?
(iv) How should the processed data be utilized ?
(v) How should the processed data be publisized, when necessary ?

DRAFT

Fishing Data Format for the Bering Sea Pollock Fishieries (to be submitted to the clearing House)

1 2	3 4	5	6	7	8 9	10 ~ 15	16	17 18 19	20 ~ 24	25~30
Year	Month	Country	P	S	Area	Position	G	Number of Hauling	Duration of Hauling	Catch
8 8	0 2	2 2 4 3	6	5	6 0	0 1 7 8	3	1 0 0	2 4 0 0 0	0 0 1 1 4 3

Year (lower two digits of the year) : column 1,2
Month : column 3,4
Country : column 5
P (Type of operation) : column 6
S (Class of Tonnage of Vessel) : column 7
Area : column 8,9
Position (Longitude & Latitude) : column 10 ~ 15
G (Fishing Method) : column 16
Number of Hauling (times) : column 17,18,19
Duration of Hauling (houurs) : column 20 ~ 24
Catch (metric tons : pollock only) : column 25 ~30

Code Table and Unit

Country (column 5)

PEOPLE'S REPUBLIC OF CHINA	:	1
JAPAN	:	2
REPUBLIC OF KOREA	:	3
REPUBLIC OF POLAND	:	4
UNION OF SOVIET SOCIALIST REPUBLICS	:	5
UNITED STATES OF AMERICA	:	6

P : Type of Operation (column 6)

(Mothership (processing) : 1 Mothership (other) : 2
Joint Venture (catcher) : 3 Trawl (processing) : 4
Trawl (other) : 5)

More detailed definition needed or regrouping; eg. Catcher (Surimi processor, other processor, freezer and other)

S : Class of Tonnage of Fishing Vessel (column 7)

~ 300 ton	0	~ 350	1	~ 400	2
~ 500	3	~ 1,000	4	~ 1,500	5
~ 2,500	6	~ 3,500	7	~ 4,500	8
4,500 ~	9				

Area (column 8,9)

By the five areas (I, II, III, IV, V) plus international waters as independent Block VI

Position (column 10 ~ 15)

By subarea of 1 degree in longitude and 30 minutes in latitude

* Distinction of 0 ~ 30 minutes and 30 ~ 60 (0) minutes in longitude identified by the third digit of Position column

0 ~ 30 minutes : 0 , 30 ~ 60 (0) minutes : 1

Distintion of the east longitude and west longitude is identified by the first digit of last four digit numbers.

East Longitude : 0 , West Longitude : 1 .

G : Fishing Method (column 16)

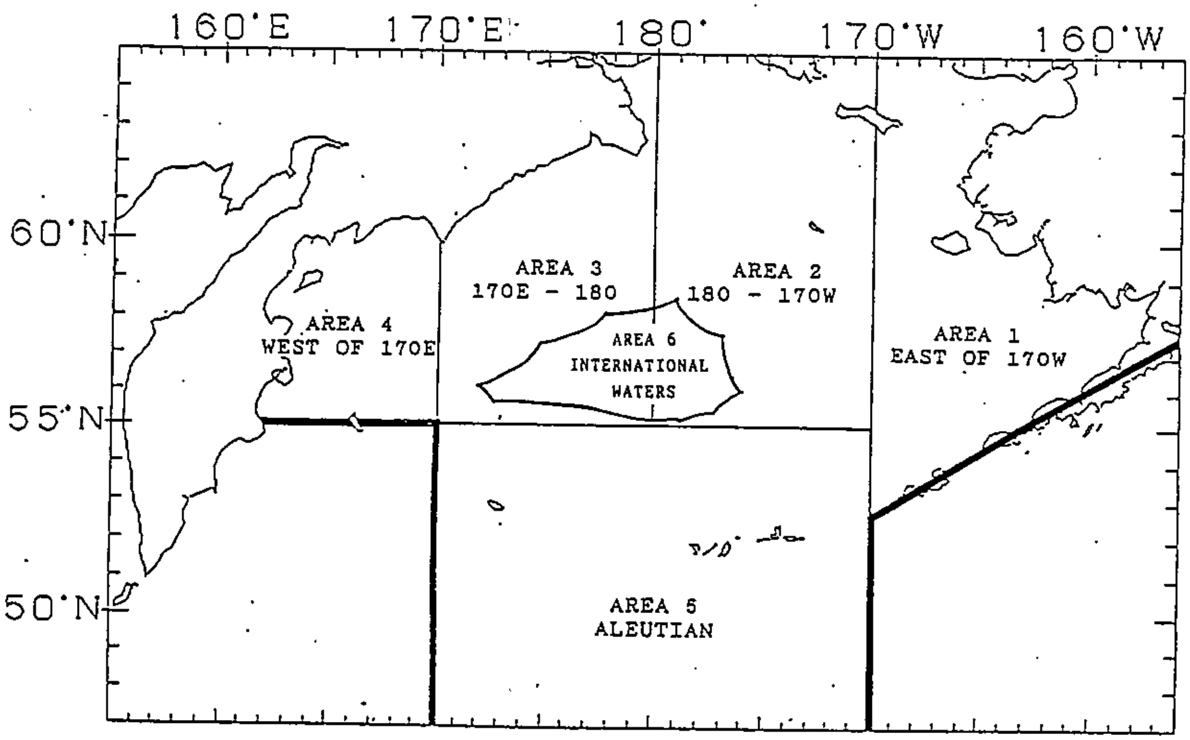
On-bottom Trawl : 1 Demarsal : 2
Mid-water Trawl : 3

Duration of Hauling (column 20 ~ 24)

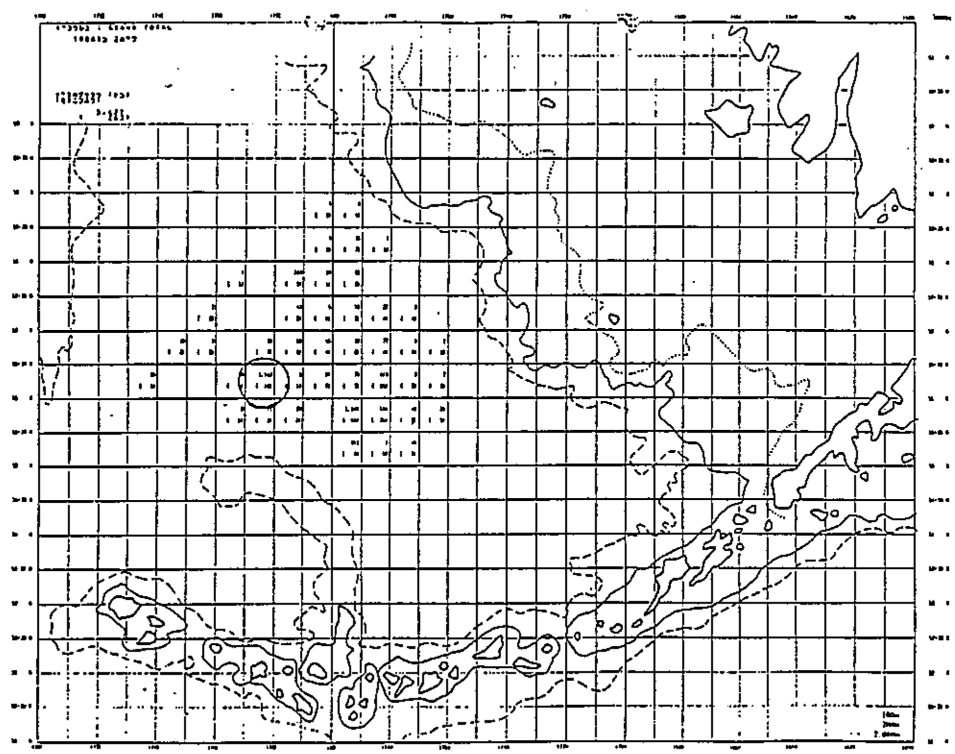
Unit : hours

Catch (column 25 ~ 30)

Unit : metric ton



Statistical areal divisions of the Bering Sea and Aleutian Region.



Closing Statements
by
Each National Section

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Closing Remarks by Canada

Given by: William Shaw
Pacific Biological Station
Nanaimo, Canada

On behalf of the Canadian delegation I would like to thank Dr. Novikov and all of our Soviet colleagues for organizing the Symposium and for the warm hospitality extended to all of us.

During the course of this Symposium a large number of papers have been presented. It is through forums as this which enable all of us to come together and to contribute to the knowledge of the biology of Bering Sea pollock and to discuss the development of rational management.

As I mentioned in my opening remarks Canada is not engaged in a pollock fishery in the Bering Sea yet I can see that we are pursuing the same goals, as for pollock off of our coast, and that is to attain a better understanding of the pollock resource.

When I was participating for the first time on the walleye pollock cooperative survey aboard the Japanese research vessel KAIYO MARU, I was amazed how hard it was to work in the Bering Sea. This is not only due to such adverse weather but observing the complexity of Bering Sea pollock. There are many unknowns, yet I am impressed at the great strides everyone has taken to reveal these unknowns.

We have heard how very large stocks of certain commercially important species have existed in the past, however they can only be found in textbooks. All of us are deeply committed to conserving this very valuable resource and to prevent history from repeating itself. I admire all of you for your strong committment to continued cooperation research and will continue to support this effort.

Closing Remarks by the Chinese Delegation

Given by: Song ZhiWen
Ministry of Agriculture, Fisheries and Animal Husbandry
Beijing, People's Republic of China

Mr. Chairman, ladies and gentlemen:

First of all, please allow me on behalf of the Chinese delegation to express our heartfelt gratitude to the host of the Symposium, our Soviet colleagues, particularly to Mr. Chairman, Dr. Novikov, and Dr. Studentsky, and all the organizers who successfully arranged the Symposium for the enthusiastic and friendly reception given to us.

It is over one year and a half since the International Scientific Symposium on Bering Sea Fisheries held in July of 1988 in Sitka, U.S.A. At the end of that Symposium, all of us showed concern over the Bering Sea fishery and deemed it necessary to carry out scientific investigations continuously and to further strengthen our cooperation in this sea area. Now once again we meet here to attend this International Scientific Symposium on Bering Sea Fisheries. It is of great importance and significance to us.

Walleye pollock is the most abundant fishery resource in North Pacific and provides a huge source for human food supplies. Chinese vessels have been using the resources in the high seas of the Bering Sea since 1985, catching about 32,000 metric tons in 1989. It is still a developing fishery, but has become more important for our developing long distance fishing operations. We pay a great attention to the sustained and steady state of the fishery resources.

At this Symposium, many scientists and fishery experts have furnished some information of the progress they have made in fishery production and investigations on fishery resources and put forth their views and opinions which will contribute to a better understanding of the present state of fishery resources, particularly the walleye pollock resource in this sea area. As we know, fishery resources are renewable living resources which have their own characteristics. It is very difficult to carry out fishery investigations for there exist many limiting factors. It is a time-consuming and very expensive activity. It is specifically noted that many of the views at this Symposium are quite different and, as a whole, the information on the fishery resources and the fisheries is extremely scant in this area. No clear explanation for some changes has been given so far, and the major causes are probably natural and that a direct link with the effects of fishing may be very weak. Further intensified research and documentation in this area is still urgently awaited. In this regard, we should make sustained efforts to accumulate data over a long period of time and maybe no immediate effects can be brought about in a short period of time. Meanwhile, we all know that if scientific evaluations lack for fishery resources, the views and opinions on the development of the fishery in a sea area will be groundless. Therefore, it is really a complicated and difficult task, a long-term task before us. We should cooperate fully with each other in the work and make prompt evaluations of the progress we will make so as to develop the fishery in the Bering high seas and in the whole Bering Sea on a sustained basis.

Thank you.

Closing Remarks by the Japanese Delegation

Given by: Dr. Takashi Sasaki
National Research Institute for Far Seas Fisheries
Fisheries Agency of Japan
Shimizu, Japan

Mr. Chairman, ladies and gentlemen and distinguished delegates. I would like to express my highest appreciation to the government and scientists of the USSR as well as to Khabarovskrybprom and the city of Khabarovsk who have given us their wholehearted hospitality here in Khabarovsk and who have quite successfully carried out this important international meeting.

During the last three days we have had meaningful and frank scientific discussions on subjects such as oceanography, reproduction, population structure, fisheries data, and stock assessment. I believe this scientific symposium has succeeded in presenting a significant amount of new scientific knowledge obtained on the pollock resources of the Bering Sea since the Sitka and Shimizu meetings.

However, there exists some differences of opinion among the participants of this meeting. For example, Japanese data and study demonstrates that there is an abundant and stable pollock resource in the Aleutian Basin. Although this data and study is recognized by some scientists, others disagree. There also seems to be some differing hypotheses on stock structure.

The very existence of these differences in opinions supports our long-standing belief that we should be discussing these issues of the Bering Sea pollock fisheries within an international forum in which all nations concerned, including both the fishing and coastal nations, would participate on an equal basis. As we are all committed to rationally conserving, managing, and utilizing the pollock resources in the Bering Sea for years to come, we should not impose a particular opinion upon others. We also should not disregard any scientific opinions. What we should do is to discuss these issues within an international forum with all the necessary data available.

From this point of view, earlier today we proposed a draft format of standardized procedures for reporting catch and effort data in the Bering Sea pollock fisheries. This format was completed by the help and suggestions from Poland and the Republic of Korea on the basis of our mutual understanding reached at the international meeting for scientific research cooperation on the pollock resources in the Bering Sea which was held in Shimizu, Japan, in 1989. Although we could not adequately discuss this draft format at this meeting because of the limited time available, let me stress that it is most important to report catch and effort on the pollock fisheries both within and outside the Bering high seas in order to have a better understanding of the pollock resources. It seems to be necessary ~~to have a workshop~~ to study more extensively the draft format and the procedures for compiling and utilizing the data.

We also proposed research in the Commandor Basin of the western Bering Sea within the 200-mile zone of the USSR. It is essential to conduct research in this area to have a comprehensive understanding of the entire Bering Sea, particularly the Aleutian Basin. The significant increase in the pollock catch by the Soviet fleet in this area in 1988 also gives us an obligation to study this area.

Page two

Japan supports the proposal made by the delegation of Poland to hold a workshop in Poland this fall on the subject of age determination technology. This proposal is in line with the agreement at the Shimizu meeting to hold technical workshops on particular subjects regarding pollock studies.

We understand that the United States has agreed to host a workshop on ~~cohort analysis~~ Stock Assessment techniques. This is a very important subject and there are obviously significant disagreements between us in this area, as shown by some of the presentations and discussions at this symposium. Therefore, we would strongly support the formation of such a workshop.

Furthermore, Japan intends to continue and strengthen its research and study activities with the cooperation of scientists from the nations participating in this symposium. As I explained earlier today, we will conduct a mid-water trawl survey this summer employing a quantitative echo-sounder system. The construction of a new Kaiyo Maru research vessel will also be completed in 1991 for further improvement of our future research capability.

Finally, as an interim measure until a true international fisheries organization dealing with pollock resources in the Bering high seas is established, let me express my support for the idea to hold international scientific discussions like this symposium on a periodic basis to further the scientific knowledge on the pollock resources of the entire Bering Sea.

Thank you Mr. Chairman.

Closing Remarks by the Korean Delegation

Given by: Chong Kab Lae
Director-General
National Fisheries Research and Development Agency
Republic of Korea

Dear Chairman.

It is my great pleasure to have an opportunity to express my express my opinion on the discuss in this symposium by the extensive research work from the coastal and fishing nations since last symposium

I fuond that many useful information on the Alaska pollock in the Bering Sea were presented to the symposium by the extensive research work from the coastal and fishing nations since last symposium.

However, I noticed that there are split ideas in the discussion on the stock structure and population size which were main topics in this symposium.
This means that we need much more research works and information on the fishery to get generally to get generally acceptive results on the topics.

I would like to suggest that every nations involved in the fishery in the fishery in the entire Bering Sea should exchange every information from research vessels as well as from commercial fishing activities between the scientific groups.

It seems to me that an integration of groups be organised and through which all the opinions of the countries involved in the fishery in this area be reflected for the effective utilization of the pollock resources in the high seas of the Bering Sea.

Finally, I would like to express my sincere thanks to the Khabarovsk governor and the staffs of VNIRO and TINRO.

Thakk you.

Closing Remarks by the Polish Delegation

Given by: Dr. Z. S. Karnicki
Sea Fisheries Institute
Gdynia, Poland

(The closing statement by Dr. Karnicki was not given out at the symposium)

Closing Remarks by United States Delegation

Given by: Dr. William Aron
Science and Research Director
Alaska Fisheries Science Center
National Marine Fisheries Service
Seattle, Washington

It is with pleasure that I begin my closing comments with a strong sense of gratitude to our hosts for their many kindnesses, their effective organization of a challenging meeting and their warm hospitality. I must also thank each of the Symposium participants for the excellence of their presentations and analyses. All of us learned a great deal at this Symposium both in terms of clarifying past uncertainties and, of no less importance, providing a sense of the direction that must be followed to close critical gaps of our knowledge.

What have we learned?

1. Based on investigations of stock identification by scientists from Japan, Korea, the USSR and the US there is a broad agreement on the existence of at least three stocks in the Bering Sea. These papers provided no support for the existence of a unique, self-sustaining stock in the "doughnut hole".

2. Studies by Soviet scientists on the distribution of eggs, larvae and the movement of pollock in the Bering Sea are consistent with the above conclusions.

3. We listened to important contributions from Japan, Korea and Poland regarding their commercial fisheries in the "doughnut hole". These papers all showed a downward trend in CPUE data, consistent with the downward trends in the Bering Sea reported by the USSR and the USA. Questions were raised by some delegates about the value of using CPUE data for assessing these trends.

4. There was little agreement on the health of pollock populations, widely disparate views on the status of stocks were presented. Currently available data and analysis do not permit a satisfactory resolution of these differences.

What must we do?

1. The grave uncertainty that exists virtually demands that fishing practices be conservative. Foolish optimism carries the risks of repeating the history of other geographic regions and destroying a world class natural resource.

2. With the clear recognition that conservative fishing practices have a cost in terms of human food resources our differences of views must be urgently resolved through:

a. Expanded research to gather necessary data about pollock populations, their distribution, abundance and the impacts of environmental change on these parameters.

b. Strengthened cooperation between all scientists working on the problem to minimize duplication, resolve disagreements about scientific analises, assure comparability of field data. Interchange of scientists and the development of joint research cruises can assist these efforts.

c. For some critical areas of concern including aging methods, analytical approaches, especially cohort analysis, workshops should be held to standardize methods and resolve differences. Accordingly the US support Poland's proposal to host an aging workshop and also offers to host a workshop on Age-Structured Analysis of Bering Sea Pollock. We will be please to provide the necessary computer facilities and be pleased to examine all of the data provided by the participants through appropriate combinations of analysis.

The U.S. is, of course, prepared to fully cooperate in the efforts essential to build the understanding required to menage the pollock resource of the Bering Sea.

Closing Remarks by Soviet Delegation

Given by: Dr. S.A. Studenetsky
Director, VNIRO, Moscow

Dear colleagues, I would like to note the importance of our symposium, and I hope it is going to be a good tradition from now on.

I should say that the problem of exploitation of the Bering Sea pollock is vitally important for us, not only for the Far East fishermen to follow the development of this problem very closely, but also the people of the Far East who are connected with the development of this region's economy. All of them want to be sure that pollock catches will be stable for the future years. Naturally, we are greatly concerned with the pollock stock stake.

On the basis of scientific study carried out by Soviet scientists in the past during the two years after the Sitka Symposium and on judging from our colleagues, scientists from other countries' presentations at this symposium, the Soviet delegation believes that modern knowledge on biology and Bering Sea pollock population structure allows us to a very high degree of certainty to come to the conclusion that the international water's fishery is mainly directed on the pollock of mixed U.S. and U.S.S.R. origin. At the same time, we believe that we should go on with the intensive study of pollock and other species of the Bering Sea, as well as environmental conditions study.

In conclusion, I would like to note that exchange of results of scientific research and exchange of ideas are very important for national use of the Bering Sea resources. I suppose we are on the right tract, and we should go on with organization of this kind of symposium.

Thank you for your attention.

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Panel 1: Oceanography

Warming of the Bering and the Okhotsk Seas in the Last Decade

Khen, G.V. and S.Y. Glebova
TINRO, Vladivostok, U.S.S.R.

When analyzing interannual variations of thermal conditions, revealing apparent and oblique regularity, it is always necessary to be supported by a series of observations for many years, while drawing up a series of forecasts. The more number of periods of one or another temporary extent is in a series, the safer the forecast of appropriate scale of priority. That is why one of the primary tasks of commercial oceanographh is a search of such criterion that could allow to have the maximum long series of observations in actual commercial area.

Unfortunately, there is no section like Kolsiy in the Barent sea both in the Bering sea and the sea of Okhotsk. But even in case it were, it would be impossible to have a notion about thermal state of the entire Basin by one section, for in the Far-East seas cases of apparent counterphase between north and south, east and west are not infrequent, the data of shore stations cannot reflect the essence of processes taking place in high seas. That is why icing was taken as a criterion of thermal state, regular observations of icing have been conducted since 1960 in the Bering sea and since 1957 - in the sea of Okhotsk.

While studying interannual variations of any oceanological parameter it is necessary to exclude interannual fluctuations; amplitude of which is rather high to conceal a course for many years. It might be possible to choose any decade or month for an analysis but it is difficult to determine the most informative among them. Even the term of maximum icing is changed from year to year from the third decade of February to the first decade of April. Averaging of icing was conducted in January-April to avoid errors that allowed to derive average winter icing for each year.

Average winter icing was subjected to high interannual fluctuations (Fig.1) within the limits of observed series in both seas. Amplitude of fluctuations was 24% in the Bering sea: from 18% - in the warmest year, 1979 up to 42% - in the coldest 1976. The amplitude of fluctuations is higher in the sea of Okhotsk (36%) but total icing is also higher: from 50 to 86% in extreme years.

Spectral analysis didnot reveal apparent prevalence of any regularity. The best contribution is made by 11-year-old cycle in both seas, then 5-6 year-old cycle comes as for the level of significance. 2-year-old regularity is additionally distinguished in the sea of Okhotsk.

The availability of 11-year-old cycle is probably related to the fluctuations of solar activity. It is not by chance that as solar activity increases in the Bering sea, the level of icing considerably decreases and in the sea of Okhotsk it is just vice versa, -the level of icing increases. When Wolf's numbers are reduced, the change of signs of anomalies takes place in one of the seas, but counterphase of processes is the same. Counterphase was revealed particularly clear in extreme years. The colder in one sea the warmer in another one.

Grouping of adjacent years of the same type (table 1) was carried out to have clearer idea of counterphase of processes. Alternation of warm and cold periods is clear from the table both in the Bering sea and the sea of Okhotsk.Therefore,cooling with increased level of icing was observed in the Bering sea in 1960-1965,1971-1977, and warming with low-icing winters - in 1966-1970,1978-1983.Cold periods for the sea of Okhotsk are 1960-1961,1966-1973,1978-1983 and warm periods - 1962-1965, 1974-1977,1984-1989.Therefore,thermal conditions were actually developed in counterphase in both seas. till 1983. Nevertheless, ice processes have been developing by type of warm or mean years in both seas starting since 1985 and up to nowadays. Icing was quite below the norm in the Bering sea even in extremely warm year for the sea of Okhotsk,1989.

Warming of the sea of Okhotsk in the second half of the 80s proves 11-year-old rhythmics of interannual fluctuations, whereas the warm background is likely to be an anomaly in the Bering sea. By analogy with past years alternation of signs of anomalies had to occur in the Bering sea in the mid 80s and up to nowadays icing in winter must be above the norm.

By present state of thermal conditions (reduced level of icing is in both seas for the last 5 years) it can be concluded about change of counterphase of processes.Is it really so? Let us go back to the schedule of course for many years but with 5-year-old sliding averaging (Fig.2). Therefore,2-year-old and 5-6 year-old fluctuations were artificially excluded from the course for many years,that allowed to demonstrate 11-year-ol cycle more visually. As it can be noted,notwithstanding the low icing during the last years,11 year-old cycle has been violated in the Bering sea.An increase of icing with regard to previous phase of low icing winters occured here in the mid 80s in conformity with 11 year-old rhythmics.Nevertheless,it

Table I.

Indices of warm conditions of the Bering Sea and the sea of Okhotsk

Years	The Bering sea			The sea of Okhotsk		
	Signs of anomalies	types of years	periods	signs of anomalies	types of years	periods
I960	+	A	C	+	C	COLD
I96I	+	C		+	C	
I962	0	A	O	–	W	W
I963	0	A		–	W	
I964	+	C	L	–	C	A
I965	+	C	D	–	W	R M
I966	–	W	W	+	C	
I967	–	W		+	C	C
I968	–	W	A	–	A	
I969	–	W	R	0	A	O
I970	–	A	N	+	A	L D
I97I	+	C	C	–	C	C
I972	+	C	O	+	A	C
I973	+	A	L	+	C	C
I974	+	A	D	–	W	W
I975	+	C		–	W	A
I976	+	C		–	W	R
I977	+	C		+	A	M
I978	–	W		+	C	C
I979	–	W		+	C	
I980	–	A	W	+	C	O
I98I	–	A		0	A	
I982	–	W	A	+	A	L
I983	–	A		+	C	
I984	+	A	R M	–	W	D
I985	–	W		+	A	W
I986	–	A		–	W	
I987	–	W		–	W	A
I988	–	A		–	A	
I989	–	W		–	W	R M

C-COLD, A-AVERAGE,W-WARM

is much lower than that of previous cold periods, even lower than average meaning for many years.

The given situation is very likely to be related to general warming of the Bering sea, the reasons could be either anomalous development of atmospheric processes or the global warming of the Earth climate.

It is no doubt that fluctuations of icing are related to peculiarities of atmospheric processes that occur over the North Pacific and counterphase of the sea of Okhotsk and the Bering sea are related to location and intensity of high-altitude ridges and hollows that have direct influence upon cyclonic activity off the Earth surface. Three types of macroprocesses are distinguished by Girse A.A. by the state of high-altitude frontal area in the Far-Eastern region: first - meridional (M_1), second - meridional (M_2), zonal (3) (Fig.3).

At M_1 vast ridge is located over the North-western Pacific, high-altitude hollows are by both sides of it: one hollow is directed southward from the Arcticareas along the eastern coast of Asia (Far-eastern hollow) and the second hollow - to the west areas of American continent. At M_2 the sign of baric field is alternated: large-scale hollow is located over the North-western Pacific, and well-developed ridges are to the right and left of that hollow. Both types of processes are an example of meridional form of circulation.

Tropospherical waves either completely disappear or their amplitude is very low at zonal state of high-altitude frontal zone, besides they are changed over some areas but rapidly shift in the direction from the west to eastward.

At M_1 development highly-gradient zone with severe northern winds appears to be over the sea of Okhotsk transfering cold masses of Arctic air from Chukotka that promotes intensive cooling of the Okhotsk sea waters and as a consequence it promotes development of extremely high icing in this area. The opposite situation is observed in the next basin. Cyclones moving from the south transfer warm oceanic air to the Bering sea preventing rapid water cooling.

In case of dominance of macrocirculation from M_2 in troposphere in winter, the character of development of hydrothermal regimes of the Okhotsk and Bering seas is considerably changed, primarily due to the change of trajectory of shifting near-ground cyclones. Cyclonic activity gets lower over the Bering sea, that leads to inflow limit of warm air masses into this area from the ocean, located in the rear part of cyclones of Aleutian depression. The Bering sea is subjected to the inflow of cold arctic air that results in intensive cooling of water surface and development of considerable icing.

And vice versa, an increase of total temperature background in the sea of Okhotsk basin is stipulated by development of cyclogenesis over this area. Moreover, the shift of the Aleutian depression center eastward protects the sea of Okhotsk from the influence of its cold rear part. All this results in slower cooling of the area and quite slow ice accumulation.

Therefore, development of icing occurs in counterphase in the sea of Okhotsk and Bering sea when one or another meridional form of processes prevails in troposphere. More intensive icing is marked in the sea of Okhotsk at M_1, and in the Bering sea - at M_2.

In some years, the level of icing in neighbouring Basins can be changed in one phase as it has been revealed. As a rule it is observed during zonal transfers. Moreover, ice condition can be either identically easy ar identically hard, depending on high-altitude front zone position.

In case if latitude-orientated frontal zone is located southernmost of both seas, over the North-west Pacific, both areas are turned out to be in the Arctic sector under the influence of cold air masses. Cyclones, moving southernmost, affect the sea by their rear parts. that is why northern transfers are observed in the entire area. Under such situation identically rapid cooling takes place in both Basins. resulting in extreme high icing. Penetration of Arctic air to the area is decreased and vice versa, an influence of warmer air masses of temporate latitude gets higher when high-altitude frontal zone is northernmost. Total increase of temperature background limits icing development both in the Okhotsk and Bering seas.

Such are the main counterphase mechanisms of processes in the Bering sea and sea of Okhotsk hydrosphere and possible variants of synchronous cooling in both Basins. If it is assumed that peculiarities of development of atmospheric processes are the main reason of synchronous warming of the Okhotsk and Bering seas in the last decade, - restoration of counterphase of signs of anomalies in hydroshere cam be expected after a number of years.

Consequences of global warming of the Earth can be non--inverse and lead to further intensification of processes of warming in both seas that will be related to the state of commercial objects. Possible shift of hydrological zones causes the concern that will undoubtedly result in violation of modern ecological balance. It is not excepted that an amount of some species of fish will rapidly fall down and the amount of other species will be increased. Even "outburst" in abundance of non-traditional species are possible for these seas.

Certainly, it is difficult to confirm that it will namely be this way. It is no doubt that more detailed investigations of causes and regularities of long-term variations of warm stete of the Far-eastern seas are required and thorough working out of both cause and effect variants to the last detail.

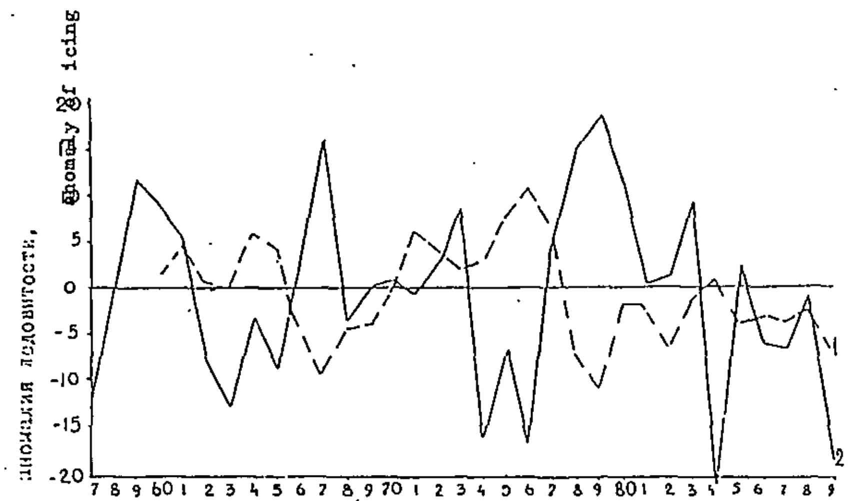

Fig. 1. Fluctuations of icing anomalies in the Bering (1) and Okhotsk (2) seas for many years.

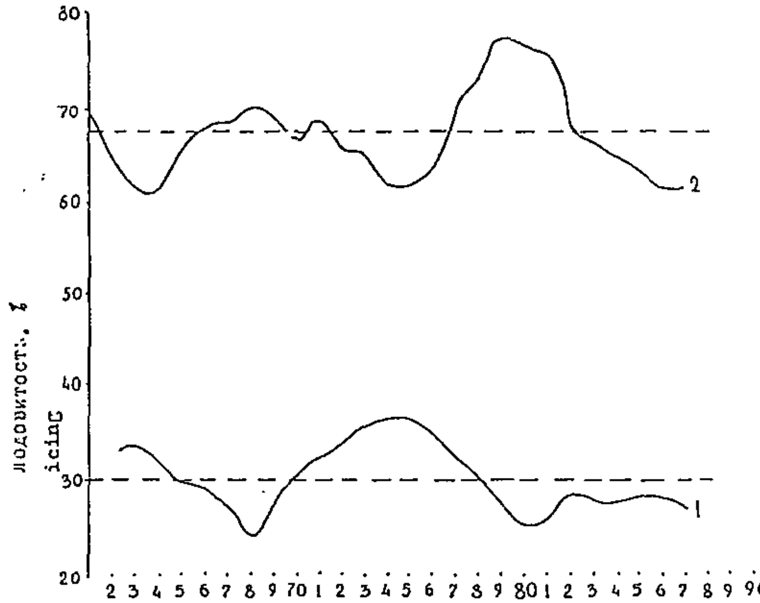

Fig. 2. Fluctuations of icing of the Bering (1) and Okhotsk seas for many years at 5 year-old sliding averaging. Average levels of icing for many years are shown as dotted lines.

Interannual Variability of Thermal Conditions in the Bering Sea

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During the last decades three periods are distinguished rather clearly in variations of thermal conditions in the Bering Sea: 1965-1969, 1970-1976, and from 1977 up to now. Fig. 1a shows the changes of sea surface temperatures (SST) around the Pribilof Islands. As it is seen the first period is characterized by positive anomalies of SST. In 1970 a rather sharp decline of temperature occurred and the cold period started. But since 1977 a level of SST fluctuations rose again abruptly.

The existence of these three periods of quasistationary SST variations with rather sharp transition from one climatic regime to another is not only regional phenomenon which is inherent with the Bering Sea. Similar periods show up in other time series of thermal characteristics, often thousands of miles distant from the Bering Sea. Thus, Namias (1982) defined the above climatic regimes in air temperatures in the south-eastern United States. The variations of air temperature in Fig. 1b are out-of-phase with those of SST in the eastern Bering Sea. Another good example is changes of water temperature in the layer 0-200 m at Kola section in the Barents Sea. These changes serves as a good indicator of thermal conditions in the whole Northeast Atlantic Region.

There is no doubt that manifestation of these three climatic regimes is associated with global or at least hemispherical processes in the ocean and atmosphere. It is known that during 1960's the zonal atmospheric circulation over the Northern Hemisphere was relatively weak, but in 1970's its considerable intensification occurred. Some features of atmospheric circulation change which happened in 1977 are seen in Fig. 2. During 1977-1982 a significant increase of geopotential heights at 500 gPa surface in high latitudes was observed in comparison with the period of 1971-1976 while they decreased in the middle latitudes. As a result zonal atmospheric circulation over the Northern Hemisphere was weakened. This process was accompanied by frequent outbreaks of arctic air masses in the Northeast Atlantic which led to cooling there. On the contrary, the increase of geopotential heights over Alaska and their decrease over the Central North Pacific were responsible for strengthening of southerly flow in the lower troposphere over the Bering Sea which resulted in warming in this region.

As shown by Pavlychev et. al. (1989), the changes of thermal conditions in the Bering Sea are closely related to the pattern of storm tracks. In winter of warm years when meridional forms of atmospheric circulation prevail over the North Pacific the axis of most frequent occurrence of cyclones stretches from the southwest to the northeast bringing about enhanced advection of warm air to the eastern Bering Sea. On the contrary, in cold years zonal forms of circulation develop over the Bering Sea and to the south of it. The axis of most frequent occurrence of cyclones runs along latitudes in the region south of the Aleutian Chain. In this case strong northerly winds over the Bering Sea produce severe winters.

Location and central pressure of the Aleutian Low may be considered as an integral characteristic of storm activity. The deepening of this center of action and its displacement to the east of normal position result in cooling in the Bering Sea. On the contrary, the relatively high central pressure and westward shift or split of minimum lead to mild winters in the Bering Sea. It should be noted that location of the Aleutian Low seems to be more important than atmospheric pressure in its center.

As Namias (1976) pointed out, the Aleutian Low is associated with El Nino/Southern Oscillation (ENSO). During the ENSO events zonal circulation in the temperate latitudes of the North Pacific is enhanced. The Aleutian minimum tends to be more intense and displaced southward and eastward of normal. As shown above this situation brings about the cooling in the Bering Sea.

Statistical correlation analysis of time series of atmospheric and oceanic parameters for the eastern Bering Sea region with an Southern Oscillation Index (SOI) carried out by Neibauer (1986) gives an evidence of significant teleconnections between the tropical Southern Hemisphere SOI and events in the subarctic region of the North Pacific. Maximum correlations range from 9 to 15 months lag behind ENSO events for processes in the Bering Sea. The signs of correlation coefficients all suggest that warming in the eastern Bering Sea follows an ENSO event.

At the first glance, these results are in some contradictions with findings of Namias (1976) and Pavlychev et al. (1989). But disagreement disappears if we take into account a conceptual model of development of large-scale atmospheric and oceanic processes in the subarctic North Pacific, proposed by one of the authors (Rodionov, 1987). This model may be used as a possible explanation of about one year lag between the ENSO and Bering Sea events and existence of quasibiennual oscillations in the subarctic region. According to the model an intensification of zonal atmospheric circulation over the North Pacific (as, for example, during the ENSO events) and correspondent strengthening of North Pacific Drift lead to warming along the west coast of the North America. This can be explained using a well-known Icelin's hypothesis (1940). When the currents in the subtropical gyre become more intensive the gyre shrinks and the split point of North Pacific Drift shifts southward. As a result warmer water is transported into the Gulf of Alaska. The warming in the Gulf of Alaska encourages the deepening of the Aleutian Low and its eastward displacement. Both deepening and its more eastern location lead to further strengthening of North Pacific Drift and increase of SST. However, as the positive SST anomaly is driven by the current along the Aleutian Chain toward the Asian coast, the Aleutian Low shifts in the same direction and sometimes splits. Zonal atmospheric circulation weakens and meridional circulation, on the contrary, enhances. The subtropical high pressure ridge extends to the Aleutian Is. region and advection of cold arctic air along its eastern flank results in the appearance of the negative SST anomaly along the North American coast. This anomaly driven by the Alaska current system to the north and then to the west promotes increasing of meridional gradients both in ocean and atmosphere. As a result, the zonal type circulation establishes again. The period of this auto-oscillatory system is about two years.

As it is really known, the quasibiennual oscillation (QBO) is strongly pronounced in fluctuations of thermal conditions of the

Bering Sea. The QBO is also displayed in variations of relative abundance of pollack stock (RAPS) in the eastern Bering Sea (Hen, 1988). So it is natural to assume an existence of relationship between RAPS and thermal conditions. Nevertheless, correlation coefficients between RASP and water temperature and ice conditions are turned out to be insignificant.

Probably the matter is that the relationship between RASP and thermal conditions is different in various frequency bands. Both thermal conditions and RASP exhibit linear trends so that the warming in the Bering Sea coincides with the negative tendency in the pollack stock size.

Alternative type of relationship seems to exist in the high and intermediate frequency bands, that is in variations from year to year and from one group of years to another. Variations of RASP and ice conditions after the removal of linear trends are represented in Fig.3. The above mentioned climatic regimes become more pronounced in these data. The association between RAPS and thermal conditions is positive now: the warmer the sea the higher the pollack stock.

In order to reveal the similar relationship in QBO cycle the following table has been constructed. Sign "plus" ("minus") in the first row of this Table means that RAPS increases (decreases) up to the year given in the Table from the previous year. Sign "plus" ("minus") in rows 2-5 means warming (cooling) in the Bering Sea in accordance with such factors as ice conditions, southern boundary of cold water (SBCW), water temperature in the layers ~~0-100 m and~~ 0-bottom at sections located to the south of the Pribilof Islands (Pavlychev et al., 1989; Hen,1988) and SST in the grid point 55 N, 170 W (data from archive of Hydrometeorological Center of the USSR).

The Table shows that odds for coincidence of signs of year-to-year variations in RAPS and thermal conditions are rather high and correspondent frequencies vary from 0,64 (for ~~ice~~ SST) to 0,71 (for t_w, 0-bottom.). The frequency increases up to 0,91 if we take into account only those years when the signs in rows 1 and 2-5 are the same that is one can judge about warming or cooling in the Bering Sea rather firmly. The same frequency value is in the case when even one sign in the rows 2-5 coincides with sign in row 1. Thus, we can induce that in interannual time scale warming (cooling) in the Bering Sea is associated with increasing (decreasing) of the relative abundance of the pollack stock.

In order to answer the question whether the warm climatic regime started in 1977 is going on or not let us consider the situation observed during the last years. Changes of mean winter (January-March) SST in the grid point 55 N, 170 W for the period 1970-1989 are shown in Fig.4. As seen, a level of SST fluctuations continue to be rather high despite the fact that in 1988 and 1989 SST decreased slightly.

Fig.5 demonstrates a sequence of maps of geopotential height anomalies in January for the period from 1984 to 1990. All anomaly patterns excluding those of 1986 and 1989 indicate that southerly winds over the eastern Bering Sea prevail.

As it was noted by McLain and Favorite (1976) the severe winters in the Eastern Bering Sea established in the 1970's were associated with the change in SST anomaly pattern in the North Pacific. During the 1960's the positive SST anomalies predominated along the western coast of North America and the pool of colder than normal water was present in the central North Pacific. In contrast, during the 1970's the general sea surface temperature pattern was the opposite: cold along the West Coast and warm in the central North Pacific. As seen in Fig.6, patterns of SST anomalies for winters of 1984-1988 are similar to those in the 1960's but in 1989 spatial distribution of SST anomalies has changed toward the situation observed in 1970's.

A question arises when the existent warm climatic regime will come to the end. The answer on this question is very difficult and speculative. According to Namias (1982), characteristic time scale of the climatic regimes under consideration is about 5-15 years. So it is possible that soon warm regime in the Bering Sea will be terminated. As it was shown above, SST anomaly patterns give us some evidence in favor for this assumption. However, we should take into account that maximum of solar activity is expected about 1991. Favorite and Ingraham (1978) pointed out that during the periods of sunspot maximum the mean winter position of the center of the Aleutian low pressure shifts from the Gulf of Alaska to the western Aleutian Islands. So it can be assumed that the current warm climatic regime in the Bering Sea prolongs until about 1991. Then as the solar activity will start to decrease and zonal atmospheric circulation over the Northern Hemisphere, in accordance with Girs's hypothesis (1971), will strengthen, the cold climatic regime will possibly establish.

Table 1.

NN	Factors	1960's (0–9)	1970's (0–9)	1980's (0–9)	Odds	Frequencies
1	RAPS	+ - + - + - + - +	- - + - + - - + - +	- + + -	—	—
2	Ice	- + + - + + + - -	- - + + - - - + + +	- + + -	16:7	0.70
3	SBCW	+ + + - + - + - +	- - - + - 0 0 + + +	- + - +	14:7	0.67
4	t_w, 0-Bottom	+ - +	- - - + + - - + + +	- + - +	12:5	0.71
5	SST, (55°N, 170°W)		+ - - + - + - + - +	- + + -	9:5	0.64

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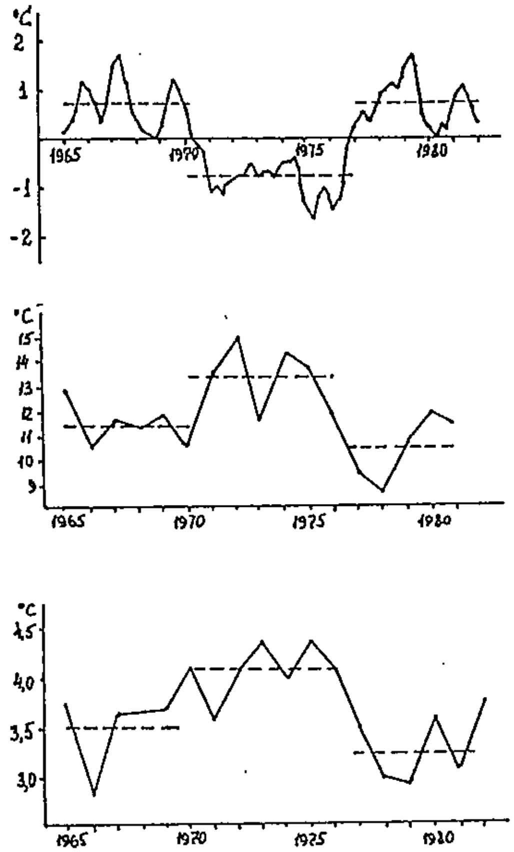

Fig.1 Thermal regimes over the last decades.

a) sea surface temperature around the Pribilof Islands (after Niebauer,1986);

b) winter mean air temperature for New Orleans, Louisiana (after Namias, 1982);

c) sea temperature in the layer 0-200 m at Kola Section in the Barents Sea.

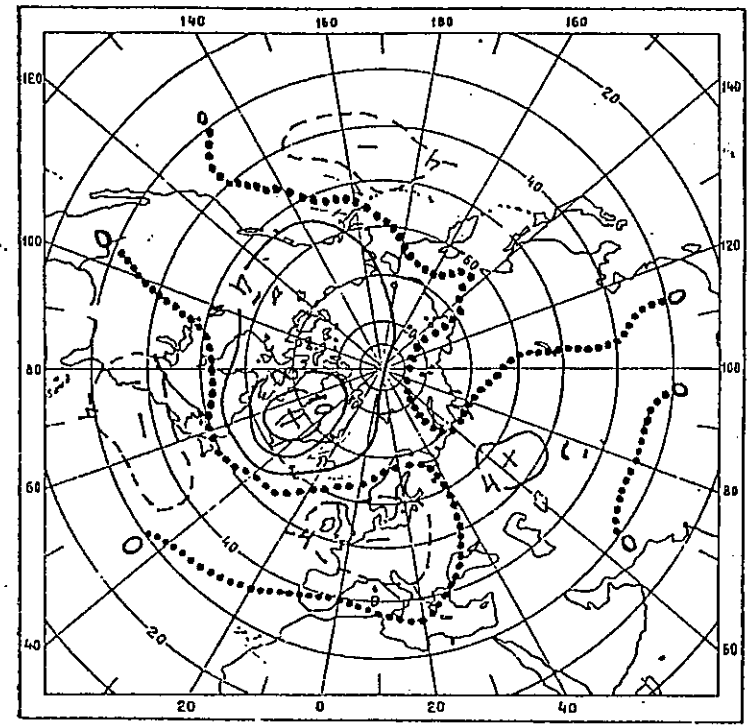

Fig.2 Differences between winter geopotential heights at 500 gPa surface from 1971-1976 to 1977-1982

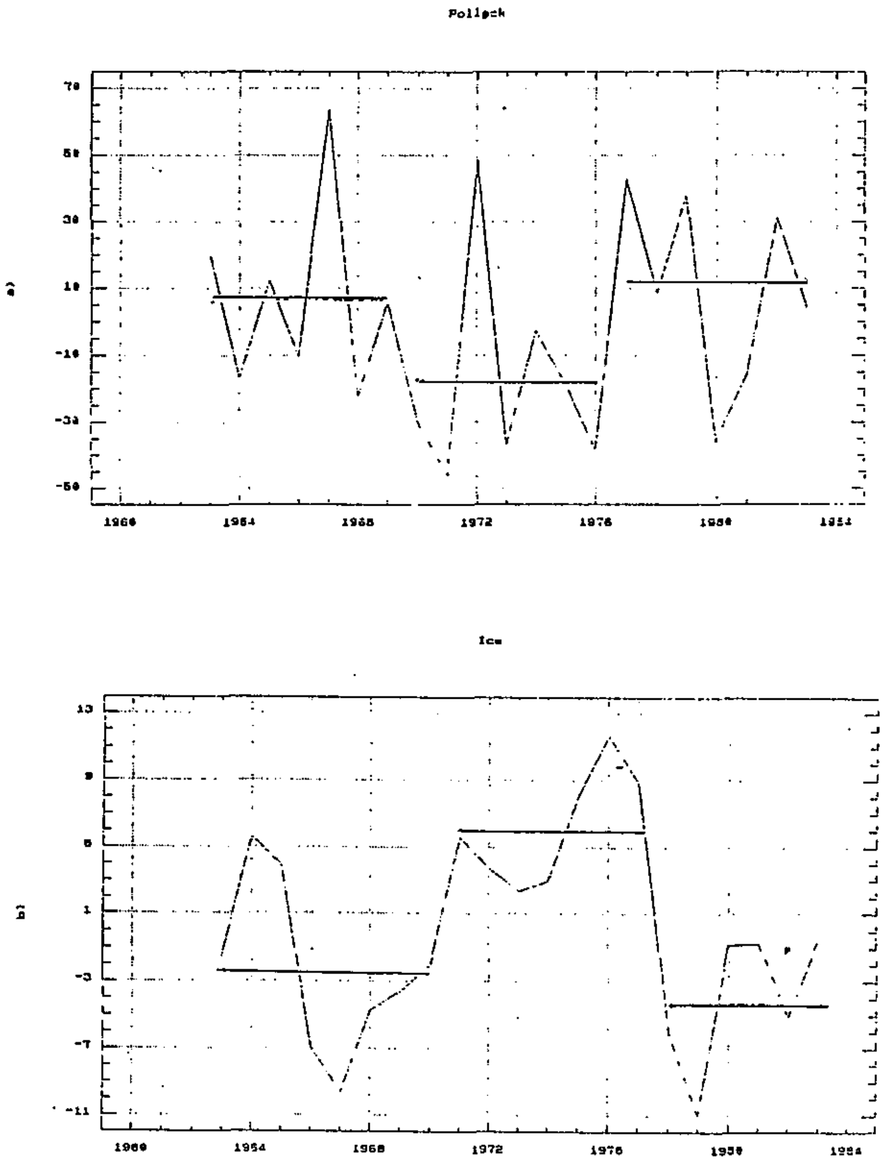

Fig.3 Changes of relative abundance of pollack stock and ice conditions in the Bering Sea after removal of linear trend

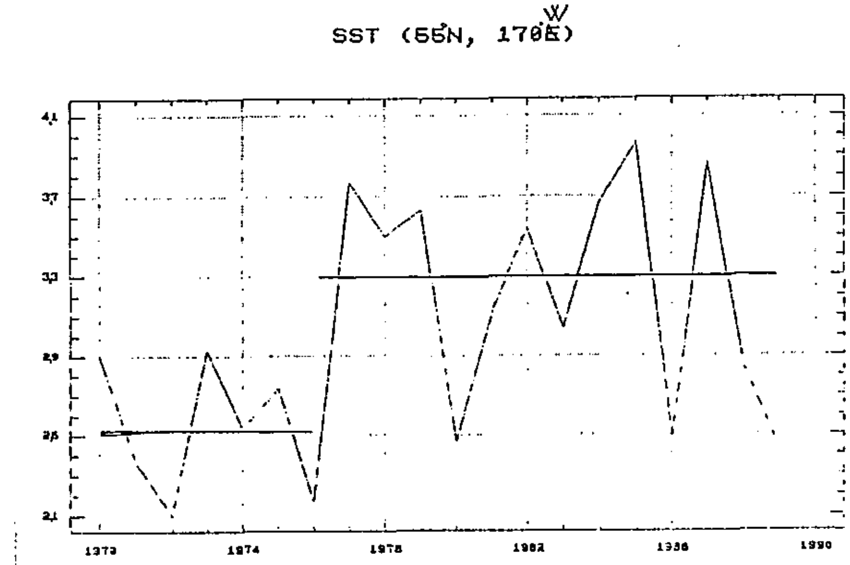

Fig.4 Variations of sea surface temperature at grid point 55°N, 170°W during 1970-1989

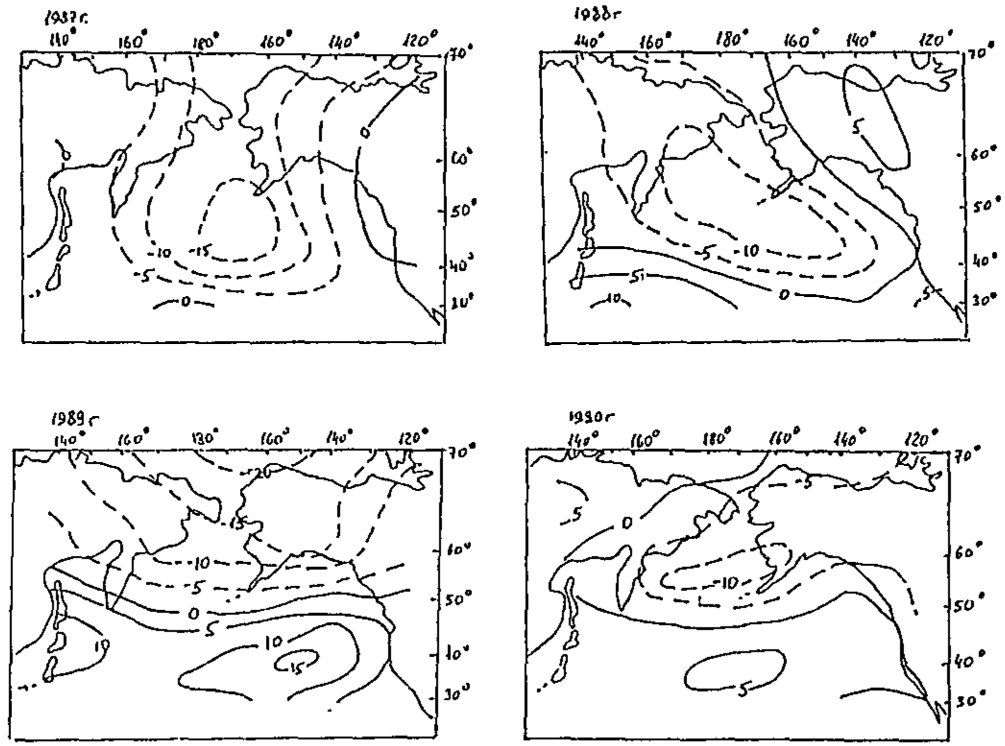

Fig.5 Anomalies of geopotential heights at 500 gPa surface in January, 1984-1990. Departures from mean for 1951-1980

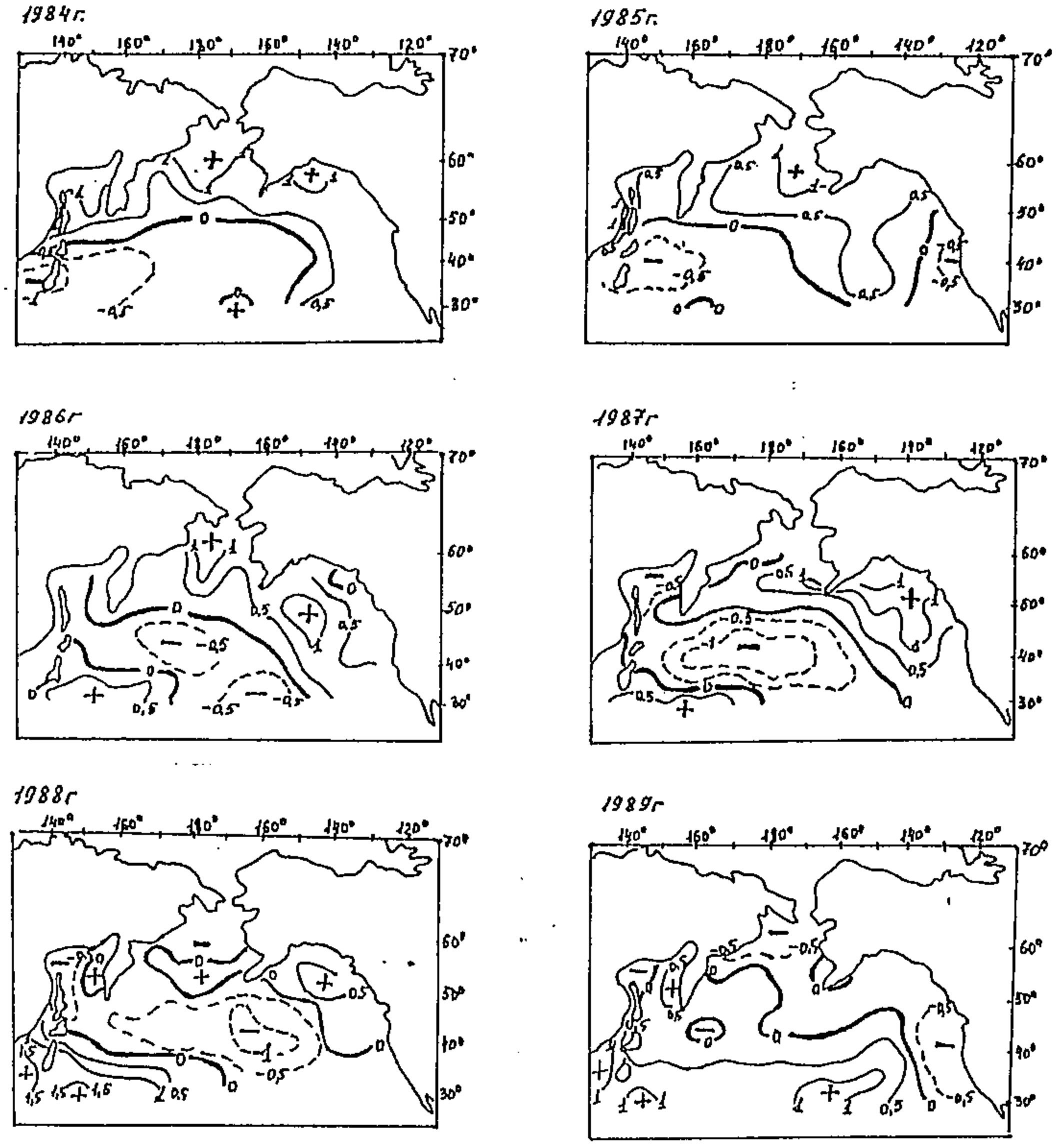

Fig.6 Anomalies of sea surface temperature in winter (January-March),1984-1989. Departures from mean for 1957-1989

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Suggestion for a Fishery Oceanography Coordinated Investigation Cruise for the Bering Sea for Summer 1991

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Prepared for

International Symposium on Bering Sea Fisheries

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at

Khabarovsk, USSR

Pacific Marine Environmental Laboratory
National Oceanic and Atmospheric Administration.
Uited States Department of Commerce

Bering Sea FOCI Plans, Summer 1991

Introduction --The Fisheries Oceanography Coordinated Investigations (FOCI) is an effort by the National Oceanic and Atmospheric Administration (NOAA) to understand causes of recruitment variability of valuable fish and shellfish stocks of the Gulf of Alaska and Bering Sea. Our main interest is in walleye pollock (*Theragra chalcogramma*), which is a major commercial resource in the Bering Sea. Variations in survival during early life stages, especially the larval stage, are thought to be the major factor leading to enhanced or reduced recruitment. Numerous biological interactions and physical processes play important roles. Variations in ocean circulation and the transport of larvae are especially significant.

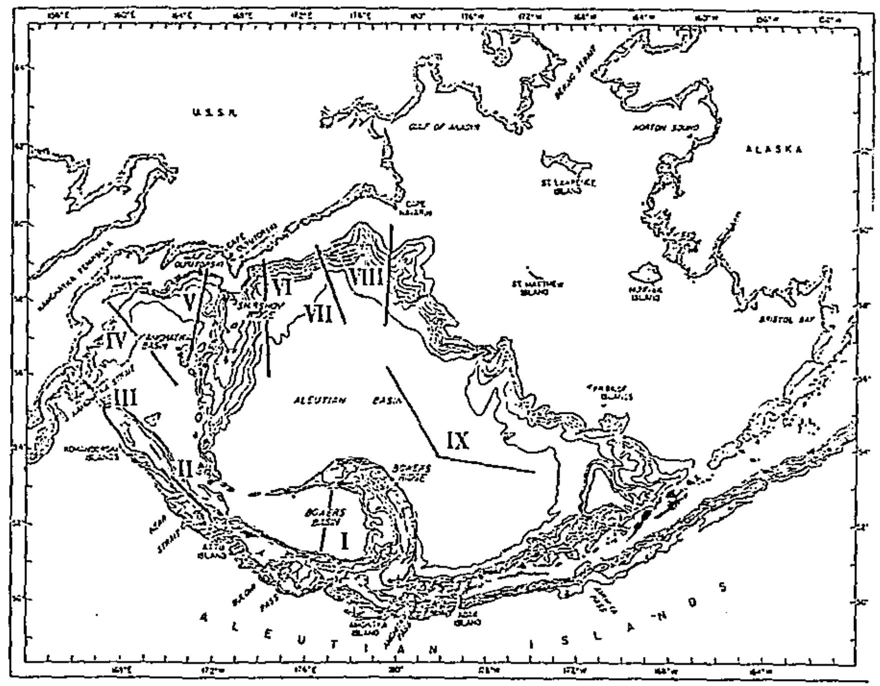
Research Cruise -- An investigation of the circulation and physical properties in the western Bering Sea is the objective of FOCI studies in summer 1991. Although this proposed study is mainly concerned with physical oceanographic aspects of the region, it will be integrated with our general ecosystem studies. The field work will be conducted by the Pacific Marine Environmental Laboratory of NOAA.

We plan to occupy CTD (conductivity/temperature/depth) casts along the sections shown in the figure. The sections across Near and Kamchatka straits should permit examination of the exchange of upper and deep waters between the Pacific and Bering Sea. Sections along the Kamchatka Peninsula should help define the flow of the swift boundary current there. Other stations in the deep basin would provide valuable information on the temperature, salinity, and nutrient (phosphate, nitrate, and silica) distributions in the region. Many of the casts would be taken to near bottom, and casts in the straits and near the continental margin would be at intervals of 10 km or less.

In addition to CTD work, we plan to deploy several satellite-tracked drifting buoys to obtain direct measurements of upper-ocean circulation. The vessel will have an acoustic Doppler current profiler, which measures currents in the upper 300 m. We also plan to deploy a few current moorings to obtain long-term measurements.

<u>Opportunities for Cooperative Research</u> -- The Bering Sea FOCI work is planned for August 1991 aboard the NOAA ship *Miller Freeman*, a 65 m-long research vessel and stern trawler. The vessel is well-equipped for research and has computer systems, satellite navigation, and fish detection sonars. The cruise is tentatively planned for 25 days and would probably start and end in Dutch Harbor, Alaska.

We would welcome cooperative research activities with Soviet scientists. Berthing space for a few visiting scientists would be available. Activities that could be undertaken include plankton-larval tows, limited midwater trawling, sonar detection of fish schools, and collection of water samples for biochemical analyses. The vessel would also provide a good platform for observing various oceanic phenomena. Although observation time is limited because of the large amount of CTD work, perhaps three days' ship time could be devoted to other research. Cooperative research programs should greatly enhance the value of the investigation of circulation and water property distributions.



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Panel 2: Reproduction and Early Life History

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Fecundity of Walleye Pollock, Theragra chalcogramma (Pallas) from the Bering Sea

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A study was made of walleye pollock fecundity in the eastern Bering Sea based on material collected in 1987-1989. A method for intravital evaluation of oocyte state in walleye pollock ovaries and identification of normally functioning and pathologically maturing gonads was developed and applied. Individual absolute fecundity number of pathologically maturing oocytes and characteristic features of their resorption were determined. Walleye pollock is characterized by synchronous vitellogenesis type and asynchronous maturation of oocytes with subsequent accumulation of ripe eggs in ovarian cavity. Spawning of walleye pollock is simultaneous. Pathologically developing oocytes were recorded in 67 % of females and their relative number amounted to 80 % in some individuals. Females with total oocyte resorption in ovaries costituted 12 % of spawning stock at the beginning of spawning season and decreased to 3.5 % at the end of spawning. The exterior view of pathologically developing ovaries is often normal, wich can be erroneously interpreted as spawning of walleye pollock in summer.

When individual absolute fecundity was estimated both normally maturing oocytes (actual IAF) and yolked altogether with pathologically maturing oocytes (possible IAF) were taken into account in each female. In 1987 the value of possible IAF in the eastern Bering Sea varied from 73,000 oocytes in females 30-32 cm of body size to 700,000 in individuals of maximum size. Actual IAF was on the average by 6% lower and constituted 72,000 and 600,000 oocytes respectively. In 1989 possible fecundity of the recruited spawners was lower than in 1987 and was estimated at 54,400 oocytes, whereas females of larger size exibited higer fecundity of up to 1,700,000 oocytes. Actual fecundity was on the average by 16 % lower and was estimated at 38,000 and 1,140,000 oocytes.

The values of actual fecundity in 1987 and 1989 all size groups averaged 318 and 432 thousand oocytes, respectively.

Population fecundity (P_f) was estimated as a total sum of contributions made by individuals of all size groups constituting spawning stock. In 1987 the major contribution into population fecundity was made by females of size groups of 37-44 cm long (41 %) and lower shares (27, 13 and 16 %) were contributed by females of other size groupings of 45-52, 53-60 and 30-36 cm long.

In 1989 45 % of contribution into population fecundity was made by females 45-52 cm long, 26 % was contributed by fish 53-60 cm long and 20 % share was made by the size group of 37-44 cm. Contribution of recruited spawners 30-36 cm long exhibited 16-fold decrease (1 %) as as compared with 1987.

The value of walleye pollock population fecundity in the eastern Bering Sea was estimated in 1987 at 1801.65×10^{12} eggs, while in 1989 it showed 4.2-fold decrease constituting 423.82×10^{12} eggs, which would necessarily affect state of walleye pollock stock in the nearest 2-3 years. In view of the fact that quantitative estimation of oocyte resorption phenomena in walleye pollock had not been performed before, the obtained values of abundance and biomass of the species from the results of ichthyoplankton survey appeared to be underestimated up to 7 % at the beginning of spawning season and to 17-20 % in the second half of the spawning period.

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Panel 3: Population Structure

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Information on the Stock Structure of Bering Sea Pollock

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Introduction

Major increases in the harvests of pollock have taken place over the last 5 years in new fishing areas of the Bering Sea, centered in the Aleutian Basin region and in particular in the doughnut hole region (the international zone of the Bering Sea) (Figure 1). It is essential to understand the stock relationship of pollock populations in the new and traditional fishing grounds. If pollock in the doughnut hole and in the U.S. EEZ are the same stock, these major new fisheries may over-exploit the pollock population and endanger the productivity of the stock. Thus, the determination of the stock structure of pollock in the Bering Sea and the determination of the degree of stock mixing has become increasingly important.

Age Composition

Past research has indicated that the age composition of pollock has varied depending on the location (Dawson 1989). Pollock on the eastern Bering Sea shelf tend to be younger than pollock found in the Aleutian Basin (Figure 2). In both areas the 1978 year class has been a dominant year class but at different times. By the time it had become dominant in the basin as 7 year olds, the 1978 year class no longer made up the largest fraction of the catch on the shelf, having been surpassed by the 1982 year class.

In 1982, in the Aleutian Island area the pollock age composition was broadly similar to that of pollock on the eastern shelf with the 1978 year class dominant as 4 year olds. However, as the 1978 yearclass grew older and no strong younger yearclasses emerged, the Aleutian Islands pollock age composition has shifted and become similar to that of pollock in the Aleutian Basin.

Beginning in 1987 a large scale fishery for pelagic pollock in southeastern Aleutian Basin began in the region of Bogoslof Island within the U.S. EEZ. The age composition of pollock caught in both the doughnut hole and in the vicinity of Bogoslof island is similar (Figure 3). A persistent feature of the age composition of pollock in the Aleutian Basin is the absence of any pollock that are younger than 4 years old.

Age data from 1989 is consistent with the above patterns. The age composition of commercial catches on the shelf is currently dominated by the 1984 and 1982 year classes while Aleutian Basin catches are made up of the 1978 year class at the advanced age of 11 (Figure 4). Again the age composition is not different between catches in the U.S. portion of the Aleutian Basin (hereafter called the southeastern basin) and those from the doughnut hole.

Length at Age

Like age composition, length at age varies by region in the Bering Sea. Lynde et al. (1986) and Hinckley (1987) demonstrated that the mean length at age of pollock on the continental slope northwest of the Pribilof Islands was smaller than that of pollock to the south of the Pribilofs. The length at age of basin pollock was most similar to that of pollock from the slope to the northwest of the Pribilofs.

Dawson (1989) found that Aleutian Island pollock had a greater mean length at age than Aleutian Basin pollock. Doughnut hole and southeastern basin pollock had a very similar mean length at age. A comparison of the mean length at age for individual ages showed that the mean length at age of fish from the basin was consistently greater than that of pollock from the northern slope of the eastern Bering Sea up to age 7 or 8 but at older ages the mean length at age of basin pollock is either equal to or less than that of the northern slope pollock. Figure 5 shows the sample areas that the data came from and Figures 6-9 display the actual mean lengths at age.

The recent data from 1989 again supports the above basin observations. Pollock from the area of Bogoslof Island and the doughnut hole have a similar length at age (Figure 10).

Genetic Studies

Past genetic studies have not included Aleutian Basin pollock. Mulligan et al.(1990) compared the mitochondrial DNA sequences of pollock from the Aleutian Islands, Bogoslof Island area, doughnut hole, and Shelikof Strait in the Gulf of Alaska (Figure 11). They found that the Bogoslof and doughnut hole samples were similar and both were distinct from the sample from the Aleutian Islands. The Shelikof Strait sample was more closely related to the Bogoslof/doughnut hole samples than to the Aleutian Island sample. Clustering of genetic distances is shown in Figure 12. Mulligan et al. concluded that three stocks were represented in the samples, a Bogoslof/doughnut hole stock, an Aleutian Island stock and a Gulf of Alaska stock.

Spawning

Hinckley (1987) and Mulligan et al.(1989) described the spawning times and locations for pollock in the central and eastern Bering Sea during 1984 and 1985. They found spawning occurring in the basin from January through March, with spawning on the southern shelf and slope and northern shelf from March to June and spawning on the northern slope from July to November (Figure 13).

Surveys in 1988 and 1989 of spawning concentrations in the basin found very few fish spawning in the doughnut hole while at the same time large concentrations of spawning pollock were found in the southeastern basin in the vicinity of Bogoslof Island (Traynor 1990). During the same period the commercial fleets operating in the doughnut hole had low catches.

Oceanography

The absence of pollock younger than 4 years old in the Aleutian Basin while spawning pollock are found in large quantity in the southeast basin, raises the question as to the fate of eggs spawned in the basin. Satellite-tracked drifter buoys deployed in the region of Bogoslof Island in 1976 had ended up on the eastern shelf in the general vicinity of the Pribilof Islands. This offered the possibility that the eggs and larvae ended up on the shelf.

Additional satellite-tracked drifter buoys deployed in March, 1988 in the southeastern basin showed a drift pattern along the shelf break until approximately 58 N where one drifter headed west across the basin while two more headed up onto the northern shelf (Reed and Stabeno, 1989) (Figure 14). This new data supports the earlier hypothesis that eggs and larvae from spawning in the southeastern basin may end up on the eastern Bering Sea shelf.

Conclusions

The combination of age composition, length at age and mitochondrial DNA evidence indicates that pollock in the doughnut hole and in the U.S. portion of the Aleutian Basin are members of the same stock and are separate from the pollock in the Aleutian Islands. The lack of any significant spawning concentrations in the doughnut hole during recent surveys indicates that pollock are leaving the doughnut hole to spawn elsewhere. Large spawning concentrations found in the U.S. portion of the Aleutian Basin of the same stock of pollock as those in the doughnut hole indicate that many of the doughnut hole pollock probably spawn in the U.S. EEZ. The continued absence of young adult pollock in the Aleutian Basin indicates that recruitment to the basin is coming from elsewhere, most likely the adjoining shelves. The most probable hypothesis for the disposition of the eggs spawned in the southeastern basin is still that they are carried by currents either directly onto the eastern Bering Sea shelf or very near the shelf. The data indicate that neither pollock in the doughnut hole nor elsewhere in the eastern Aleutian Basin are a self-contained stock but are dependant on recruitment from outside the region.

Much more work needs to be done to fill in the details of this picture. Of particular interest is the relationship of pollock in the western Bering Sea to pollock in the central and eastern Bering. Several Soviet scientists (Stepanenko, 1989; Bulatov and Sobolevsky, 1989) have hypothesized that some western Bering Sea pollock migrate into the doughnut hole. Multi-lateral cooperative studies are required to obtain a more complete understanding of pollock in the Bering Sea.

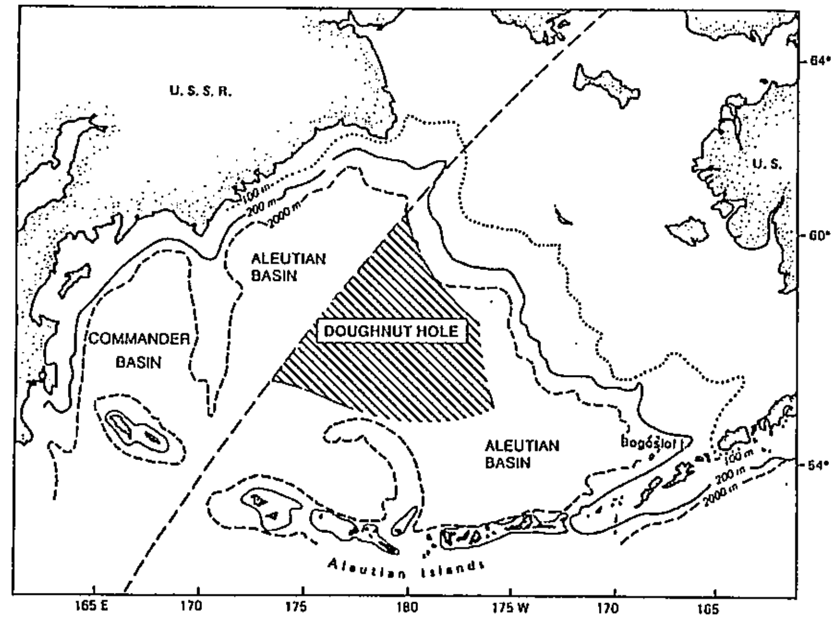

Figure 1. Chart of the Bering Sea.

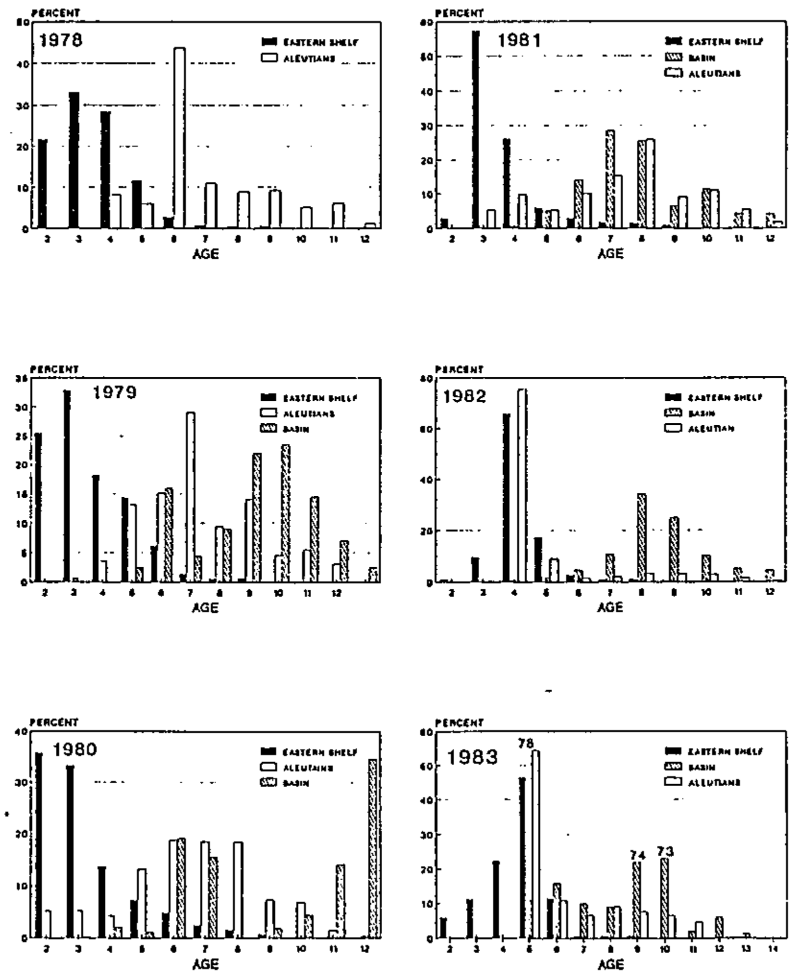

Figure 2. Age composition of pollock caught on the eastern Bering Sea shelf, Aleutian Islands and the Aleutian Basin.

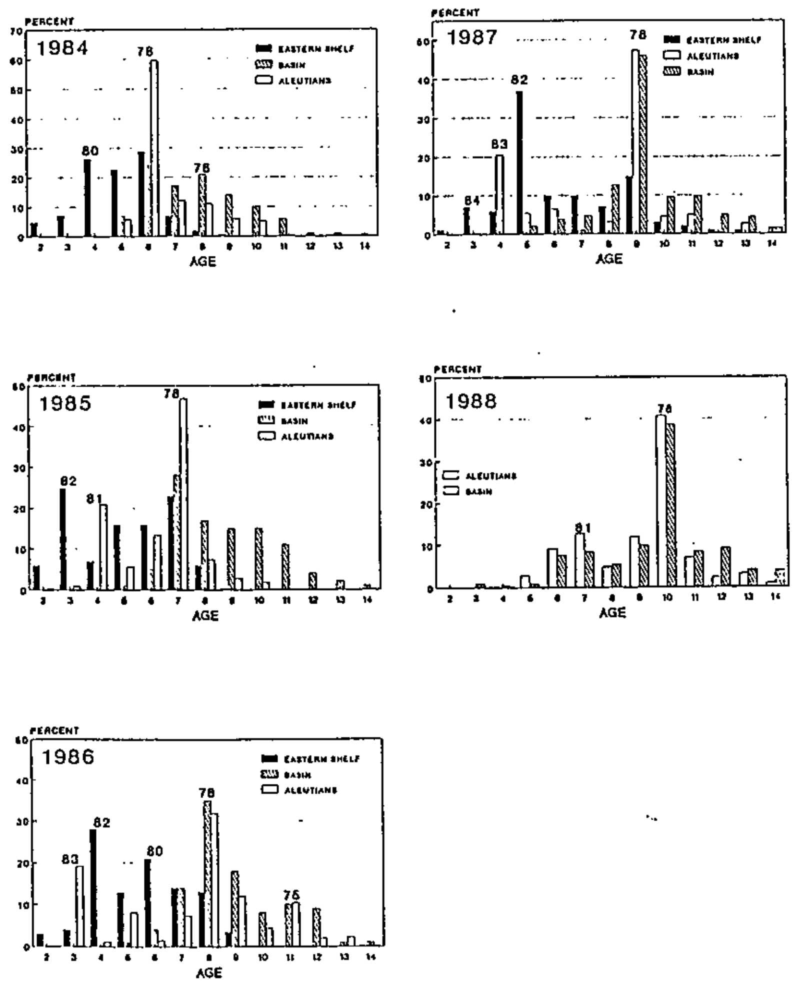

Figure 2. Continued.

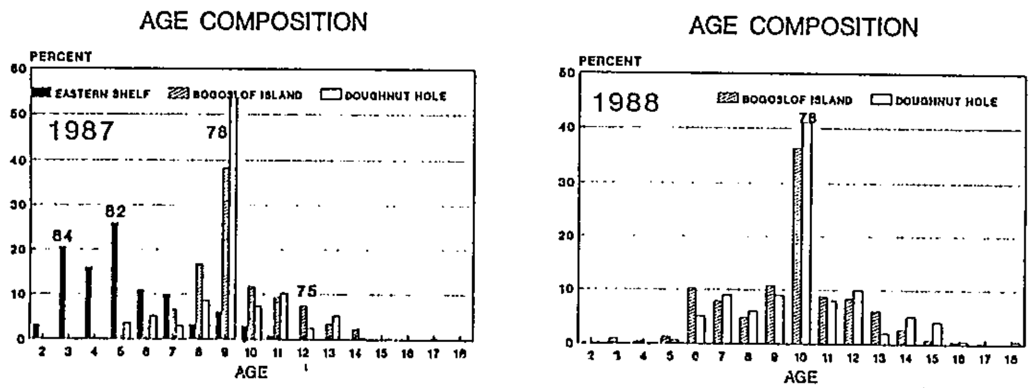

Figure 3. Age composition of pollock caught on the eastern Bering Sea shelf, Bogoslof Island and the doughnut hole.

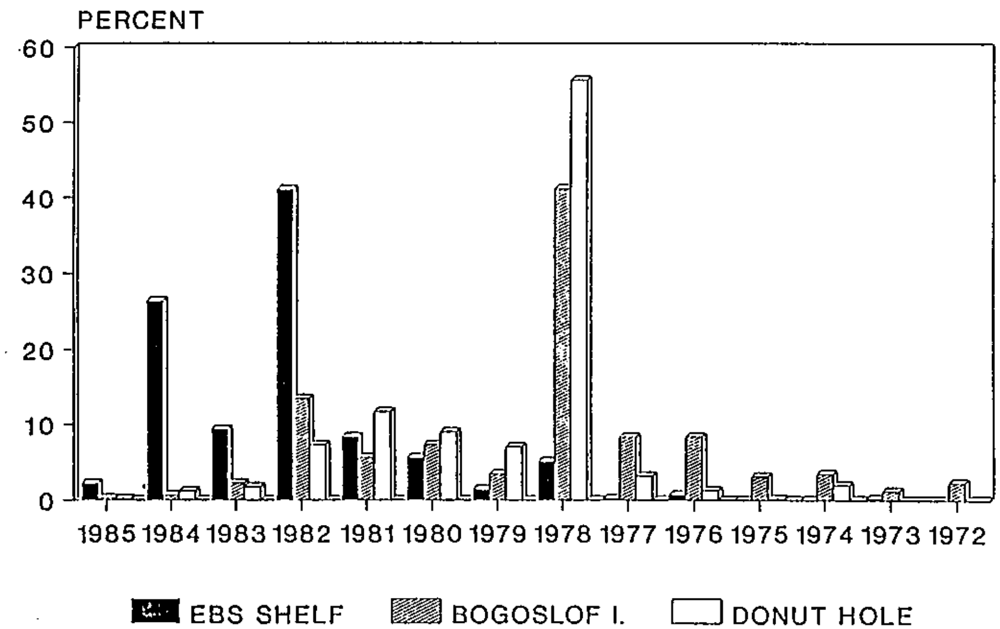

Figure 4. 1989 age composition of pollock caught on the eastern Bering Sea shelf, Bogoslof Island and the doughnut hole.

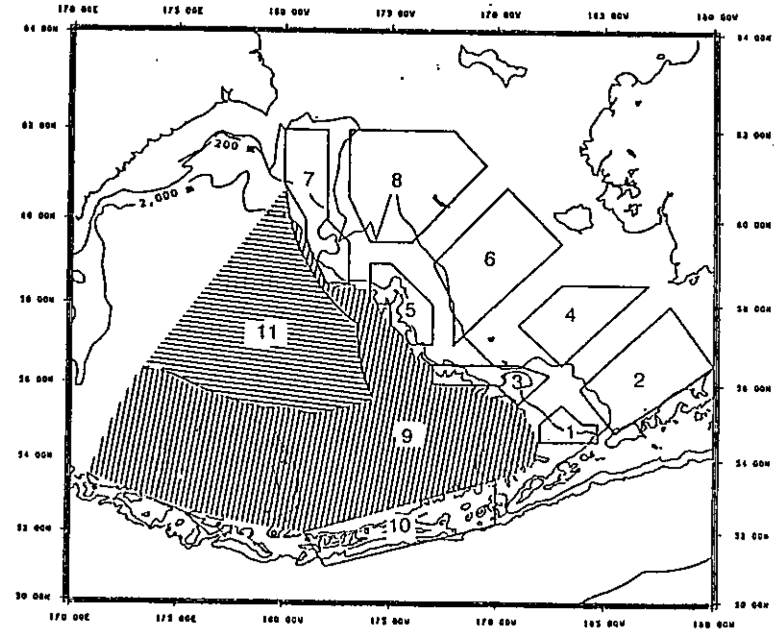

Figure 5. Sample areas in the Bering Sea for the length-at-age samples.

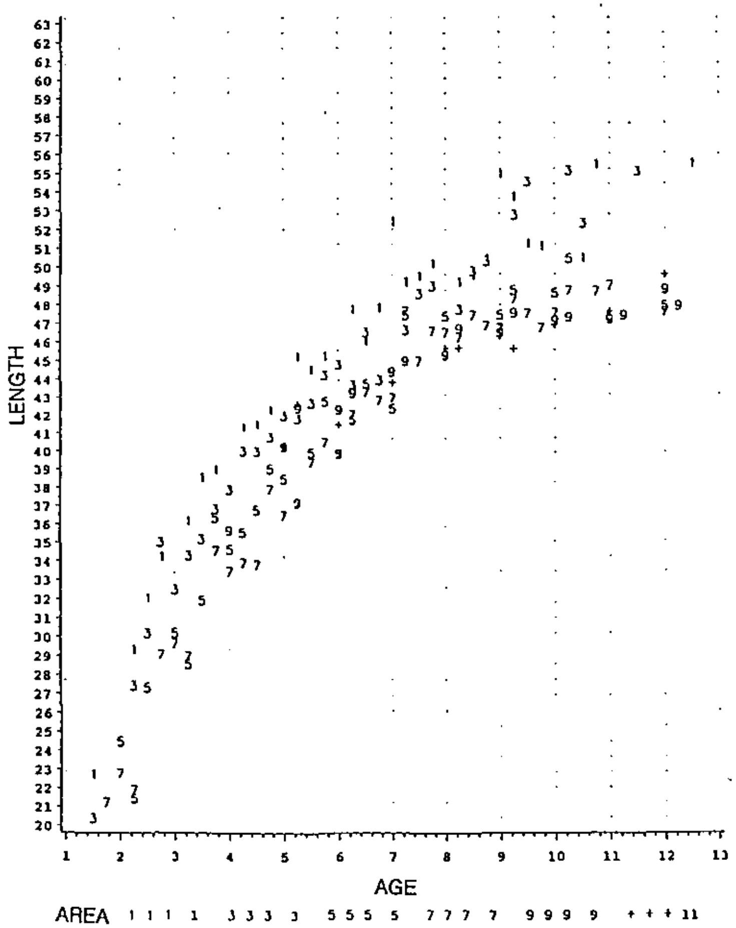

Figure 6. Mean lengths-at-age of male walleye pollock averaged across the years 1978-87 for each age, quarter and areas 1, 3, 5, 7, 9 and 11. Areas are as in Figure 5.

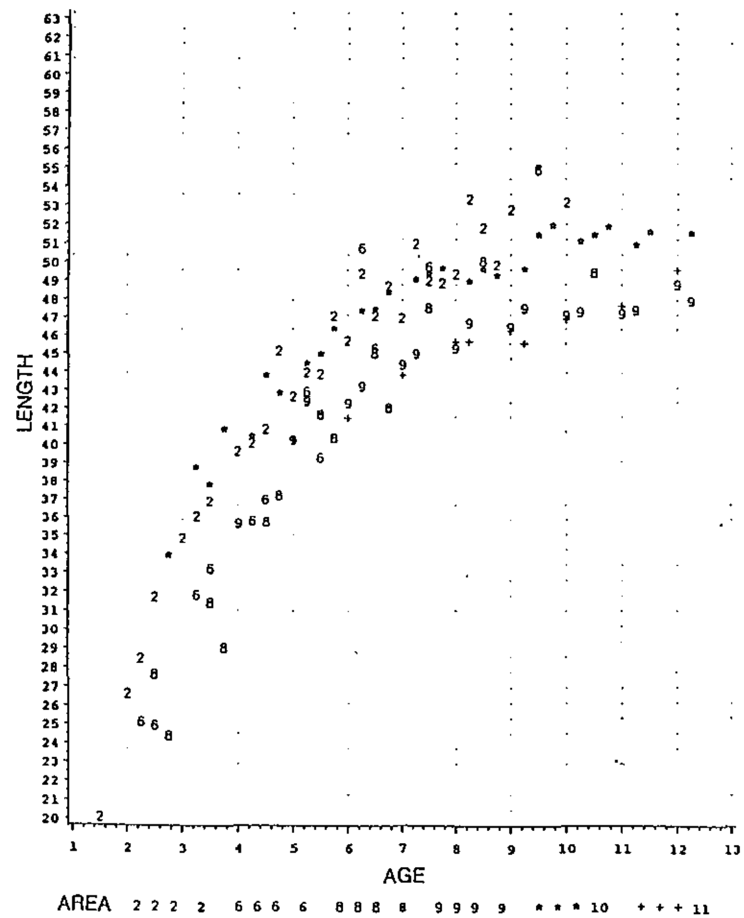

Figure 7. Mean lengths-at-age of male walleye pollock averaged across the years 1978-87 for each age, quarter and areas 2, 6, 8, 9, 10, and 11. Areas are as in Figure 5.

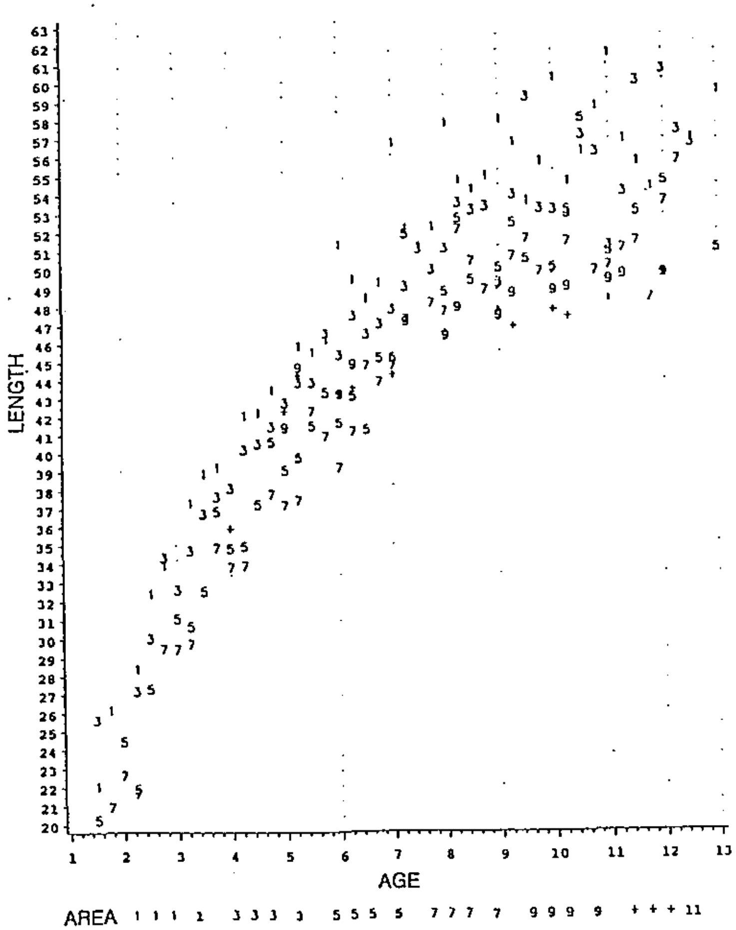

Figure 8. Mean lengths-at-age of female walleye pollock averaged across the years 1978-87 for each age, quarter and areas 1, 3, 5, 7, 9, and 11. Areas are as in Figure 5.

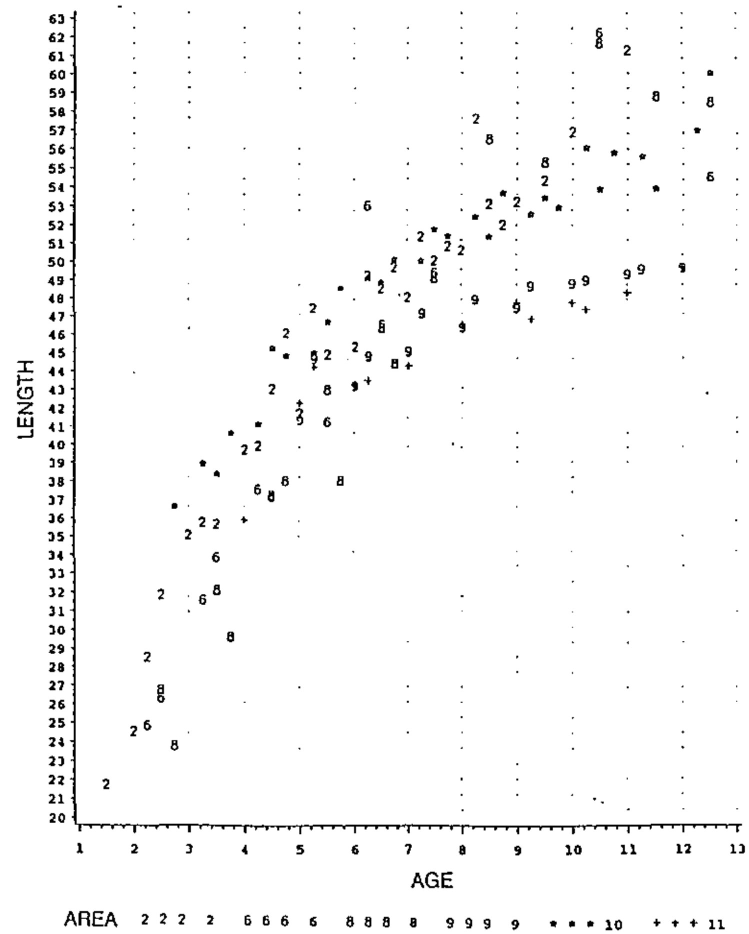

Figure 9. Mean lengths-at-age of female walleye pollock averaged across the years 1978-87 for each age, quarter and areas 2, 6, 8, 9, 10, and 11. Areas are as in Figure 5.

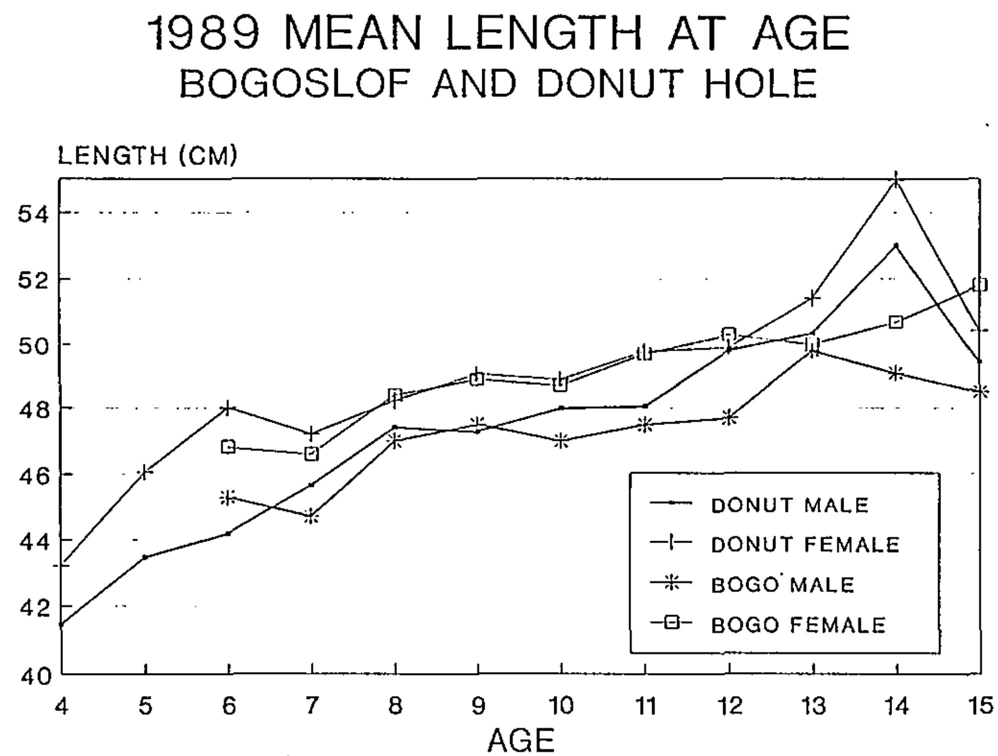

Figure 10. 1989 mean length at age comparison between pollock from Bogoslof Island and the doughnut hole.

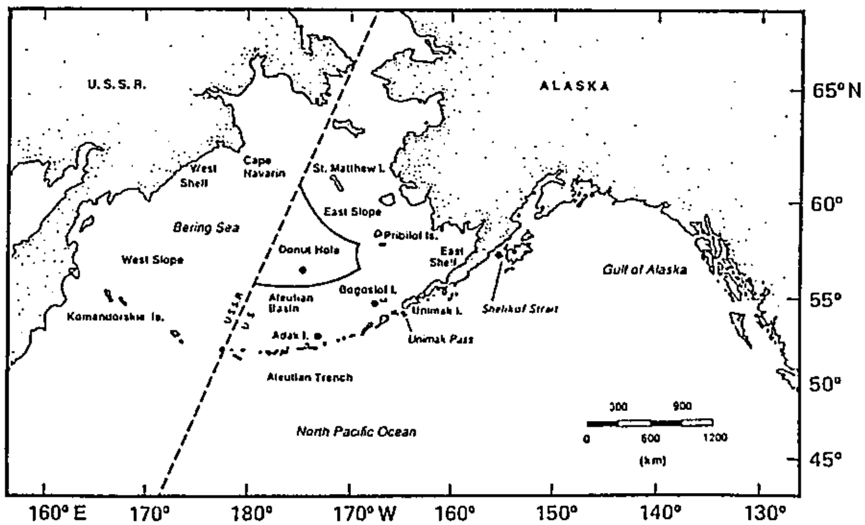

Fig. 11 Map of the Bering Sea and Gulf of Alaska. Solid circles designate the four collection sites.

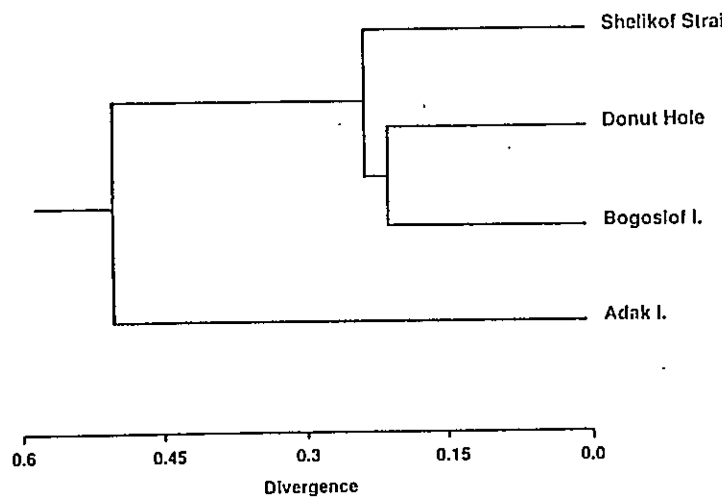

Fig. 12 UPGMA clustering of genetic distances among <u>Theragra chalcogramma</u> populations in the eastern Bering Sea and Shelikof Strait, Gulf of Alaska.

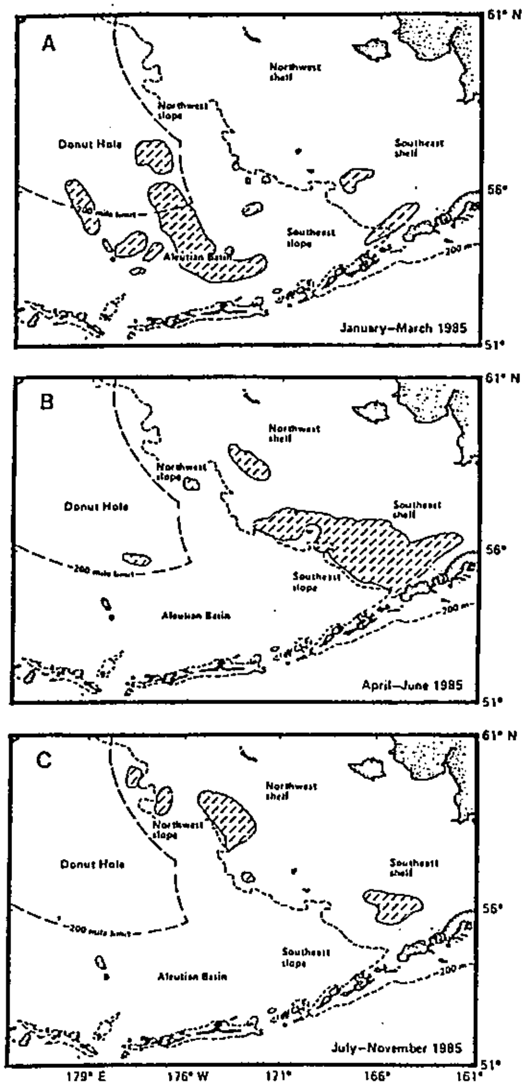

Fig. 13. Spawning distributions of walleye pollock, Theragra chalcogramma, in the eastern Bering Sea, 1985.

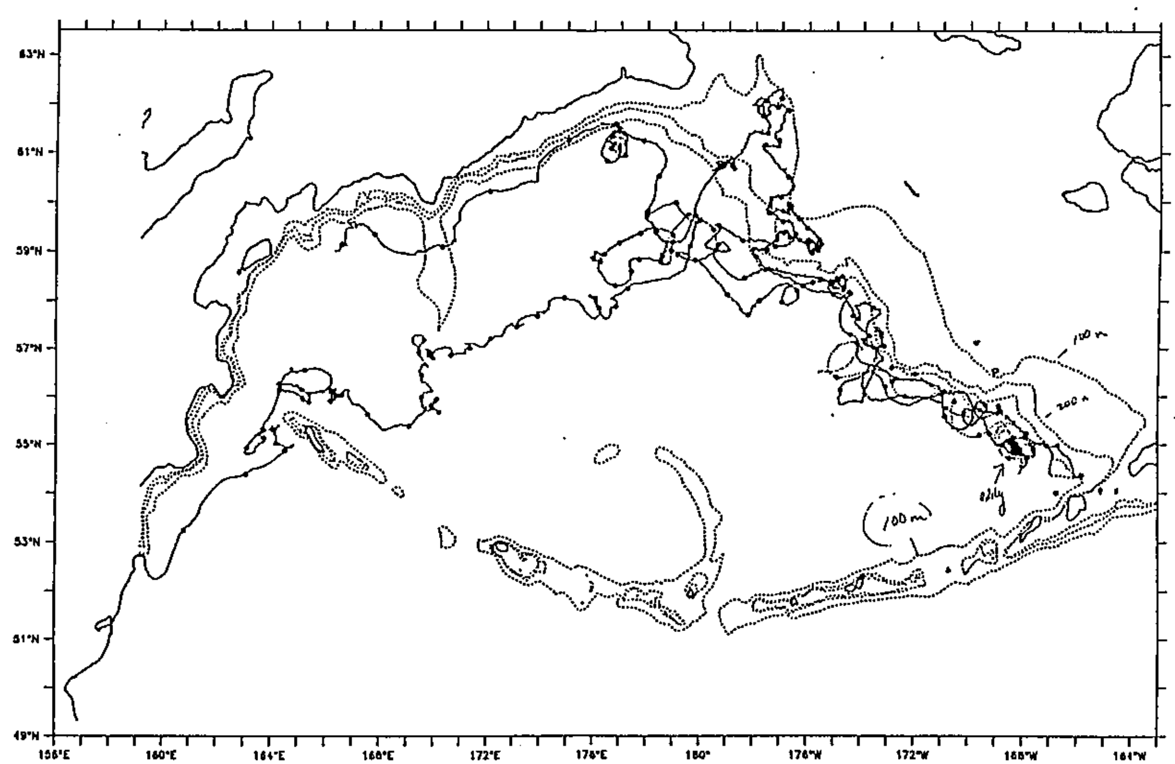

Figure 14. Tracklines of 4 satellite-tracked drifter buoys deployed from mid-March to mid-April 1988. Adapted from Reed and Stabeno 1989.

Study on Stock Identification of Walleye Pollock Based on Morphometric Data

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Introduction

Attempts to identify fish stocks have been made using various methods based on morphometric and meristic variability as well as biochemical methods. Under the method based on morphometric variability, an approach to test statistically the variability in relative growth has been adopted, and Wians (1984) showed the effectiveness of the method to process through multivariate analysis the values concerning the morphometrics measured through Truss Network Measurement (TNM) Method as a method to identify Pacific salmon juveniles having different origins. A study was made to find out whether it is possible to analyze stock structure of pollock in the Bering Sea using this method, especially whether it is possible to identify the fish living in the Aleutian Basin, including the international waters of the Bering Sea, and the school of individuals living on the continental shelf of the eastern Bering Sea.

This study, initiated in 1988, showed the possibility of distinguishing one sample group from another through morphometric variability, despite the fact that relatively few specimens were made available. However, as the range of body length of the specimens on the continental shelf of the eastern Bering Sea was relatively wide, only a part of specimens which belonged to the body length range of specimens in the international waters could be used for discriminant analysis. For this reason, analysis of relative growth was made in 1989/1990 to study whether there were morphometric changes in the process of growth, and fishes from the international waters and the continental shelf of the Bering Sea were identified on the basis of data obtained through measurement of large quantity specimens under the TNM method. As a result, it was made clear that determination was possible at a fairly high level of probability.

Materials and Methods

The TNM method is designed to study the morphometric variability by grasping morphometrics by means of continuous cells from the head to tail, and deal each cell and diagonal lines as statistics. The four vertexes of the cell serve as points forming the morphometrics. In pollock, 19 points, as shown in Fig. 1 (8 cells and a total of 43 Euclid distances) were established. In what follows, the distance between Point 1 and Point 2 is expressed as Point 1-2.

Specimens collected in the international waters of the Bering Sea and the continental shelf of the southeastern Bering Sea were used, but, in order to compare them with specimens collected in areas far from the Bering Sea, specimens collected off Hachinohe along the northeastern Pacific coast of the Tohoku region in Japan were also used (Fig. 2). Specimens from the continental shelf of the southeastern Bering Sea were collected by Japan-U.S. joint venture fisheries at the request of researchers. The number of specimens were as follows:

Sampling Area	Date	Number
U.S. Waters (Bering Sea)	Apr. 1987	682
International Waters (Bering Sea)	Jan. 1988	291
Off Hachinohe (Western North Pacific)	Sep. 1989	249

Measurement was conducted according to the following procedure.

1) Place fully defrozen specimen on the measuring sheet (YUPO paper 150) in a natural manner
2) Punch the measuring point with a needle
3) Read coordinates on the measuring sheet with digitizer
4) Calculate the 43 Euclid distances from the coordinates

Analysis was conducted according to the discriminant analysis. The program used in the analysis was FACOM OSP Statistic Package.

Results and Discussion

As shown in Fig. 3, the standard length (Point 2-19 under the TNM Method) of the measured specimens was large with a relatively narrow length range in the international waters of the Bering Sea and off Hachinohe whereas those from the continental shelf of the southeastern Bering Sea was small and had a wide length range. Before conducting discriminant analysis, examination was made on whether there were morphometric changes according to body length in specimens taken from the same area. The frequency distribution of the proportion of each of the 43 Euclid distances to standard length (ED/SL) for each area was unimodal with little variance. It was concluded from this that there were no morphometric changes within the range of body length measured.

Discriminant analysis was conducted using 43 ED/SL. As shown below, classification of specimens from the continental shelf of the southeastern Bering Sea and the international waters of the Bering Sea to the original area were determined at the probability of 85% each, and those from off Hachinohe at the probability of 88%. As a result of discriminant analysis using actually measured values of each

Euclid distances, the determination rate declined to 75% for the specimens from area off Hachinohe whereas those from the continental shelf of the southeastern Bering Sea and the international waters of the Bering Sea were 88% and 90%, respectively, showing a slight increase.

Sampling Area	Sample size	Percent classified into area		
		U.S. Waters	Int'l Waters	Off Hachinohe
U.S. Waters	682	84.9	11.9	3.2
Int'l Waters	291	8.2	85.2	6.5
Off Hachinohe	248	1.6	10.9	87.5

Dawson (1989) applied this method to pollock juveniles and attempted to clarify whether it is possible to distinguish the sample groups in the four areas of the continental shelf of the eastern Bering Sea and an area of the international waters, but the discriminant rate between sample groups was low. Dawson explained that this might have been due either to the fact that the specimens did not have had their proper morphometric characteristics by area or, even when they did, specimens in each area might have been mixed schools from several areas of different origins. The high discriminant rate obtained in the present study might have been due to the fact that the specimens in the southeastern Bering Sea were collected during the spawning season when they can be regarded as one identical stock.

Recognition of variability between sample groups by means of discriminant analysis shows that the proportion of various parts to the body length, as measured by the TNM method, differed in the three areas. In order to clarify which specific part contributed to the determination, t tests were conducted concerning the proportion (ED/SL) between 43 Euclid distances and standard length about specimens from two areas of the Bering Sea. The test showed a level of significance of 1% difference for almost all parts in both areas. But the results of the t test can be attributed to the fact that significant difference is detected when there is a slight difference in average values because variance is extremely small. Therefore the results were not considered to have biological significance.

As the future task, it is necessary to examine through various methods whether there are parts which specifically contribute to the determination and study whether area-to-area differences can be detected concerning the head length, eye diameter and other characteristics which cannot be measured through the TNM method.

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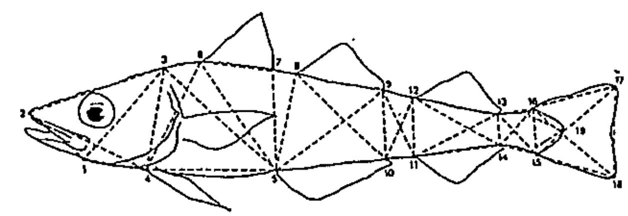

Cell 1		Cell 2		Cell 3		Cell 4		Cell 5		Cell 6		Cell 7		Cell 8	
1	1 - 2	6	3 - 4	11	5 - 6	16	5 - 8	21	9 - 10	26	11 - 12	31	13 - 14	36	15 - 19
2	2 - 3	7	3 - 5	12	5 - 7	17	5 - 9	22	9 - 11	27	11 - 13	32	13 - 15	37	16 - 19
3	1 - 4	8	3 - 6	13	6 - 7	18	5 - 10	23	9 - 12	28	11 - 14	33	13 - 16	38	15 - 16
4	1 - 3	9	4 - 5	14	6 - 8	19	8 - 9	24	10 - 11	29	12 - 13	34	14 - 15	39	15 - 17
5	2 - 4	10	4 - 6	15	7 - 8	20	8 - 10	25	10 - 12	30	12 - 14	35	14 - 16	40	15 - 18
														41	16 - 17
														42	16 - 18
														43	17 - 18

Figure 1. Walleye pollock morphological landmarks for Truss Network Measurement and Euclid distances shown as dashed lines.

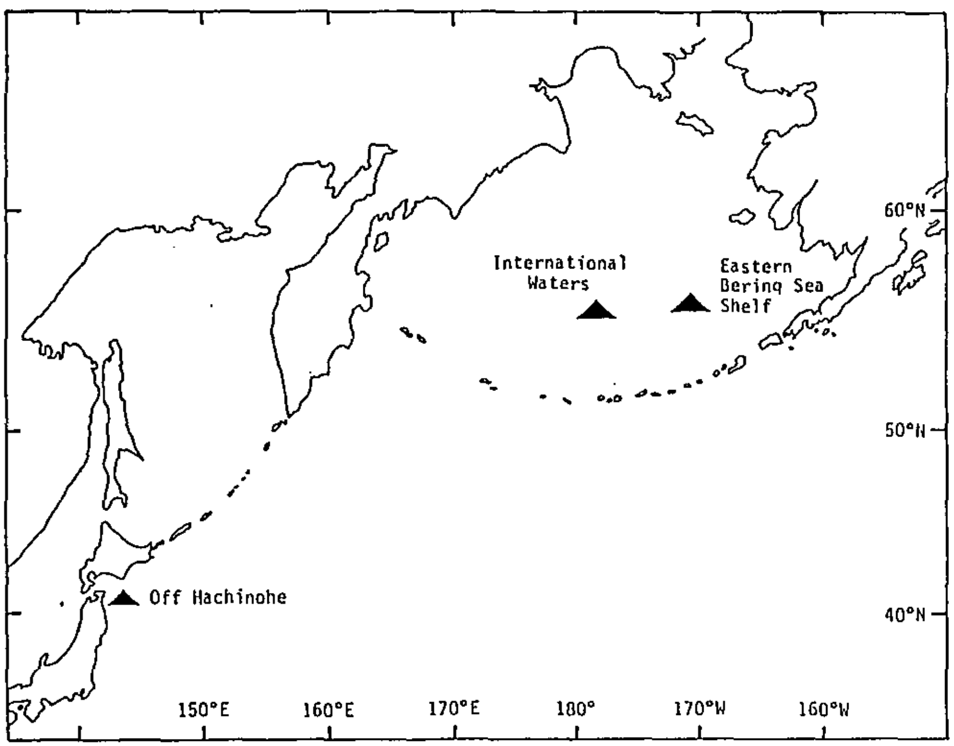

Figure 2. Sampling area of pollock used in this study.

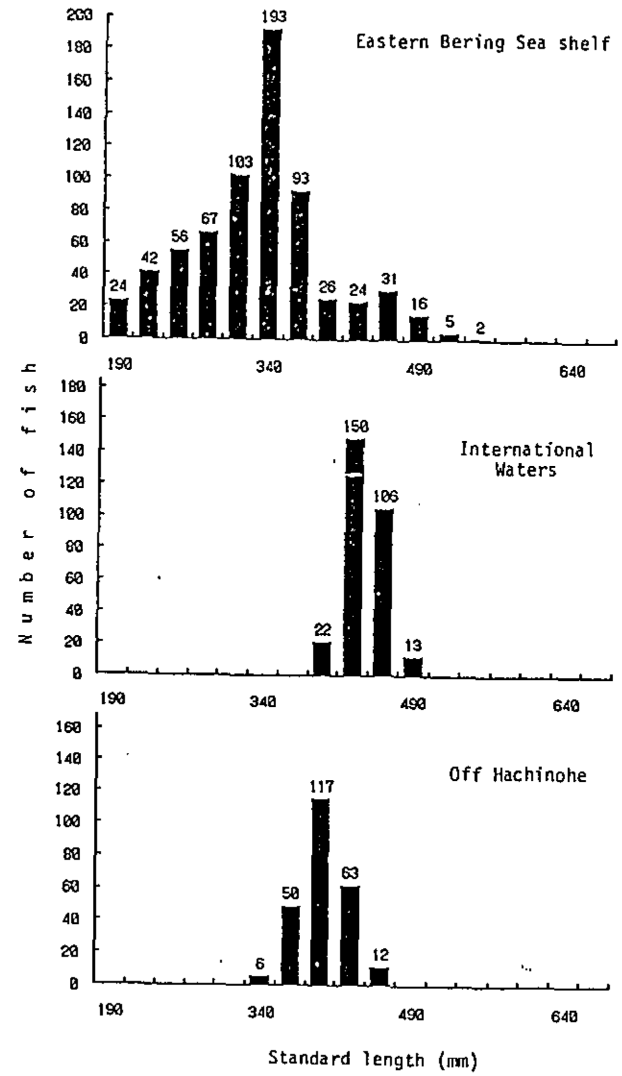

Figure 3. Length composition of pollock by area used for morphometric study.

Comparison of Meristic Characters of Alaska Pollock, <u>Theragra chalcogramma,</u> from Seven Geographic Areas of the North Pacific

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Abstracts

Meristic phenotypes of Alaska pollock from the seven geographic areas of the North Pacific were compared based on the samples from the Korean commercial fishing vessels.The numbers of rays of the three dorsal fins and two anal fins, the number of gillrakers on the first gill arch and the number of vertebrae of the fish were counted.

The mean numbers of vertebrae and gillrakers were very significantly different between the Bering Sea group and the Asian waters group. However,they did not show significant differences from the three different regions within the Bering Sea and the four different regions within the Asian waters.

Materials and Methods

Alaska pollock were sampled from the seven geographic areas of the North Pacific: three areas from the Bering Sea(southeastern,eastern and central Bering Sea),two areas around Hokkaido, two areas from the Japan Sea (Yamato Bank and the east coast of Korea) in 1987 through 1989(Fig.1).

The following seven meristic characters were enumerated: rays of the three dorsal fins(ND1,ND2,ND3) and the two anal fins(NA1,NA2),the total vertebrae(NVE) excluding urostyle, gillrakers from the upper(NGRU),lower(NGRL) and total limbs(NGRT) of the first right branchial arch including rudimentary rakers.

ANOVA test and multiple comparison test(Scheffe) were applied to compare means of meristic characters.

Results and Discussion

ANOVA test on 7 meristic counts showed significant differences between the seven geographic groups except for the number of the first and second dorsal fin rays(Table 1).

Scheffe test did not showed significant differences in the means of the numbers of vertebrae,gillrakers and first anal fin rays between the three groups within Bering Sea,and between the four groups within the Asian waters .

However, the Bering Sea group and the Asian waters group were significantly different. The mean numbers of vertebrae and gillrakers from the Bering Sea showed greater than those from the Asian waters. In the Bering Sea group the mean number of vertebrae was 51 and that of total gillrakers was 37.6. In the Asian waters group the mean number of vertebrae was 49 and that of total gillrakers was 35.9 (Table 1,2,and 3, Fig.2,and 3).The result of our data on the number of vertebrae is simillar from those of Wilimovskiy et al(1967) and that of Serobaba(1978) in the eastern Bering Sea. Koyachi and Hashimoto(1977) noted that the number of vertebrae increased in northern and eastern directions ,which our data showed the simillar results,However, our data did not show distinctive differences within the Asian waters groups and within the Bering Sea groups. This result suggests that Alaska pollock inhabiting Bering Sea and Asian waters are clearly independent stocks. However because the present samples are insufficient and did not cover all the geographic range of Alaska pollock it is somewhat dangerous to conclude that they are all the same stocks or stocklet within the Bering Sea groups and within the Asian waters groups.

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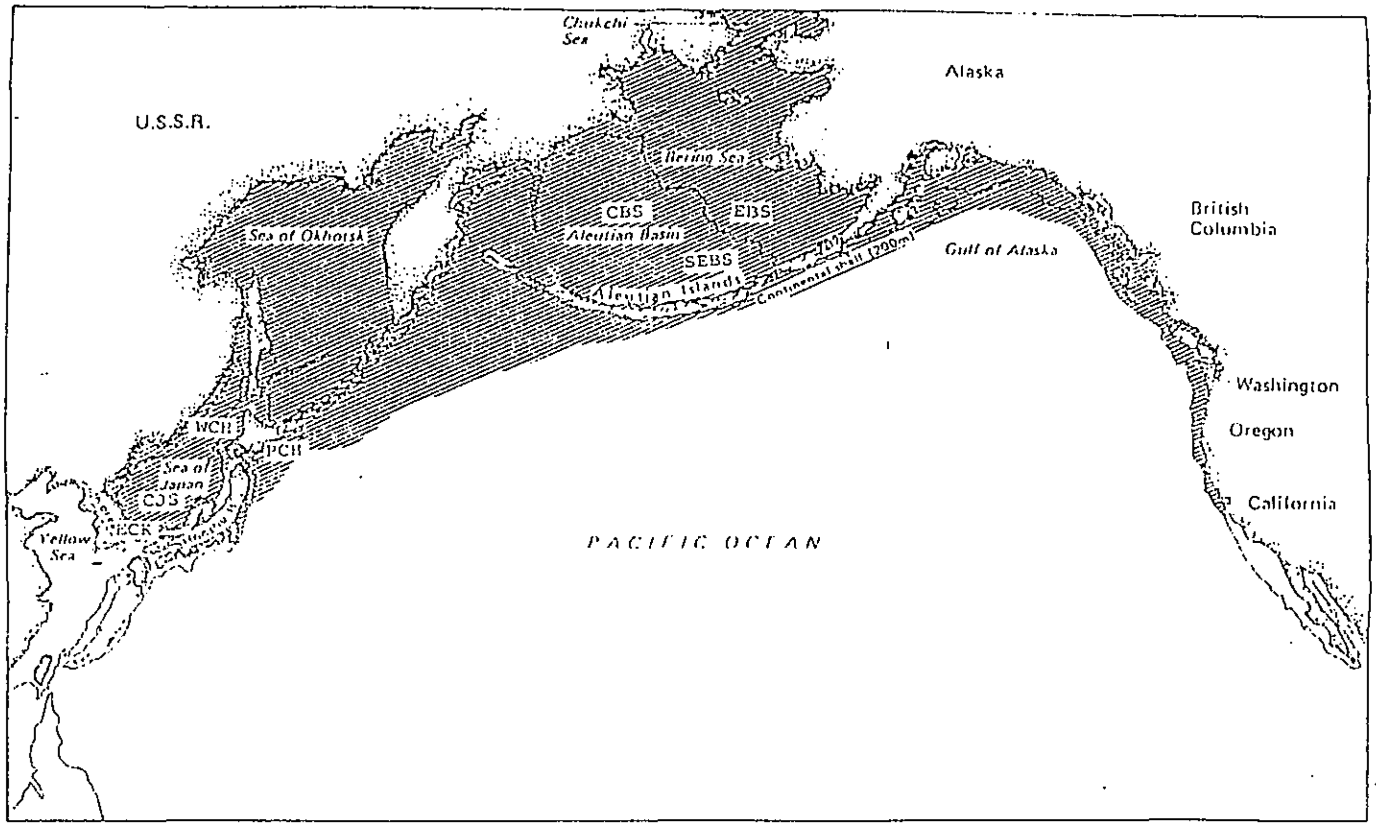

Figure 1. Distribution areas of the Alaska pollock and places samples were taken :
SEBS : Southeastern Bering Sea, EBS : Eastern Bering Sea, CBS : Central Bering Sea, PCH : Pacific coast of Hokkaido, WCH : West coast of Hokkaido, CJS : Central Japan Sea (Yamato Bank), ECK : East coast of Korea

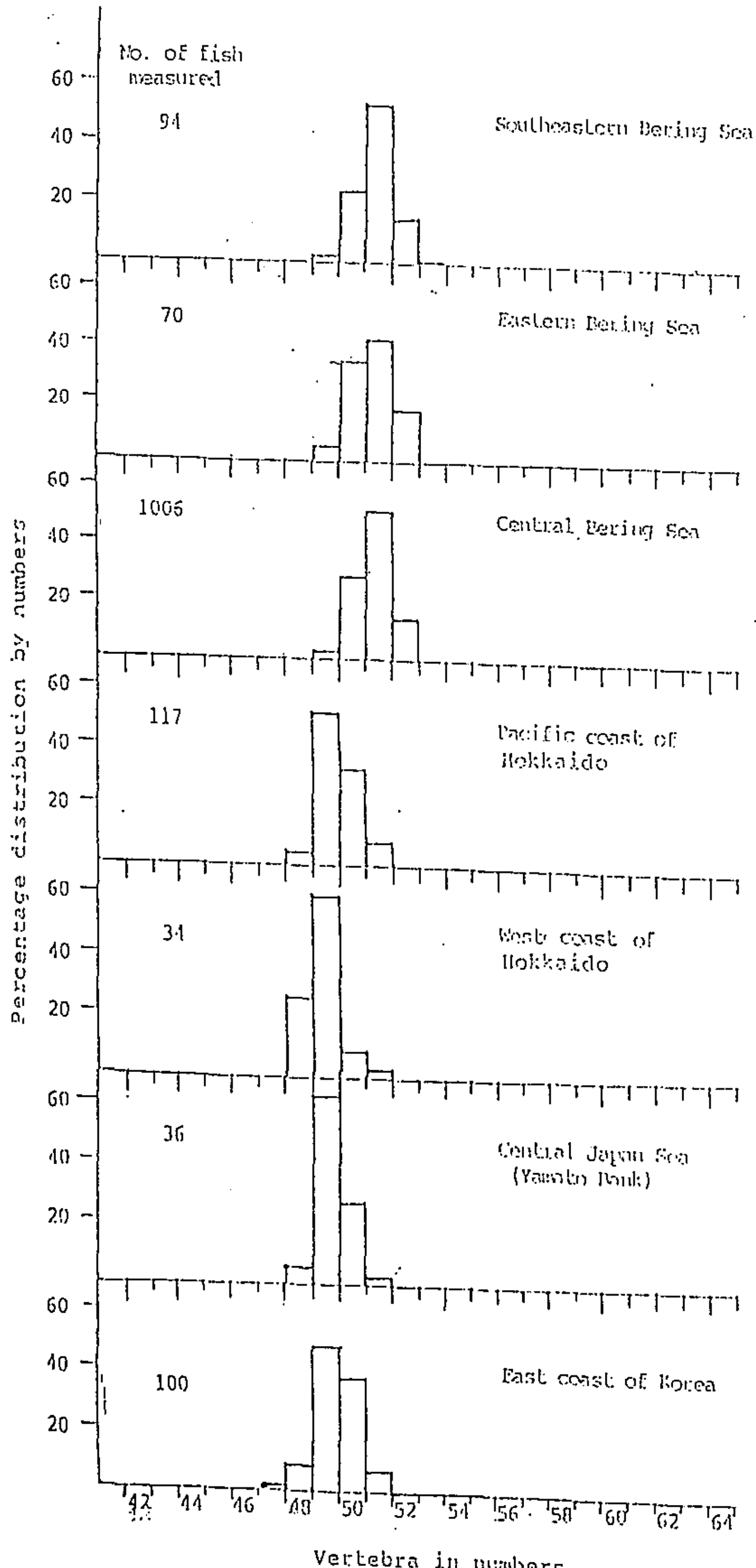

Figure 2 The regional distribution of vertebrae of Alaska pollock (*Theragra chalcogramma*) in the North Pacific.

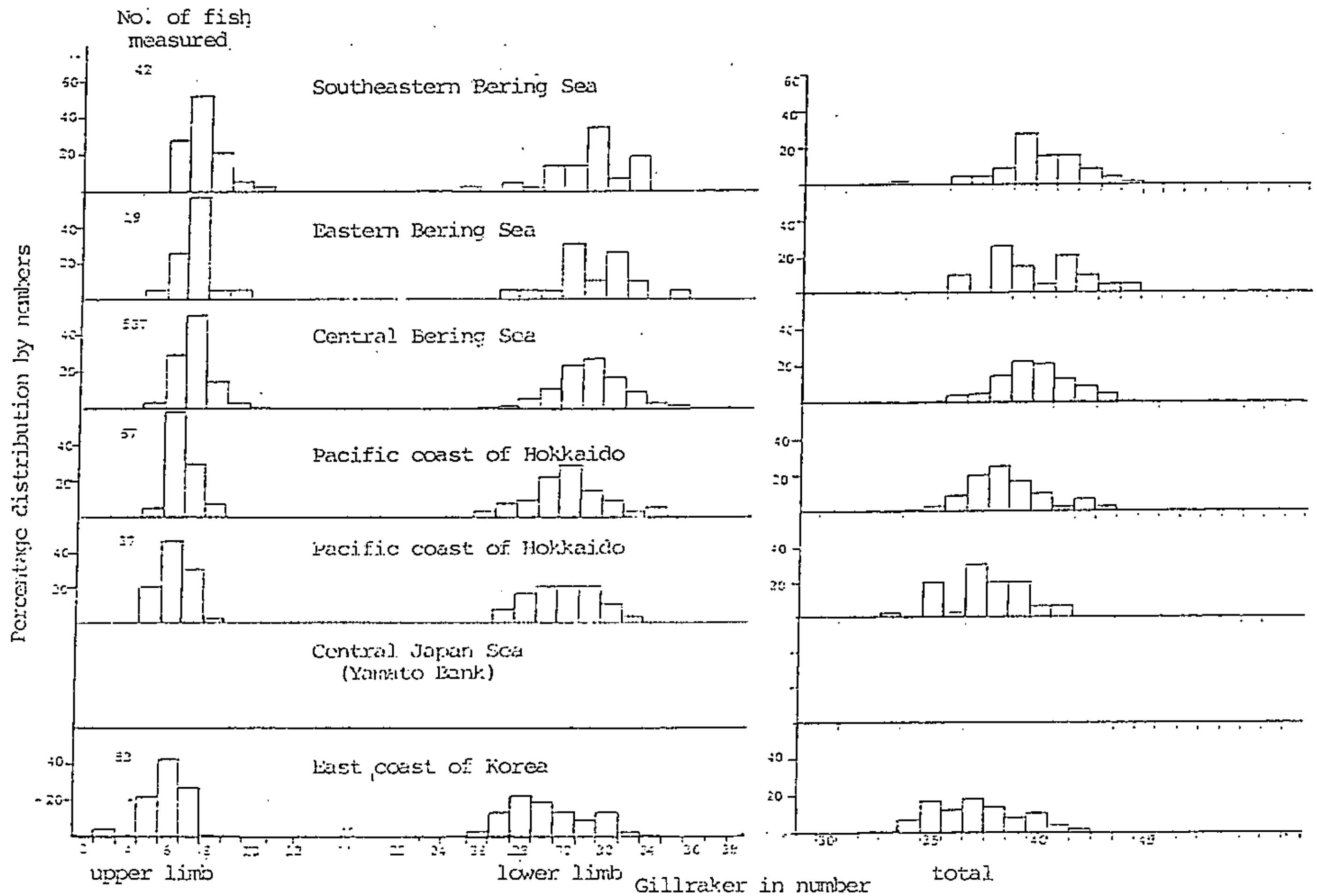

Figure 3. The regional distribution of gillrakers of Alaska pollock in the North Pacific.

Table 1. Meristic counts, F values, and results of Scheffe's multiple comparison test of the Alaska pollock from the seven geographic areas of the North Pacific

VARIABLE	Region							F	Scheffe
	SEBS	EBS	CBS	PCH	WCH	CJS	ECK		
NVE	50.9(94)	50.8(70)	50.8(1006	49.5(117)	48.9(34)	49.3(36)	49.4(100)	420.85*	(SEBS, EBS, CBS) (PCH, WCH, CJS, ECK)
	(0.73)	(0.81)	(0.74)	(0.76)	(0.69)	(0.62)	(0.76)		
ND1	13.4(49)	13.3(21)	13.4(643)	13.4(100)	12.8(36)	13.3(11)	13.1(100)	2.19NS	
	(1.07)	(0.71)	(0.89)	(1.14)	(0.98)	(0.65)	(0.67)		
ND2	16.5(48)	16.5(20)	16.8(632)	16.9(98)	16.4(36)	16.8(11)	17.1(100)	1.35NS	
	(1.71)	(1.73)	(1.44)	(1.44)	(1.46)	(1.60)	(1.23)		
ND3	19.4(11)	19.6(21)	20.8(264)	20.3(54)	21.0(36)	20.3(6)	20.7(98)	5.86*	(SEBS, EBS, PCH, WCH, CJS, ECK) (SEBS, CBS, PCH, WCH, CJS, EC
	(1.06)	(1.03)	(1.33)	(1.44)	(1.34)	(1.51)	(1.01)		
NA1	22.6(91)	21.6(21)	22.6(620)	21.8(36)	21.6(36)	22.1(35)	22.3(99)	9.84*	(SEBS, EBS, CBS, PCH, CJS, ECK) (SEBS, EBS, CBS, WCH, CJS, EC
	(1.75)	(1.36)	(1.45)	(1.35)	(1.29)	(1.41)	(1.36)		
NA2		20.2(9)	22.3(271)	21.6(51)	22.1(36)		21.5(15)	5.80*	(SEBS, CBS, PCH, WCH, ECK) (EBS, CBS, PCH, WCH, ECK)
		(1.48)	(1.72)	(1.15)	(1.26)		(0.74)		
NGRU	7.0(42)	6.8(19)	6.8(527)	6.4(67)	6.2(30)		5.9(83)	22.39*	(SEBS, EBS, CBS) (PCH, WCH, ECK)
	(0.91)	(0.85)	(0.77)	(0.70)	(0.79)		(1.07)		
NGRL	30.6(42)	30.9(19)	30.8(537)	29.9(67)	29.5(30)		29.2(83)	17.14*	(SEBS, EBS, CBS) (PCH, WCH, ECK)
	(1.82)	(1.88)	(1.62)	(1.74)	(1.98)		(1.92)		
NGRT	37.6(42)	37.6(19)	37.7(538)	36.3(67)	35.7(30)		35.2(83)	44.71*	(SEBS, EBS, CBS) (PCH, WCH, ECK)
	(2.03)	(2.24)	(1.88)	(1.86)	(1.80)		(2.20)		

*very significant $p<0.001$.
Mean in upper column, number of specimens in parenthesis, standard deviation in lower column.
NS, nonsignificant($P>0.01$): Nonsignificantly different groups are included in the same parentheses.
SEBS: Southeastern Bering Sea, EBS: Eastern Bering Sea, CBS: Central Bering Sea, PCH: Pacific coast of Hokkaido,
CJS: Central Japan Sea (Yamato Bank), ECK: East coast of Korea

Table 2. Number of observed fish(N), range, mode and mean number(X) variance(S) and F value of the number of vertebrae from the seven regional groups of Alaska pollock in the North Pacific

	Region							
	SEBS	EBS	CBS	PCH	WCH	CJS	ECX	F(6,1006)
N	94	70	1006	117	34	36	100	361.45
Range	49–53	49–52	49–54	48–51	48–51	48–51	47–51	
Mode	51	51	51	49	49	49	49	
X	50.9	50.8	50.8	49.5	48.5	49.3	49.4	
s	0.53	0.65	0.55	0.58	0.47	0.38	0.58	

Table 3 Number of observed fish(N), range, mode, mean number(X), variance(s), and F value of the number of the gillrakers from total, upper and lower limb of Alaska pollock from the seven geographic areas of the North Pacific

	Region							
	SEBS	EBS	CBS	PCH	WCH	CJS	ECX	F(6,1006)
Total number of gillrakers								
N	42	19	536	37	30		83	44.71
Range	31–42	34–42	32–44	32–41	31–39		30–40	
Mode	37	36	37	36	35		35	
X	37.6	37.5	37.7	36.3	35.7		35.2	
S	4.33	5.02	3.52	3.45	3.24		4.86	
Upper limber								
Range	6–10	5–9	5–10	5–8	5–8		3–9	22.37
Mode	7	7	7	6	6		6	
X	7.0	6.8	6.8	6.4	6.2		5.9	
S	0.83	0.72	0.60	0.49	0.62		1.14	
Lower limber								
Range	25–33	27–35	26–37	26–34	27–33		25–34	17.14
Mode	31	30	31	30	30		28	
X	30.6	30.9	30.8	29.9	29.5		29.2	
S	3.31	3.53	2.62	3.02	3.92		3.67	

Preliminary Report on the Second Research Cruise by Kaiyo maru for fiscal 1989 -- Research on Pollock Stock in the International Waters of the Bering Sea

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Introduction

This is a preliminary report on research on pollock stock in the international waters of the Bering Sea conducted as the Second Research Cruise by Kaiyo maru for fiscal 1989. Additions and modifications were made to the prompt report compiled on board Kaiyo maru on its return cruise. Therefore, the contents reported here represent only a part of the data obtained from the research and its results are preliminary. Despite such limitations, this report may provide an overall picture of the research.

Like the previous research on pollock by Kaiyo maru in the Aleutian Basin, the present research was conducted with the participation of scientists of various countries concerned. These foreign researchers cooperated among themselves in such activities as dealing with catches, biological measurement and collection of various samples. They also collaborated with Japanese researchers in the implementation of the research. Highly efficient research was made possible, helped by favorable weather conditions and flexible application of research procedure to changing situation in the research area. We are convinced that ample results were obtained in terms of international cooperation and data collection, despite the short research period. I wish to express our sincere appreciation to Captain Teruo Morooka and all the crew of Kaiyo maru for their wholehearted cooperation.

Background and Objectives of the Research

Catches of pollock in the entire Bering Sea have increased rapidly over recent years, reaching 3,640,000 tons in 1987, because new fishery targeted at pelagic pollocks was developed in the international waters of the Bering Sea. Of the total catches, those from the international waters of the Bering Sea aggregated 1,280,000 tons, but harvesting targeted at pollock in the Aleutian Basin including the international waters, was conducted not only in the international waters but also off Bogoslof Island in the U.S. 200-mile zone, southeast of the Basin and the Kamchatka Basin in the U.S.S.R. 200-mile zone. Catches in the waters off Bogoslof Island in 1987 were 330,000 tons, and if those caught in the Kamchatka Basin are included, a total of about 2 million tons of pollock is estimated to have been taken from the Basin area.

To clarify whether these pollocks taken extensively in the Basin area belong to a single stock or what the relations are between the pollocks living in the Basin area and those living on the continental shelf have become important and urgent international issues in order to establish a strategy for a rational utilization and management of pollock stock in the whole area of the Bering Sea. Accordingly, Japan has been positively promoting research targeted at pollock since 1988, and has been exerting efforts in conducting research under international cooperation to a maximum possible extent. As part of these research activities, the Fisheries Agency of Japan implemented the Second Research for fiscal 1989 by Kaiyo maru in January and February in 1990 in international waters of the Bering Sea with the aim to collect basic data concerning pollock stock in the said area.

Under the initial program, a joint research proposal was made to the U.S.S.R. Government in the hope to conduct the research in the Kamchatka Basin area in the U.S.S.R. waters where it was disclosed that high-density distribution of pollock was observed. But, as this proposal was not accepted by the U.S.S.R., the research was conducted only in a part of international waters of the Bering Sea in consideration of the limited length of the research period. From the information obtained in recent years, it was assumed that there is little possibility for high density distribution of pollock stock in international waters of the Bering Sea in the period of the present research. However, the attempt to conduct such a research, taking every possible opportunity, was deemed very significant in that it improves our knowledge on pollock stocks and further promote international joint research and studies.

This research was first proposed by Japan at the "International Conference on Cooperation in the Bering Sea Pollock Stock" held at the National Research Institute of Far Seas Fisheries in August 1989. Not only nations participating in the conference (the Republic of Korea and Poland) but also all the nations concerned were called upon for taking part in the research. As a result, one scientist each from the Republic of Korea, Poland, the United States and the U.S.S.R. participated in the research.

Research Vessel and Research Equipment

Kaiyo maru, a stern trawl-type research vessel owned by the Fisheries Agency, was 2,644 tons, with the total length of 91.87 m, width of 15 m and depth of 9.20 m. The vessel was equipped with various equipment for research of fishery resource and marine environment. In the present research, quantitative echo sounder system, midwater trawl net, CTD, and NORPAC net were mainly used. A quantitative echo sounder system (FQ-50) manufactured by Furuno Electric Co. was equipped with a recorder to record echogram data and a printer to print integral calculus results. A transducer, using a frequency of 50kHz, was installed in the ship's bottom at about 9-10 m from the sea surface.

The Kaiyo maru midwater trawl (KMT) net, used in the present research, was the same type as the one used in the two past Bering Sea pollock stock researches. Mesh size was within the range of 600 mm at the opening of the trawl net and 75 mm at the cod end, and the length from the middle part of head rope to cod end was 78.55 m. The otter board was about 6.0 m^2, and aerial weight was about 1.8 tons (one side), with the length of hand rope was 150 m. In the middle of the head rope was installed a transducer to monitor the water depth and the height of opening of the trawl net. The average height of opening of the trawl net, when towed at an average speed of 3.6 knots, was 17 m. According to the results of the previous research, the distance between wing tips of net in case towed at a speed of 3 knots, was about 25 m, although this measurement was not made in the present research.

The vertical distribution of the water temperature and conductivity (salinity) was measured by the CTD system manufactured by Neal Brown, and the temperature of surface water was measured with a bucket thermometer. Zooplanktons were collected using the NORPAC net with an aperture of 45 cm.

Cruise Itinerary, Research Areas and Research Procedure

Kaiyo maru left the Tokyo Port for the Bering Sea on January 20, 1990, after making calibration of the quantitative echo sounder system on the previous day. The ship steamed alongside the Kuril Islands and arrived in the Bering Sea off Attu Island on January 27. The vessel hour was set at the world time + 12 hours, by making 30-minute advancement of the clock each day between January 20 and 26. In the present research, the maximum possible sojourn in the research area were estimated at 10 days, therefore it was not possible to survey the entire international waters. It was decided from the outset that research was to be conducted in a part of the international waters. The criterion to select research area was the distribution of fish schools. For this purpose, information concerning the operation of Japanese fishing boats was collected from time to time during the cruise. As the operation of Japanese fishing boats concentrated in the southeastern area of the international waters in late January, that area was decided as the research area on January 27. At 05:00 on January 29, Kaiyo maru arrived at a point of 50 30'N and 176 30'W, and started fish school searching survey by means of the quantitative echo sounder system. At 08:00 on the same day, the first CTD and NORPAC net observation was made at a point of 55 56'N and 176 30'W. The survey was followed by midwater trawling activities. In the research area, many fishing boats including those from Japan, the Republic of Korea, Poland and the U.S.S.R. were operating. As it was necessary to take heed not to hamper these operations, it was not possible to establish the fixed transect lines and survey stations for the research in advance. Fish school search survey was conducted mainly at night, using the quantitative echo sounder system, and oceanographic observation and midwater trawling were conducted during daytime.

Until February 3, in the area between 56°00'N and 56° 30'N and 176°30'W and 178°00'W, oceanographic observation and midwater trawling were conducted during daytime, and fish school searching surveys were made in the areas between 55 30'N and 56 40'N latitudinally and 177°00'W and 178 30'W longitudinally. As virtually no echograms were observed in the area south of 56°00'N and west of 177°00'W, searching was conducted in the area east of 177°00'W at nighttime on February 3. As a result, relatively clear echograms were observed around the area of 55°40' N and 176°30' W. Therefore, research was conducted near this point from February 4 to 6. No fishing boats operated in this area.

At 17:30 on February 6, the last midwater trawling was completed at the point of 55°39'N and 176°26'W, and the ship started the return cruise to Tokyo. Kaiyo maru proceeded southward taking mostly the same course as in the coming cruise and safely arrived and anchored off Haneda in the morning of February 15 as it made a smooth cruising not encountering stormy weather it had predicted. In the afternoon of the same day, the U.S.S.R. scientist who was pressed in the schedule for return trip to his home country disembarked using Kaiyo maru's craft. At 09:30 on February 16, the vessel came alongside the Harumi Pier of the Tokyo Port, marking the end of the research cruise.

Table 1 shows the results of the noon observation during the cruise, and Fig. 1 shows the track line on the basis of the noon position.

Research Items and Methods

Research items are largely divided into fish school search survey, midwater trawling research, biological measurement research and marine environment research. The fish school search survey was conducted using the quantitative echo sounder system mainly at night with the cruising speed set at 8 knots per hour. The track line is shown in Fig. 2. When clear echogram was observed, a more detailed research followed in the surrounding area and preparations were made for the midwater trawling research on the next morning.

In midwater trawling research, towing was conducted mainly during daytime, and step-by-step towing and fixed horizontal towing were conducted within the depth range of 145-500 m according to echogram. In the beginning, three one-hour towings were conducted in a day but as it was inefficient in that few fish were caught. Therefore, from the third day, two towings were made a day with towing hours set at 2-3 hours at one time. Towing speed was within the range of 3.3-4.2 knots, with the average speed standing at 3.6 knots. Operation records are shown in Table 2 and the tow positions in Fig. 3. Number and weight of catches were recorded by species or species groups to clarify catch composition. But jellyfish was not counted as individuals.

Biological measurement was conducted for 40 each of male and female pollocks for each towing. All the individuals were measured when the number of the catch was less than 40, and, when it exceeded 40, the size of the surplus catch was measured for all the individuals by sex. However, as the number of catch in the last towing (ST-21) was large, not all the individuals were measured. The items of biological measurement consisted of fork length, weight, sex, weight of gonad and maturity of gonad. Besides these items, Japan collected gonad and stomach as specimens in formalin and also collected frozen pollock specimens for biochemical analysis. As age specific data, the Republic of Korea, Poland and the United States collected otoliths and the U.S.S.R. collected scales. The Republic of Korea conducted measurement of morphometrics and collected specimens for biochemical analysis, and Poland conducted measurement of morphometrics and meristics. Observation of stomach contents were conducted by the U.S.S.R.

Although CTD observation and collection of zooplanktons had been initially scheduled to be conducted at each tow point of midwater trawling, it was considered unnecessary to do so because of the limited extension of the research area and the limited duration of the research period. Further, one observation was made per day from the second day onward. Fig. 3 shows the observation points and Table 3 shows record items at each observation point. In CTD observation, the wire length was set at 1,00 m and data to the depth of 1,000 m were collected. In collection using NORPAC net, the length of wire was set at 330 m and vertical towing was made at a speed of 1 m per second from the depth of 300 m. A water filtration device was attached to the net to measure the amount of filtrated water. The average amount of filtrated water per one towing was 56.7 m^3 (Table 3)

Scientific Personnel

Japan: Takashi Sasaki, National Research Institute of Far Seas Fisheries

Republic of Korea: Won Sook H. Yang, Resources Division, National Fisheries Research & Development Agency

Poland: Andrzei Paciorkowski, National Sea Fisheries Institute

United States: Dennis Benjamin, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration

Soviet Union: Nicolay S. Fadeev, Pacific Research Institute of Fisheries and Oceanography (TINRO)

Kaiyo maru: All the crew assisted in the research activities, but the following officials in the ship's Research Section collaborated with the scientists specially in the conduct of the research and compilation of data.

Minekiyo Hasegawa
Toshimasa Yanagisawa
Yoshizo Suzuki
Seiji Toishi
Kei Miyamoto

Summary of Research Results

The research results compiled on board the ship during the cruise are summarized as follows:

1. The density of pollock in the research area was considered fairly low judging from the records of echogram and SV values (mean volume back scattering strength) as observed on the record sheets of the quantitative echo sounder system.

2. Dot or mist like echogram was observed on the record sheet of the quantitative echo sounder system (Fig. 4). Dot like echogram appeared mainly in the depth of 150-250 m both during day and night time. Mist like echogram was seen in the depth of 400-500 m during daytime but in the depth of 150-300 at night, thus indicating a clear difference in

depth between day and night. At night, both dot- and mist like echogram was simultaneously observed in the 150-300 m.

3. A total of 21 midwater trawlings were conducted in the depth of 145-500 m on the basis of echogram, and 2,320 pollocks (total weight of 1,855.7 kg) were caught (Table 4). Besides pollocks, smooth lumpsucker (320 fish total weight of 384.4 kg), squid (144 fish total weight of 19.7 kg), and jellyfish (total weight of 81.3 kg) were among the main catches.

4. In the towing operation at the depth of 400-500 m, lanternfishes, Pacific viperfish, northern smoothtongue, deepsea smelts, longfin dragonfish, northern pearleye, and various species of squid were caught incidentally (Table 4), suggesting that mist like echogram was the DSL by the middle and deep layer biotic community.

5. According to the results of the 14 midwater trawling directed at dot like echogram at the depth of 150-250 m (ST-2, 5, 17, 18, 19, 20, 21) and mist like echogram at the depth of 400-500 m (ST-7, 8, 9, 11, 14, 15, 16), pollocks were caught at both depth layers. The average CPUE (number of fish/hour) was 83 fish at the depth of 150-250 m and 42 fish at the depth of 400-500 m. The maximum CPUE was 162 fish at the depth of 150-250 m (ST-21), 90 fish at the depth of 400-500 m (ST-7) (Table 2). It is conjectured from these results that the 150-250 m depth layer represented a higher distribution of pollock than 400-500 m depth layer.

6. According to the information from Japanese fishing vessels operating in the research area, the average daily catch per vessel between January 22 to February 6 was in the range of 17.2 tons to 53.4 tons for large vessels and 9.0 tons to 31.9 tons for small vessels (Fig. 5). With the midwater trawling of Kaiyo maru, maximum catch per hour was 131.6 kg in ST-21 (Fig. 2). This means that only 3.2 tons can be caught even if the trawling net is operated for the whole day. The difference in catch volume from fishing vessels was due to the substantial gap in the fishing technology and the difference in the fishing gear. The midwater trawl net (KMT net) Kaiyo maru used in the present research is an old-fashioned one. It was not a modernistic midwater trawl net, commonly called rope net, which has been used by Japanese fishing boats in recent years. As the resistance of KMT net was great, it was towed at the speed of only 3.6 knot on the average. The net was small and the opening of the trawl net space at the time of towing was considered to be about one fifth of the net used by fishing boats.

7. The length composition of pollock was within the range of 39 cm to 60 cm in terms of fork length, with the mode standing at 49-50 cm and the average length at 49.1 cm (Fig. 6). The mode of male was 48-49 cm, with the average length at 48.2 cm, and the mode of female was 49-50 cm, with the average length of 49.9 cm, indicating that the length of female was larger than that of male (Fig. 7).

8. Comparing the length of pollock caught in the 150-250 m depth layer and those caught in the 400-500 m depth layer, the mode of the two was within the range of 49-50 cm, and the average length from the 150-250 m depth layer was 49.3 m and the that from the 400-500 m depth layer was 49.0, thus indicating little or no difference (Fig. 8). However, the percentage of large fish of 50 cm or more was 38% for the fish from the 150-250 m depth layer and 28% from the 400-500 m depth layer.

9. The average weight of pollock on the basis of precision measurement data was 810.6 g. The average weight of female was 876.3 g, as compared with 740.1 g for male. The average weights of pollock caught in the 150-250 m and 400-500 m depth layers were 800.7 g and 815.9 g, respectively, indicating a negligible difference.

10. The relation between length and weight of pollock was shown in Fig. 9, and the following formula was assumed to express it:

$$BW = 7.7618 \times 10^{-6} FL^{2.9783}$$

Here BW means weight (g) and FL means fork length (mm)

11. The average weight of ovary and spermary of pollock was 85.2 g and 58.5 g, respectively, occupying 9.7% and 7.9% of the body, respectively. Most of gonads of both male and female were mature. While part of the male were in the stage of spermatozoa discharge, female individuals having hydrated oocyte indicating the stage of spawing was only 0.7% out of 874 individuals for which maturitygonad was checked (Fig. 10). 93.7% of female pollock had fully mature ovary, with the immature ovary standing only at 5.3%.

12. No difference in catch by depth layer was observed by human eyes in the process of development of female gonad. However, distribution of indexes obtained through dividing the weight of gonad by body weight showed that gonad of the individuals caught in the 400-500 m depth layer showed more advanced development stage of gonad than those caught in the 150-250 m depth layer (Fig. 11)

13. The sex ratio of pollock was 45% male and 55% female, indicating that there were more females than males. No

difference in sex ratio due to the catch depth was observed.

14. According to the results of CTD observation, both water temperature and salinity showed a similar vertical distribution, and conspicuous thermocline were observed in the 120-200 m depth layer (Fig. 12). Pollock was distributed mainly in waters deeper than thermocline, but some were deemed to exist in the thermocline. In areas above thermocline, the water temperature was within the range of 2.3-2.9 degrees centigrade and there was no vertical changes. But the water temperature sharply rose in the thermocline, peaking out at 3.4-3.7 degrees centigrade in the 250-300 m depth layer, and subsequently gradually declining according to depth, reaching 2.7 degrees centigrade at the depth of 1,000 m. The vertical distribution of water temperature and salinity at the last observation point (ST-20) showed unclear thermocline, unlike those observed previously (Fig. 12). In other words, both water temperature and salinity gradually increased from surface layer to 200 m depth layer, suggesting that there was either mixture of sea water because of vertical mixing of water thermocline above and below or partial flow different water mass into the area of sea depth above thermocline.

15. In areas above thermocline, salinity stayed within the range of 33.04-33.11 0/00, then suddenly rose to 33.50 0/00 or higher, and later rose in pace with the water depth , reaching 34.32- 34.35 0/00 at the depth of 1,000 m (Fig. 12).

16. In addition to what was reported in the foregoing, research institutions of various countries participating in the present research are expected to conduct research on age composition, feeding habit, studies on histology of gonad and morphometrics and meristics as well as biochemical studies concerning pollock on the basis of specimens collected in the present research.

Table 1. Noon positions and observations during the research cruise by Kaiyo maru for pelagic pollock survey in the international waters of the Bering Sea in January and February of 1990.

Date	Position		Time difference from GMT	Survey stations	Weather	Wind		Air press. (mb)	Air temp. (° C)	Sea surf. temp.(° C)	Wave
	Latitude	Longitude				Direc.	Force				
20 Jan.	35° -19.4´N	139° -19.4´E	+ 9:00		o	N	6	1019.5	6.1	10.8	4
21	38° -27.2´N	142° -18.5´E	+ 9:30		bc	NE	1	1026.3	1.2	9.1	Calm
22	42° -41.8´N	145° -31.7´E	+ 9:30		b	ESE	3	1019.8	-1.6	1.7	3
23	45° -42.2´N	150° -25.6´E	+10:00		o	WSW	6	997.2	1.0	1.5	5
24	49° -30.0´N	155° -31.0´E	+10:30		c	SW	7	994.0	-0.6	1.3	7
25	51° -29.9´N	162° -15.9´E	+11:00		o	SSE	5	999.5	-0.6	2.1	4
26	52° -40.3´N	167° -25.9´E	+11:30		s	NE	7	992.5	0.4	2.8	7
27	53° -43.3´N	172° -10.2´E	+12:00		o	WNW	2	998.0	-0.4	3.7	3
28	54° -43.8´N	178° -22.3´E	+12:00		bc	SW	4	994.3	0.3	3.0	4
29	56° -05.4´N	176° -41.7´W	+12:00	1～ 3	s	SW	4	974.5	2.0	3.0	4
30	56° -14.4´N	176° -58.8´W	+12:00	4～ 6	o	SW	7	997.2	0.5	2.8	6
31	56° -05.1´N	177° -25.1´W	+12:00	7～ 8	bc	WNW	3	995.0	0.4	2.8	3
1 Feb.	56° -06.8´N	177° -41.6´W	+12:00	9～10	o	N	5	991.5	-0.9	2.7	4
2	56° -14.1´N	177° -32.8´W	+12:00	11～13	bc	W	6	1000.9	-1.3	2.9	5
3	56° -15.9´N	177° -43.0´W	+12:00	14～15	s	NW	5	1006.5	-2.6	2.8	4
4	55° -38.2´N	176° -29.3´W	+12:00	16～17	bc	WNW	6	1012.0	-2.0	2.7	6
5	55° -42.6´N	176° -36.6´W	+12:00	18～19	o	WSW	4	1012.7	1.8	2.7	4
6	55° -38.6´N	176° -25.2´W	+12:00	20～21	s	WNW	3	1010.5	-1.0	2.7	3
7	54° -57.7´N	178° -04.2´E	+12:00		o	WNW	7	1012.6	-5.2	2.9	6
8	53° -44.1´N	170° -01.4´E	+11:30		bc	NW	5	1019.0	-6.0	3.0	5
9	51° -31.9´N	161° -28.3´E	+11:00		s	E	8	1007.5	-0.4	1.5	7
10	48° -16.1´N	155° -54.2´E	+10:30		s	WNW	7	1020.5	-3.8	1.0	6
11	45° -05.4´N	149° -20.4´E	+10:00		o	SE	5	1024.3	2.1	1.2	4
12	42° -04.6´N	145° -08.4´E	+10:00		b	WSW	6	1005.5	3.4	3.1	5
13	38° -46.7´N	141° -53.8´E	+ 9:30		c	WSW	5	1020.0	3.6	8.6	3
14	37° -21.6´N	141° -19.4´E	+ 9:00		o	N	3	1029.5	5.4	10.9	2
15	35° -34.6´N	139° -49.2´E	+ 9:00		d	NNW	5	1022.5	4.6	9.1	3
16	Came alongside the Harumi Pier of Port of Tokyo at 9:30 AM										

Table 2. Operation records of midwater trawl for pelagic pollock by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 of 1990.

Station No.		ST-01	ST-02	ST-03	ST-04	ST-05	ST-06	ST-07	ST-08
Date		Jan. 29	Jan. 29	Jan. 29	Jan. 30	Jan. 30	Jan. 30	Jan. 31	Jan. 31
Start time of tow		09:40	14:25	18:40	08:30	13:35	17:25	08:30	13:45
End time of tow		10:40	15:25	19:35	09:30	14:35	18:25	09:30	16:45
Start position	Lat.	55° -57.3´N	56° -14.7´N	56' -25.7´N	56° -22.8´N	56° -16.0´N	56° -08.5´N	56° -07.8´N	56° -05.4´N
of tow	Long.	176° -34.2´W	176° -39.7´W	176° -41.1´W	176° -57.8´W	176° -56.6´W	177° -00.0´W	177° -16.1´W	177° -28.3´W
End position	Lat.	55° -58.7´N	56° -17.8´N	56° -26.1´N	56° -25.0´N	56° -18.6´N	56° -09.9´N	56° -09.4´N	56° -04.6´N
of tow	Long.	176° -40.0´W	176° -35.5´W	176° -34.6´W	176° -53.3´W	176° -51.0´W	176° -53.8´W	177° -10.5´W	177° -50.1´W
Towing hours (h-m)		01-00	01-00	00-55	01-00	01-00	01-00	01-00	03-00
Towing speed (kn)		3.5	3.9	3.9	3.3	4.1	3.7	3.5	4.1
Towing distance (nm)		3.5	3.9	3.6	3.3	4.1	3.7	3.5	12.3
Towing depth range (m)		215-385	170-220	160-270	170-400	170-220	160-295	420-445	400-440
Height of net opening (m)		17-19	16-20	17-19	16-19	15-18	16-17	17-18	16-17
Type of echogram[1]		A	A	A	D	A	A	C	C
Range of echogram (m)		150-250	170-190	150-280	-	150-220	150-300	420-460	350-480
Pollock catch (number)		47	61	7	11	54	14	90	193
Pollock catch (kg)		41.8	51.2	5.9	7.9	45.7	12.5	75.6	158.7
Pollock CPUE (Number/hour)		47	61	8	11	54	14	90	64
Pollock CPUE (kg/hour)		41.8	51.2.	6.4	7.9	45.7	12.5	75.6	52.9

Table 2. Continued.

Station No.		ST-09	ST-10	ST-11	ST-12[2]	ST-13	ST-14	ST-15	ST-16
Date		Feb. 01	Feb. 01	Feb. 02	Feb. 02	Feb. 02	Feb. 03	Feb. 03	Feb. 04
Start time of tow		08:35	14:50	09:35	13:06	16:35	09:40	13:15	09:40
End time of tow		10:35	17:50	12:00	-	17:35	12:00	17:00	12:00
Start position	Lat.	56° -12.4′N	56° -08.0′N	56° -11.1′N	56° -14.0′N	56° -14.2′N	56° -17.8′N	56° -15.0′N	55° -44.7′N
of tow	Long.	177° -38.1′W	177° -34.9′W	177° -47.1′W	177° -26.1′W	177° -18.1′W	177° -28.6′W	177° -40.7′W	176° -41.5′W
End position	Lat.	56° -08.4′N	56° -03.7′N	56° -14.1′N	-	56° -15.1′N	56° -16.0′N	56° -18.0′N	55° -38.2′N
of tow	Long.	177° -50.7′W	177° -55.7′W	177° -32.7′W	-	177° -11.8′W	177° -42.9′W	177° -16.9′W	176° -29.3′W
Towing hours (h-m)		02-00	03-00	02-25	-	01-00	02-20	03-45	02-20
Towing speed (kn)		4.1	4.1	3.6	-	3.6	3.5	3.6	4.1
Towing distance (nm)		8.2	12.3	8.7	-	3.6	8.2	13.5	9.6
Towing depth range (m)		360-460	210-470	400-450	-	250-400	445-500	400-460	410-440
Height of net opening (m)		16-18	15-18	17-18	-	15-18	17-19	16-17	17
Type of echogram[1]		A	A+C	C	C	A	C	C	C
Range of echogram (m)		350-450	300-450	450	420-460	200-300	400-500	400-480	420
Pollock catch (number)		85	116	56	4	5	72	66	60
Pollock catch (kg)		72.9	85.5	43.3	3.2	4.3	58.9	52.3	48.8
Pollock CPUE (Number/hour)		43	39	23	-	5	31	18	28
Pollock CPUE (kg/hour)		36.5	28.5	17.9	-	4.3	25.2	13.9	20.9

Table 2. Continued.

Station No.		ST-17	ST-18	ST-19	ST-20	ST-21
Date		Feb. 04	Feb. 05	Feb. 05	Feb. 06	Feb. 06
Start time of tow		14:50	09:30	12:55	09:25	12:55
End time of tow		17:00	12:00	15:02	12:00	17:00
Start position	Lat.	55° -44.6´N	55° -38.9´N	55' -44.2´N	55° -43.3´N	55° -39.0´N
of tow	Long.	176° -41.4´W	176° -53.2´W	176° -32.1´W	176° -42.2´W	176° -25.6´W
End position	Lat.	55° -38.2´N	55° -42.6´N	55° -43.1´N	55° -38.6´N	55° -38.9´N
of tow	Long.	176° -30.0´W	176° -36.6´W	176° -36.6´W	176° -25.2´W	176° -52.1´W
Towing hours (h-m)		02-10	02-30	02-07	02-35	04-05
Towing speed (kn)		4.2	3.8	3.6	4.1	3.7
Towing distance (nm)		9.1	9.5	7.6	10.6	15.1
Towing depth range (m)		145-220	180-225	200-250	165-215	190-270
Height of net opening (m)		15-16	17-18	16-18	16-18	15-18
Type of echogram[1]		B	B	D	B	B
Range of echogram (m)		120-250	200	-	100-250	150-220
Pollock catch (number)		254	204	98	160	663
Pollock catch (kg)		180.2	161.2	79.7	128.7	537.4
Pollock CPUE (Number/hour)		117	82	46	62	162
Pollock CPUE (kg/hour)		83.2	64.5	37.7	49.8	131.6

1 Abbreviation of echogram:

A : Scattered dot like echogram

B : Dot like echogram

C : Weak mist like echogram

D : No echogram

2 Unsuccessful tow because the tow was discontinued just after start of tow due to engine trouble.

Table 3. Records of oceanographic observations by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 of 1990.

Station Number	ST-01	ST-02	ST-03	ST-05	ST-08	ST-10	ST-11	ST-14
Date	Jan. 29	Jan. 29	Jan. 29	Jan. 30	Jan. 31	Feb. 1	Feb. 2	Feb. 3
Time	08:05-09:02	13:06-13:58	17:03-18:09	12:05-13:05	12:02-12:54	13:00-14:13	08:04-08:57	08:00-09:00
Position Lat.	55° -56.3′N	56° -13.7′N	56° -25.3′N	56° -14.6′N	56° -05.1′N	56° -09.2′N	56° -10.1′N	56° -17.8′N
Long.	176° -29.9′W	176° -41.3′W	176° -43.6′W	176° -58.8′W	177° -25.1′W	177° -30.9′W	177° -51.8′W	177° -22.5′W
Bottom depth (m)	-	3,710	3,728	3,730	3,680	3,773	3,778	3,762
Weather	c	c	c	o	bc	o	bc	b
Wind direction	ENE	SW	W	SW	WNW	N	W	E
Wind force	4	4	3	7	3	5	6	4
Air pressure (mb)	975.5	974.5	977.0	997.2	995.0	991.5	1,000.4	1.007.6
Sea condition	4	4	3	6	3	4	5	4
Air temperature (° C)	3.0	1.8	2.6	0.5	0.4	-1.0	-1.3	-1.4
Sea surface temp. (° C)	2.9	2.7	2.6	2.6	2.6	2.5	2.0	2.6
CTD (m)	0~1,090	0~1,090	0~1,091	0~1,090	0~1,092	0~1,091	0~1,091	0~1,091
NORPAC (filtered vol.:m^3)	50.64	52.82	Not recorded	63.25	51.44	63.28	54.27	59.64

Table 3. Continued.

Station Number	ST-16	ST-18	ST-20
Date	Feb. 4	Feb. 5	Feb. 6
Time	08:00-09:00	08:01-09:03	08:00-08:56
Position Lat.	55° -46.9 ´N	55° -38.2 ´N	55° -44.2 ´N
Long.	176° -44.7 ´W	176° -56.3 ´W	176° -46.3 ´W
Bottom depth (m)	3,765	3,778	3,767
Weather	o	o	o
Wind direction	NW	WNW	WNW
Wind force	7	5	4
Air pressure (mb)	1,008.0	1,012.6	1,010.3
Sea condition	6	5	4
Air temperature (° C)	-2.6	-1.0	-2.2
Sea surface temp. (° C)	2.4	3.1	2.6
CTD (m)	0～1,089	0～1,089	0～1,089
NORPAC (filtered vol.:m^3)	48.62	71.04	52.16

Table 4. Catch records of midwater trawl operations by _Kaiyo maru_ in the international waters of the Bering Sea from January 29 to February 6 of 1990.

Species[1] or species group	ST-01		ST-02		ST-03		ST-04		ST-05		ST-06		ST-07		ST-08	
	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)
Walleye pollock	47	41.80	61	51.20	7	5.90	11	7.90	54	45.70	14	12.50	90	75.60	193	158.70
Pacific cod	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smooth lumpsucker	7	9.30	10	13.40	4	5.60	2	6.00	4	4.40	10	10.90	4	6.20	4	8.70
Rougheye rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific lamprey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snipe eels	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.02
Deepsea smelts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.07
Northern smoothtongue	-	-	-	-	1	0.02	-	-	-	-	8	0.06	1	0.01	2	0.01
Winged spookfish	-	-	-	-	-	-	-	-	-	-	-	-	1	0.08	-	-
Longfin dragonfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific viperfish	-	-	-	-	-	-	-	-	-	-	-	-	5	0.03	4	0.03
Northern pearleye	-	-	-	-	-	-	-	-	-	-	-	-	1	0.04	-	-
Lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	5	0.03	7	0.02
Dreamers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manefish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Squids	1	0.15	-	-	4	0.25	2	0.19	-	-	9	0.21	8	0.45	30	1.74
Jellyfishes	-	5.70	-	2.90	-	5.60	-	-	-	1.50	-	7.90	-	8.20	-	0.70
Total	55	56.95	71	67.50	16	17.37	15	14.09	58	51.60	41	31.57	115	90.64	242	169.99

Table 4. Continued.

Species[1] or species group	ST-09		ST-10		ST-11		ST-12		ST-13		ST-14		ST-15		ST-16	
	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)
Walleye pollock	85	72.90	116	85.50	56	43.30	4	3.20	5	4.30	72	58.90	66	52.30	60	48.80
Pacific cod	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smooth lumpsucker	17	30.90	13	13.50	6	13.80	1	0.40	3	3.90	5	6.00	10	24.70	24	60.60
Rougheye rockfish	-	-	-	-	1	2.10	-	-	-	-	-	-	-	-	1	2.30
Pacific lamprey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snipe eels	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deepsea smelts	-	-	-	-	-	-	-	-	-	-	-	-	1	0.02	-	-
Northern smoothtongue	-	-	2	0.01	-	-	-	-	-	-	2	0.01	2	0.02	-	-
Winged spookfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Longfin dragonfish	-	-	-	-	-	-	-	-	-	-	-	-	1	0.03	-	-
Pacific viperfish	1	0.01	-	-	-	-	-	-	-	-	7	0.06	7	0.12	-	-
Northern pearleye	-	-	-	-	-	-	-	-	-	-	-	-	2	0.12	-	-
Lanternfishes	2	0.02	2	0.01	-	-	-	-	-	-	3	0.01	4	0.02	-	-
Dreamers	-	-	-	-	-	-	1	0.39	-	-	-	-	-	-	-	-
Manefish	-	-	1	0.60	-	-	-	-	-	-	-	-	-	-	-	-
Squids	12	1.20	30	6.95	12	1.60	5	0.62	4	1.00	8	0.27	15	4.74	2	0.25
Jellyfishes	-	8.40	-	7.40	-	1.80	-	3.40	-	8.80	-	3.10	-	6.20	-	0.90
Total	117	113.43	164	113.97	75	62.60	11	8.01	12	18.00	97	68.35	108	88.27	87	112.85

Table 4. Continued.

Species[1] or species group	ST-17		ST-18		ST-19		ST-20		ST-21		Total	
	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W(kg)	N	W (kg)
Walleye pollock	254	180.20	204	161.20	98	79.70	160	128.70	663	537.40	2,320	1,855.70
Pacific cod	-	-	1	1.05	-	-	-	-	-	-	1	1.05
Smooth lumpsucker	51	41.70	26	17.00	40	40.80	22	26.00	57	40.60	320	384.40
Rougheye rockfish	-	-	-	-	-	-	-	-	-	-	2	4.40
Pacific lamprey	1	0.90	-	-	-	-	-	-	-	-	1	0.90
Snipe eels	-	-	-	-	-	-	-	-	-	-	1	0.02
Deepsea smelts	-	-	-	-	-	-	-	-	-	-	2	0.09
Northern smoothtongue	-	-	-	-	-	-	-	-	-	-	18	0.14
Winged spookfish	-	-	-	-	-	-	-	-	-	-	1	0.08
Longfin dragonfish	-	-	-	-	-	-	-	-	-	-	1	0.03
Pacific viperfish	-	-	-	-	-	-	-	-	-	-	24	0.25
Northern pearleye	-	-	-	-	-	-	-	-	-	-	3	0.16
Lanternfishes	-	-	-	-	-	-	-	-	-	-	23	0.11
Dreamers	-	-	-	-	-	-	-	-	-	-	1	0.39
Manefish	-	-	-	-	-	-	-	-	-	-	1	0.60
Squids	2	0.10	-	-	-	-	-	-	-	-	144	19.72
Jellyfishes	-	3.60	-	0.50	-	1.70	-	1.20	-	1.83	-	81.33
T o t a l	308	226.50	231	179.75	138	122.20	182	155.90	720	579.83	2,863	2,349.37

1 English common name refered to Hart (1973): Pacific fishes of Canada.

Table 5. Size (fork length) composition of pelagic pollock caught in midwater trawl operations by <u>Kaiyo</u> <u>maru</u> in the international waters of the Bering Sea from January 29 to February 6 of 1990

Size class	ST-01			ST-02			ST-03			ST-04			ST-05			ST-06			ST-07			ST-08		
(cm)	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T
35-36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36-37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37-38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38-39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
41-42	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42-43	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
43-44	-	1	1	2	2	4	-	-	-	-	-	-	1	-	1	-	-	-	-	1	1	1	3	4
44-45	-	1	1	-	-	-	-	-	-	-	-	-	2	-	2	-	1	1	-	-	-	6	4	10
45-46	1	1	2	2	-	2	-	-	-	-	1	1	1	-	1	-	-	-	5	1	6	11	3	14
46-47	-	1	1	5	1	6	-	-	-	1	-	1	1	-	1	1	-	1	2	1	3	10	5	15
47-48	3	2	5	7	3	10	-	1	1	1	3	4	2	1	3	1	-	1	11	5	16	13	6	19
48-49	4	1	5	4	2	6	1	1	2	1	-	1	10	1	11	1	-	1	6	8	14	8	15	23
49-50	2	8	10	2	6	8	1	2	3	-	-	-	3	1	4	1	1	2	5	19	24	17	29	46
50-51	3	6	9	-	6	6	-	-	-	-	1	1	6	2	8	-	3	3	2	7	9	4	15	19
51-52	-	4	4	3	5	·8	1	-	1	1	-	1	2	7	9	-	1	1	3	7	10	4	21	25
52-53	-	2	2	-	5	5	-	-	-	-	1	1	-	9	9	1	2	3	1	2	3	2	11	13
53-54	-	2	2	-	1	1	-	-	-	-	-	-	-	1	1	-	-	-	-	2	2	-	2	2
54-55	-	4	4	-	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-	1	1	-	-	-
55-56	-	-	-	1	-	1	-	-	-	-	-	-	-	2	2	-	-	-	-	1	1	-	1	1
56-57	-	1	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
57-58	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-
58-59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
59-60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60-61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61-62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62-63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63-64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64-65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	13	34	47	27	33	60	3	4	7	4	7	11	28	26	54	5	9	14	35	55	90	76	117	193

Table 5. Continued.

Size class (cm)	ST-09			ST-10			ST-11			ST-12			ST-13			ST-14			ST-15			ST-16		
	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T
35-36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36-37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37-38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38-39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41-42	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42-43	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	1	1	-	1	-	-	-
43-44	-	-	-	3	1	4	-	-	-	-	-	-	-	-	-	-	1	1	1	1	2	-	-	-
44-45	1	-	1	3	1	4	-	-	-	1	-	1	-	-	-	1	-	1	1	-	1	1	-	1
45-46	3	2	5	10	1	11	4	-	4	-	-	-	-	-	-	5	-	5	4	1	5	2	-	2
46-47	8	1	9	9	-	9	7	-	7	-	-	-	-	-	-	4	2	6	3	-	3	3	2	5
47-48	5	1	6	18	5	23	6	5	11	-	1	1	-	-	-	15	2	17	2	1	3	7	4	11
48-49	2	9	11	10	5	15	9	5	14	-	1	1	1	1	2	7	5	12	12	8	20	9	5	14
49-50	11	11	22	8	11	19	1	4	5	-	-	-	-	1	1	4	7	11	5	7	12	6	9	15
50-51	5	9	14	4	7	11	2	4	6	-	1	1	-	-	-	-	5	5	1	5	6	3	2	5
51-52	3	1	4	3	7	10	-	5	5	-	-	-	-	2	2	1	5	6	4	4	8	-	3	3
52-53	2	4	6	1	5	6	-	2	2	-	-	-	-	-	-	1	2	3	-	2	2	1	1	2
53-54	-	4	4	-	1	1	-	1	1	-	-	-	-	-	-	-	1	1	1	2	3	-	1	1
54-55	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	1	1
55-56	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56-57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
57-58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58-59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
59-60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60-61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61-62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62-63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63-64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64-65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	40	45	85	69	45	114	30	26	56	1	3	4	1	4	5	39	33	72	35	31	66	32	28	60

Table 5. Continued.

Size class	ST-17			ST-18			ST-19			ST-20			ST-21			Total		
(cm)	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	T	♂	♀	Total
35-36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36-37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37-38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38-39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39-40	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	1
40-41	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3
41-42	1	-	1	-	1	1	-	1	1	-	1	1	-	1	1	3	4	7
42-43	3	1	4	-	1	1	-	-	-	1	-	1	2	1	3	8	6	14
43-44	2	1	3	3	3	6	1	-	1	1	-	1	-	3	3	15	17	32
44-45	4	1	5	1	-	1	5	1	6	1	-	1	3	4	7	30	13	43
45-46	8	5	13	12	2	14	2	1	3	3	5	8	11	5	16	84	28	112
46-47	10	3	13	10	5	15	3	1	4	7	3	10	23	9	32	107	34	141
47-48	15	11	26	16	6	22	5	5	10	5	10	15	38	18	56	170	90	260
48-49	27	22	49	17	17	34	6	9	15	15	12	27	45	23	68	195	150	345
49-50	17	28	45	15	13	28	6	8	14	12	17	29	30	46	76	146	228	374
50-51	11	18	29	12	22	34	5	13	18	6	18	24	23	45	68	87	189	276
51-52	4	22	26	4	21	25	3	6	9	4	16	20	16	21	37	56	158	214
52-53	2	12	14	2	13	15	-	7	7	2	9	11	2	18	20	17	107	124
53-54	2	7	9	1	2	3	-	5	5	-	4	4	1	13	14	5	49	54
54-55	-	2	2	-	3	3	-	2	2	-	2	2	-	2	2	-	23	23
55-56	1	1	2	-	-	-	-	3	3	-	1	1	-	3	3	2	13	15
56-57	-	-	-	-	-	-	-	-	-	-	1	1	1	-	1	1	5	6
57-58	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	1	2
58-59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
59-60	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	1
60-61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61-62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62-63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63-64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64-65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	108	135	243	93	109	202	36	62	98	59	99	158	196	212	408	930	1,117	2,047

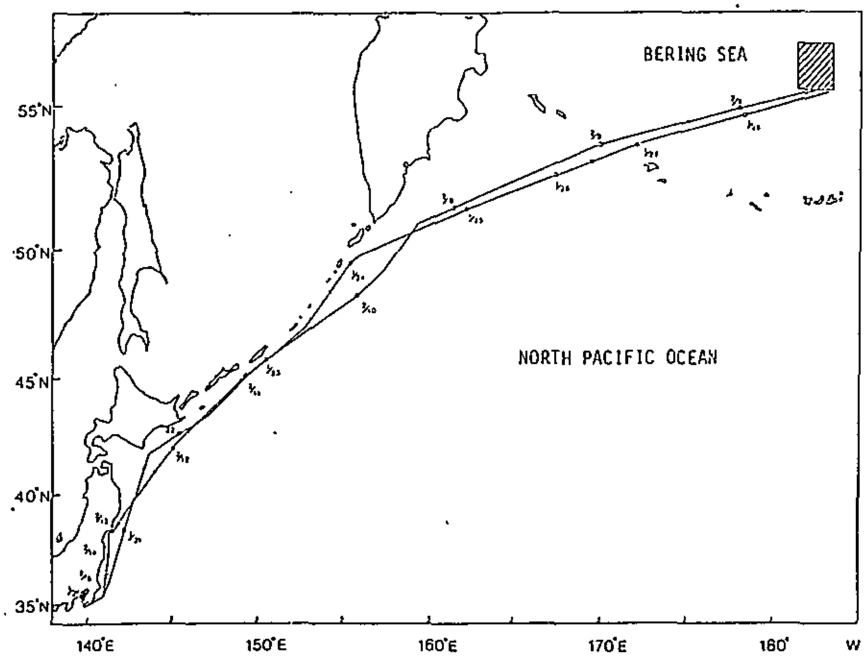


Figure 1. Track and noon positions of a cruise by Kaiyo maru for the pelagic pollock survey in the international waters of the Bering Sea from January 20 to February 16 of 1990.

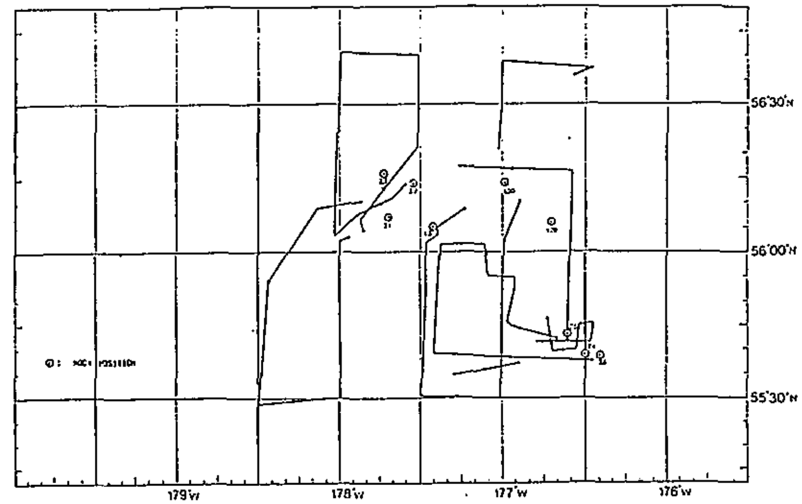


Figure 2. Track line for searching pelagic pollock school by Kaiyo maru using quantitative echo sounder system in the international waters of the Bering Sea from January 29 to February 6 of 1990.

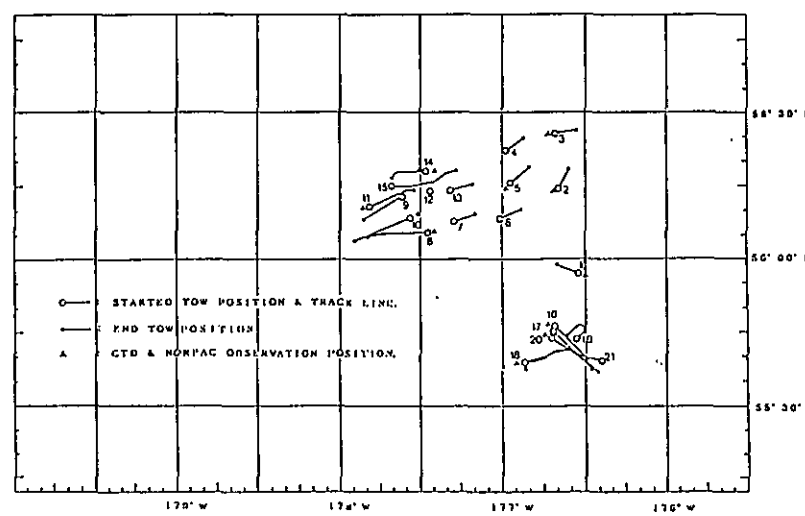


Figure 3. Track line of midwater trawl operations for pelagic pollock and oceanographic stations conducted by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 of 1990.

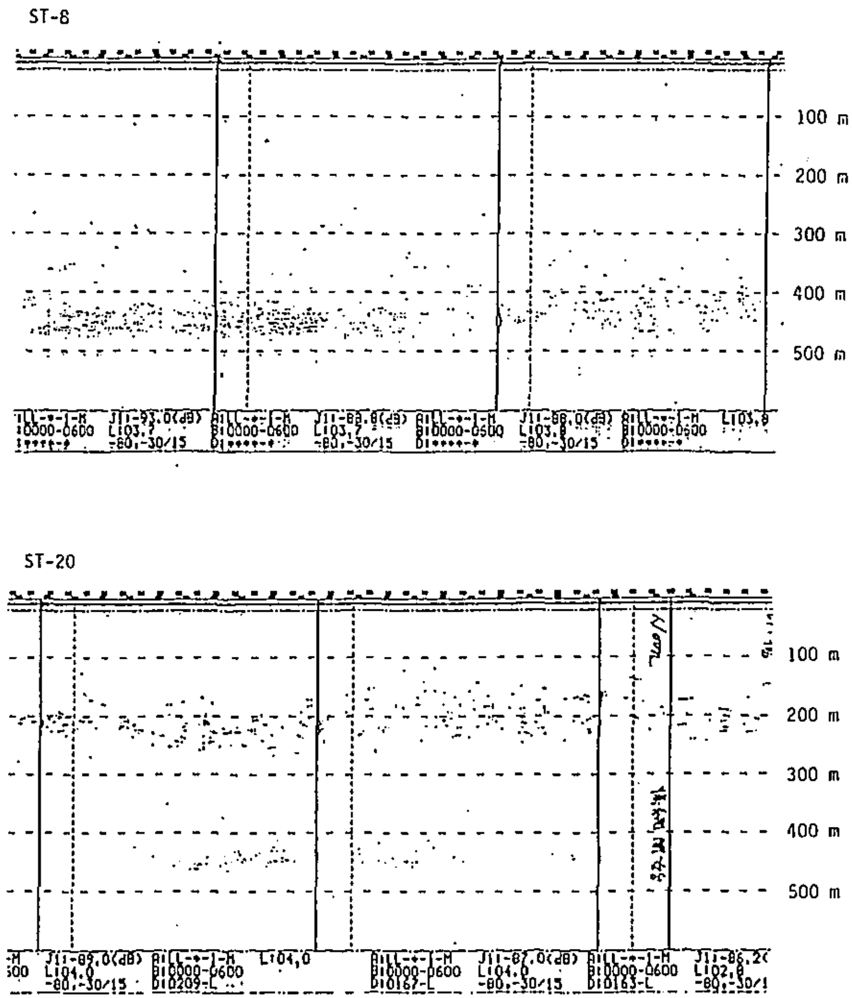


Figure 4. Echogram from quantitative echo sounder obtained in the pelagic pollock survey by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 of 1990. The upper figure shows a weak mist like echogram observed in a 400-500 m depth layer at ST-8 amd the lower figure shows a dot like echogram observed in a 150-250 m depth layer at at ST-20.

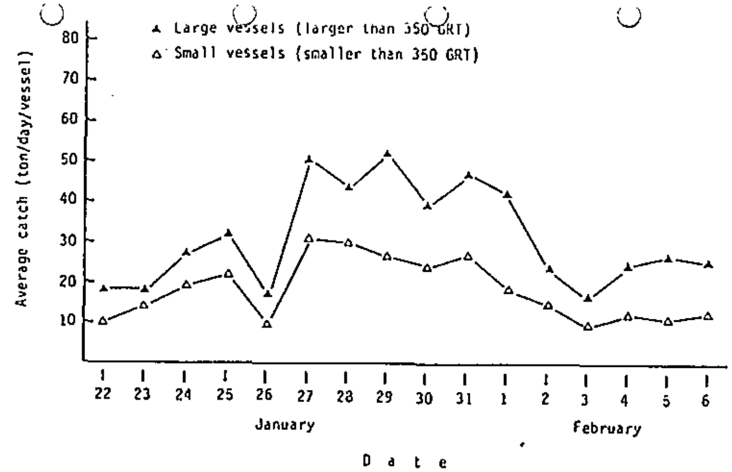


Figure 5. Average catch of pollock (ton/day/vessel) by Japanese trawl vessels operated in the international waters of the Bering Sea from January 22 to February 6 in 1990.

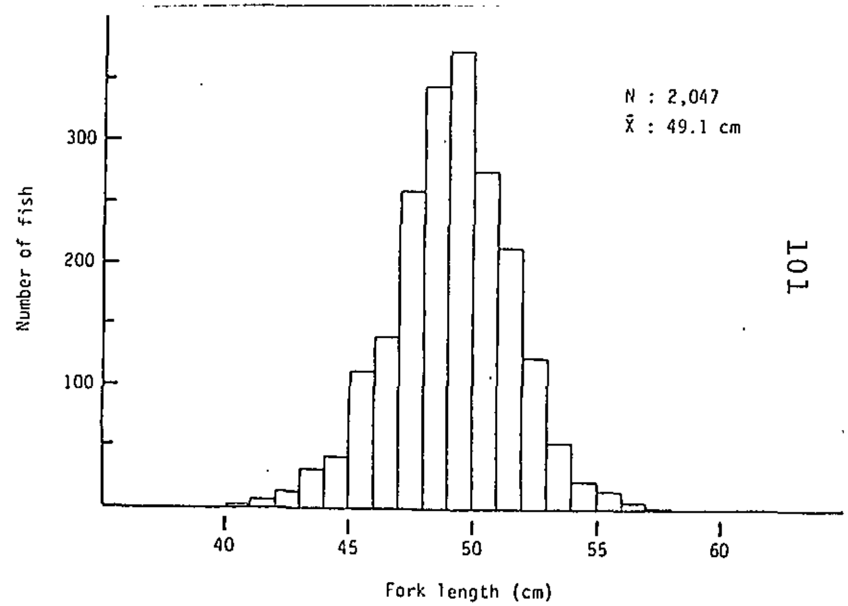


Figure 6. Size composition of pelagic pollock caught in midwater trawl survey by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 in 1990.

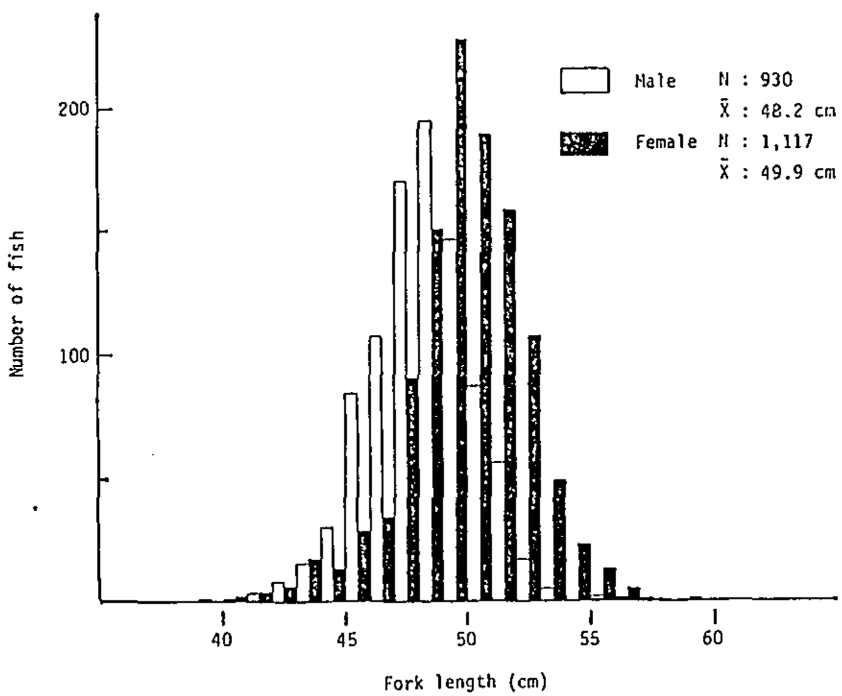


Figure 7. Size composition of pelagic pollock by sex caught in midwater trawl survey by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 in 1990.

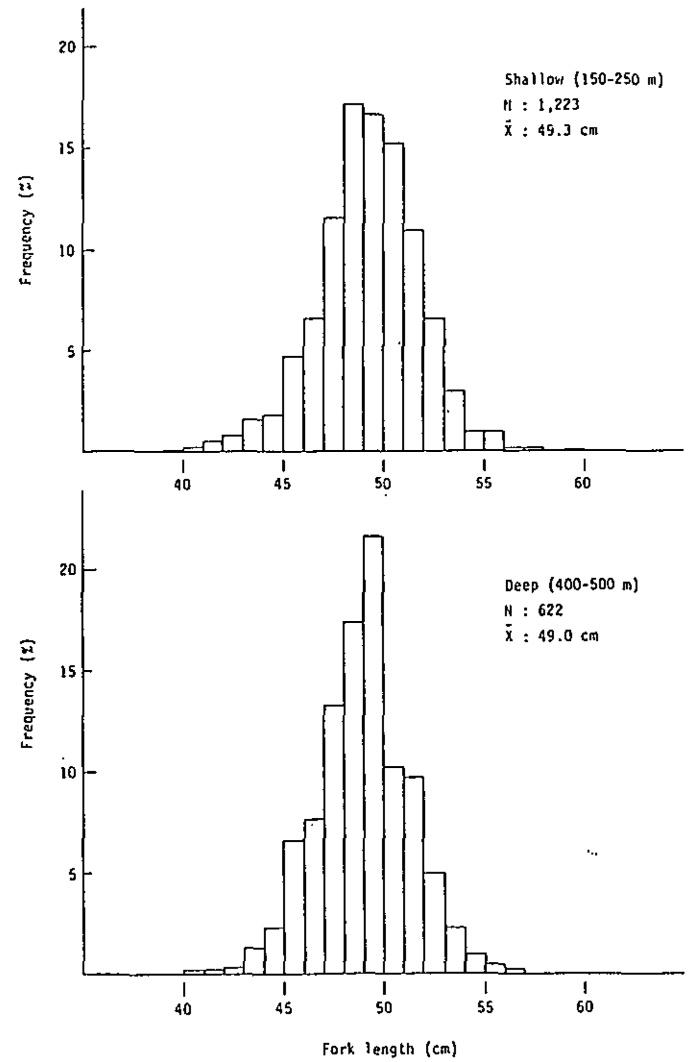


Figure 8. Size composition of pelagic pollock by depth layer caught in midwater trawl survey by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 in 1990.

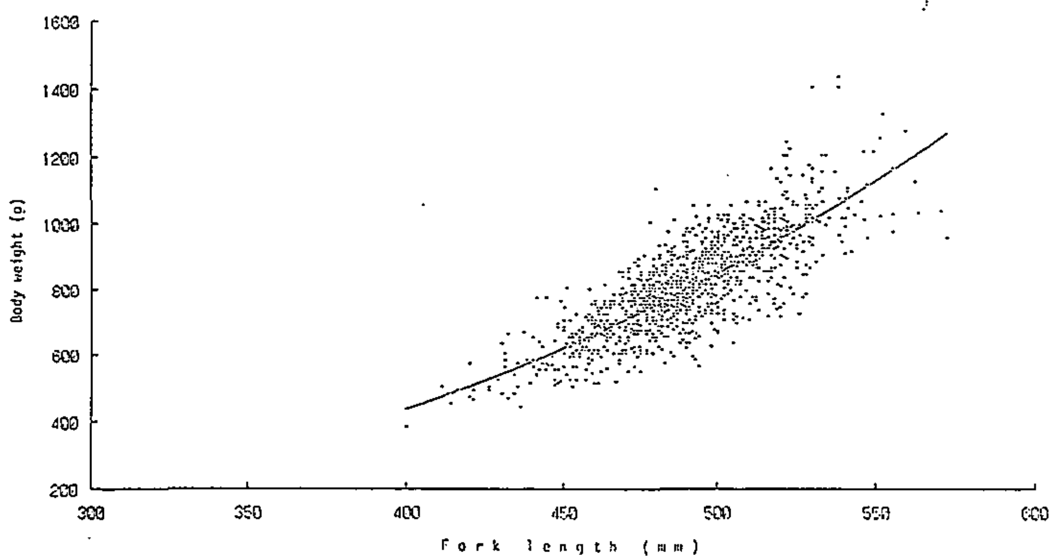


Figure 9. Length-weight relationship of pelagic pollock caught in midwater trawl survey by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 of 1990.

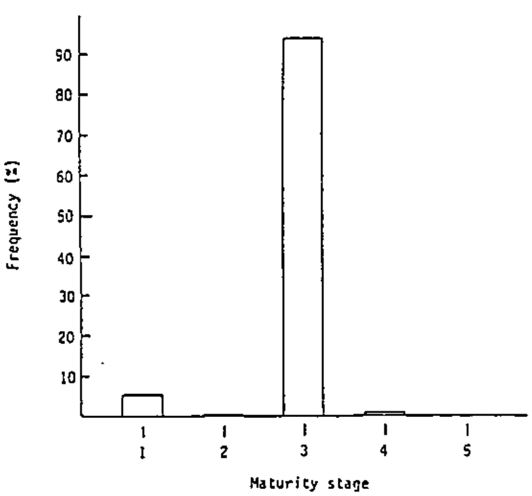


Figure 10. Frequency distribution of maturity stage of female pollock caught in midwater trawl survey by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 of 1990.

Abbreviation : 1 = Immature
2 = Maturing
3 = Mature
4 = Spawning
5 = Spent

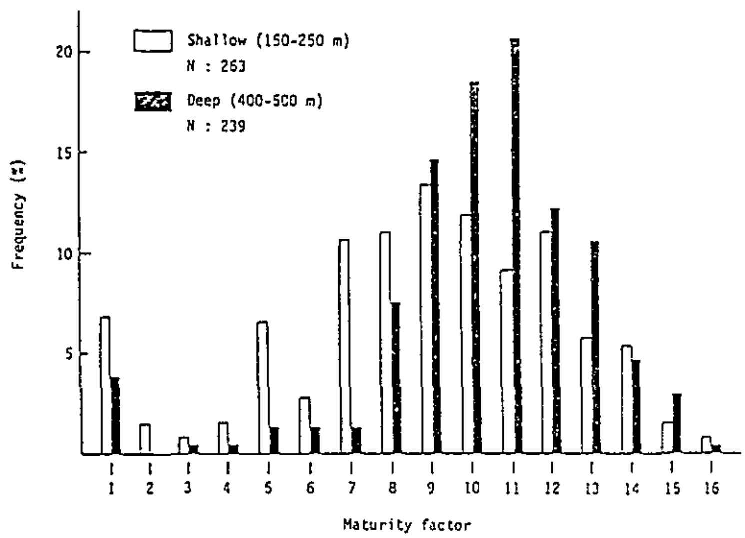
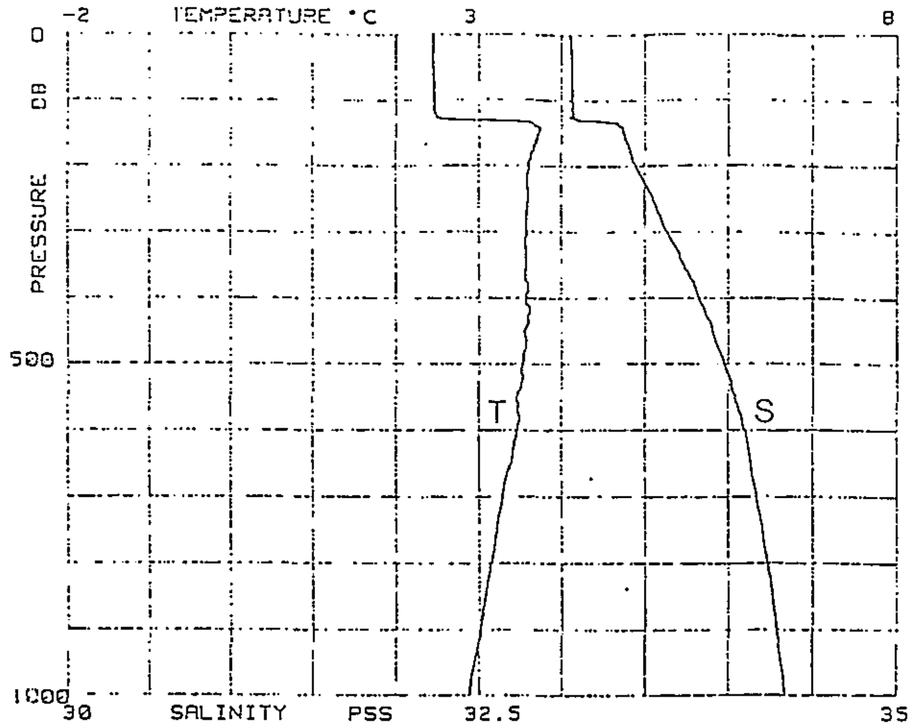


Figure 11. Frequency distribution of maturity factor of female pollock by depth layer caught in midwater trawl survey by Kaiyo maru in the international waters of the Bering Sea from January 29 to February 6 of 1990. Maturity factor was defined as (GW/BW)x100: GW is gonad weight in g and BW is body weight in g.



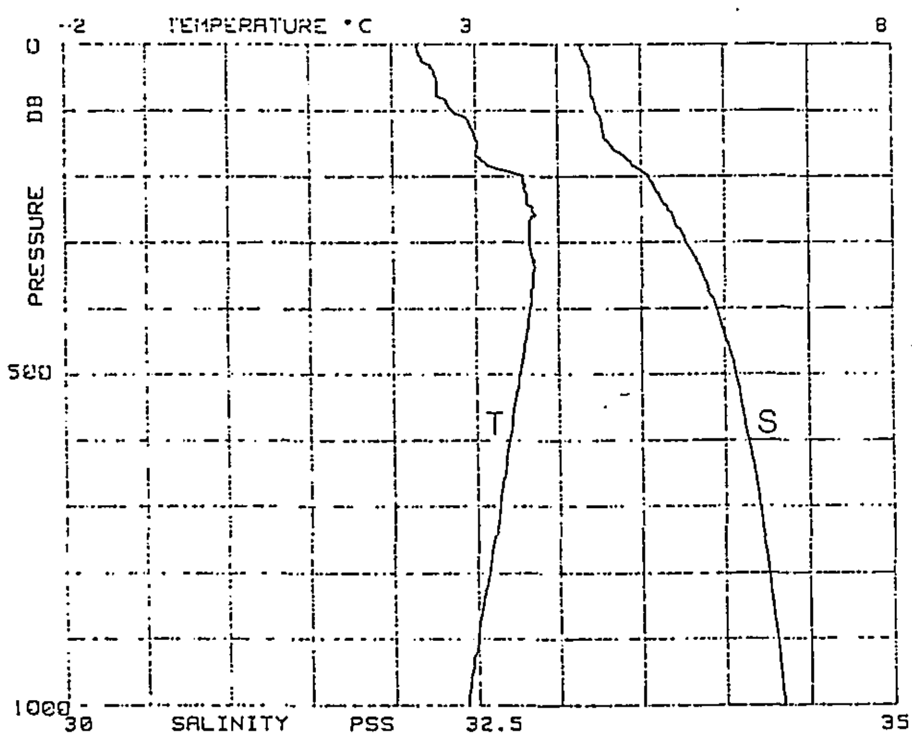


Figure 12. Vertical cross section of water temperature and salinity from CTD observations by Kaiyo maru at ST-5 and ST-20 in the international waters of the Bering Sea in January 30 and February 6 of 1990, respectively.

The hypothesis of the existence of near-bottom and pelagic pollock

Ye. I. Ilyinsky et. al.
TINRO, Vladivostok, U.S.S.R.

(Note: Written paper was not available. Figures were presented only)

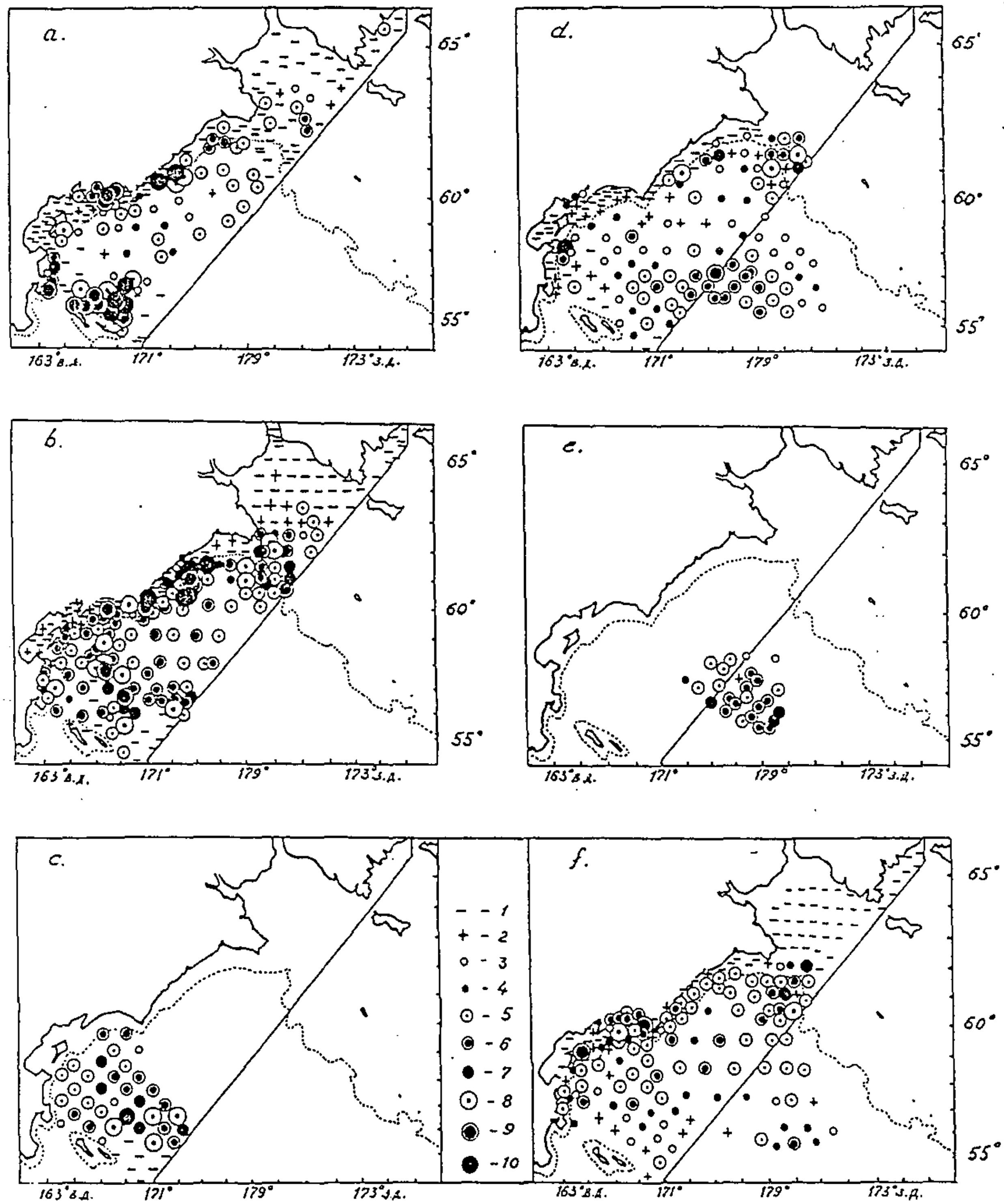


Figure 1. Distribution of catches of 40-45 length group: a - in September-October 1986, b- in August-September 1987, c - in October 1987, d - in October-November 1988, e - in November-December 1988, f - in May-July 1989. Legend as on Figure 2

ILYINSKY

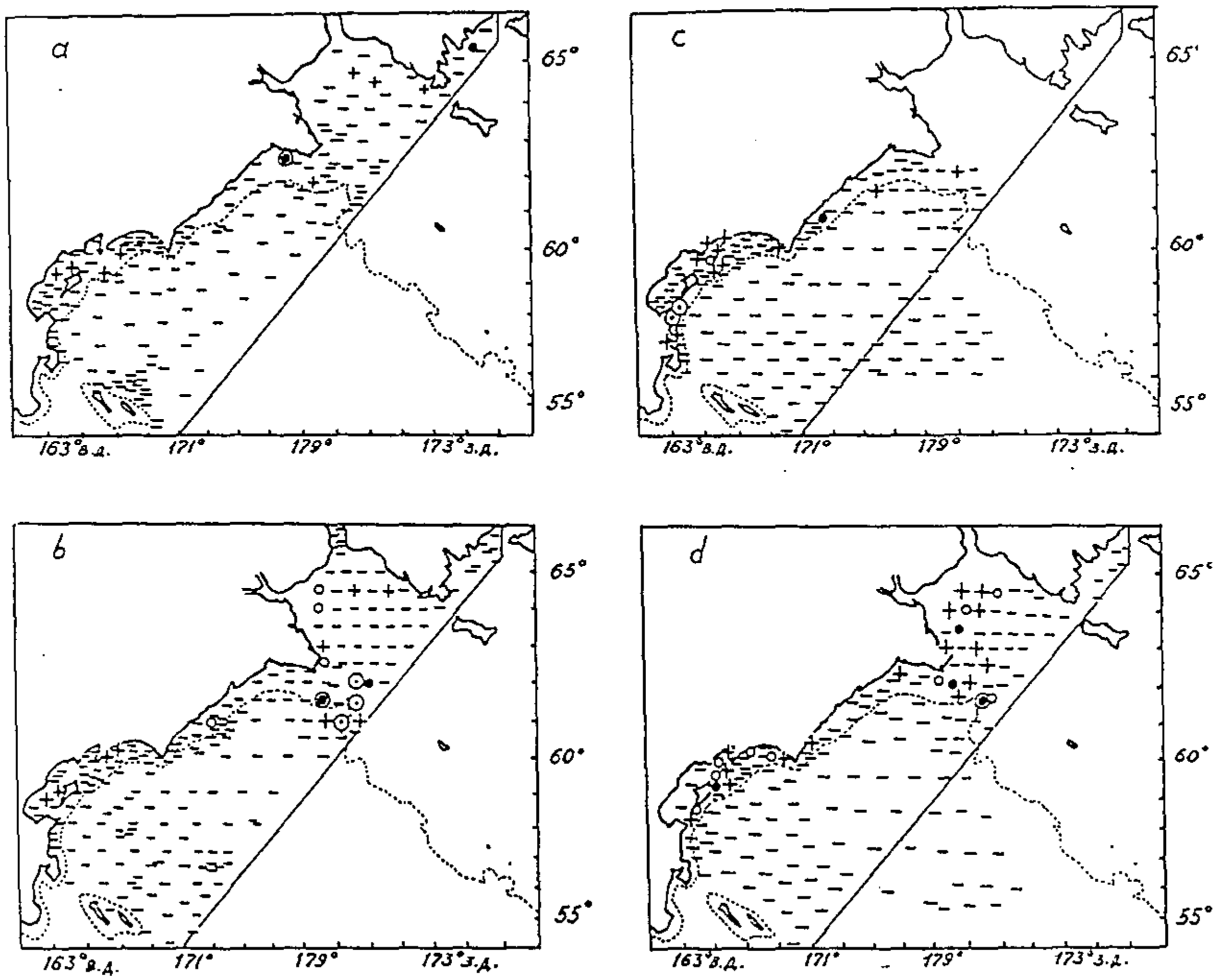


Figure 2. Distribution of catches per unit effort (numbers/hour) of above 60 sm - length groupe: a - in September-October 1986, b - in August-September 1987, c - in October- November 1988, d - in May-July 1989.
1 - 0; 2 - 1-5; 3 - 6-25; 4 - 26-50; 5 - 51-250; 6 - 251-1000; 7 - 1001-2000; 8 - 2001-5000; 5001-10000; 10 - above 10000 numbers.

I-Kissi

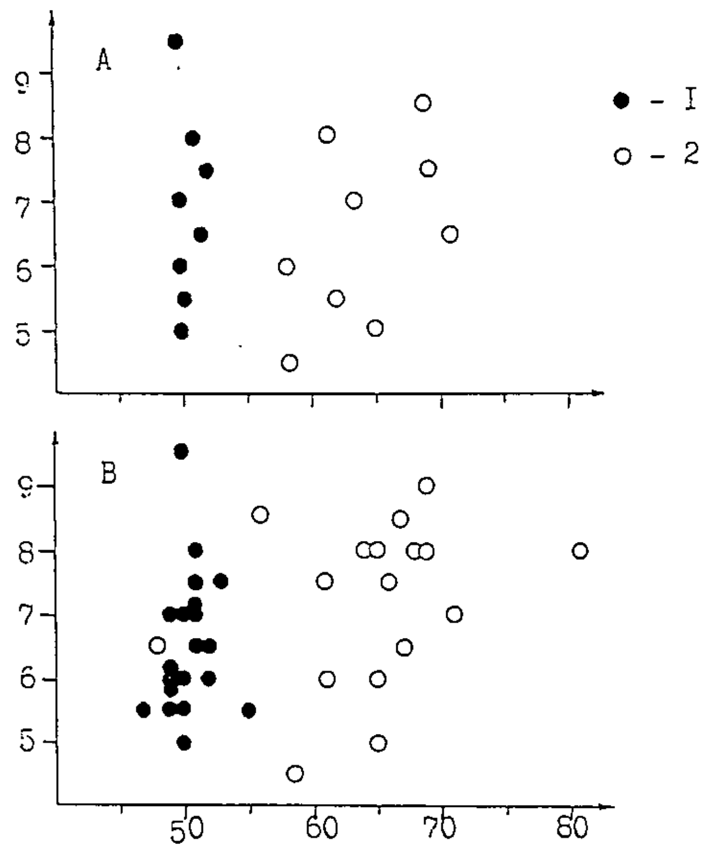


Figure 3. Length (in sm) (on axis of abscissas) and age (in years) (on axis of ordinates) of walleye pollock:
1 - from Komandorski Basin; 2 - from Gulf of Anadyr.
A - mean, B - all samples.

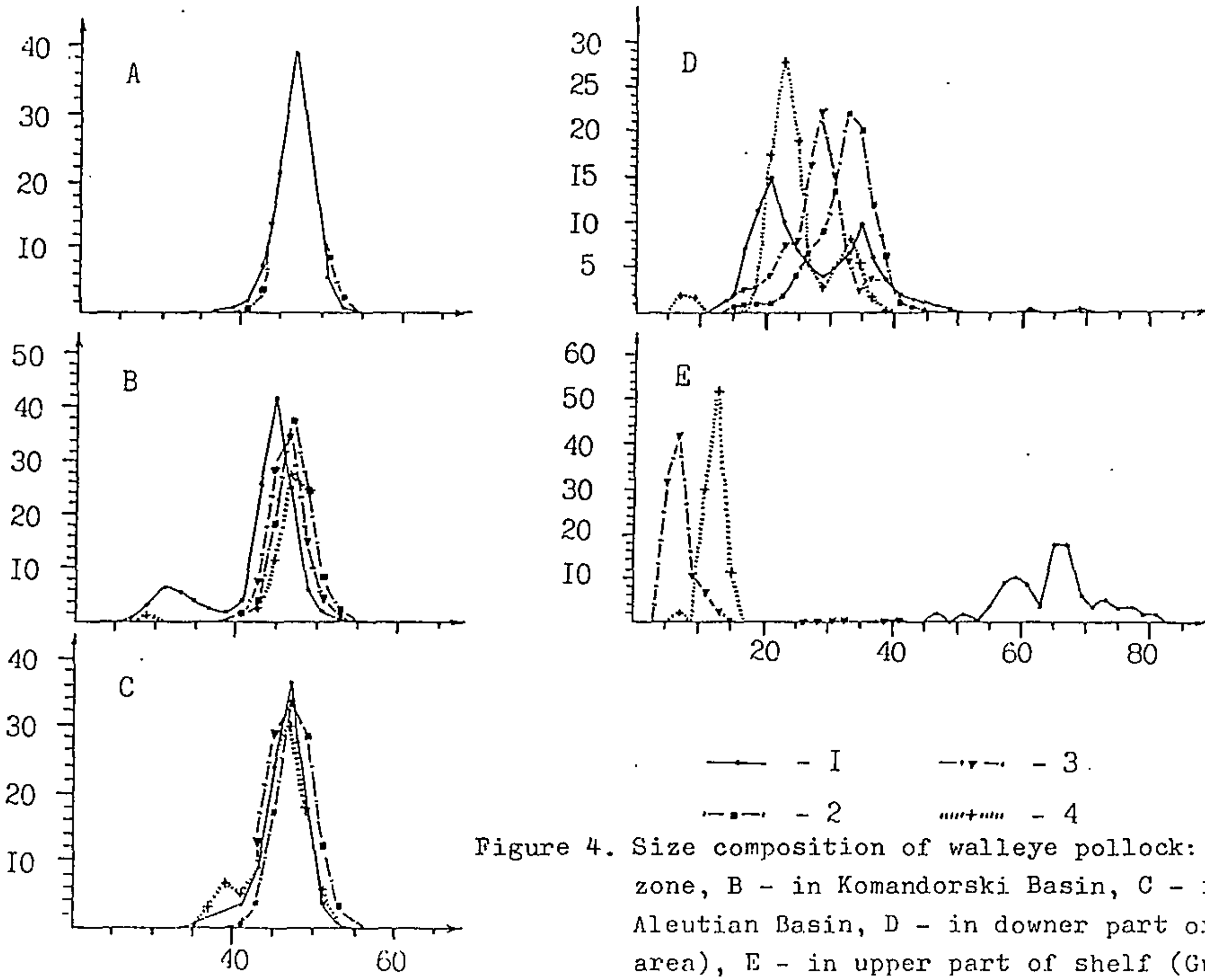


Figure 4. Size composition of walleye pollock: A - in neutral zone, B - in Komandorski Basin, C - in north-western Aleutian Basin, D - in downer part of shelf (Navarin area), E - in upper part of shelf (Gulf of Anadyr). 1 - in May-July 1989, 2 - in October-Növember 1988, 3 - in August-September 1987, 4 - in September-Octobe

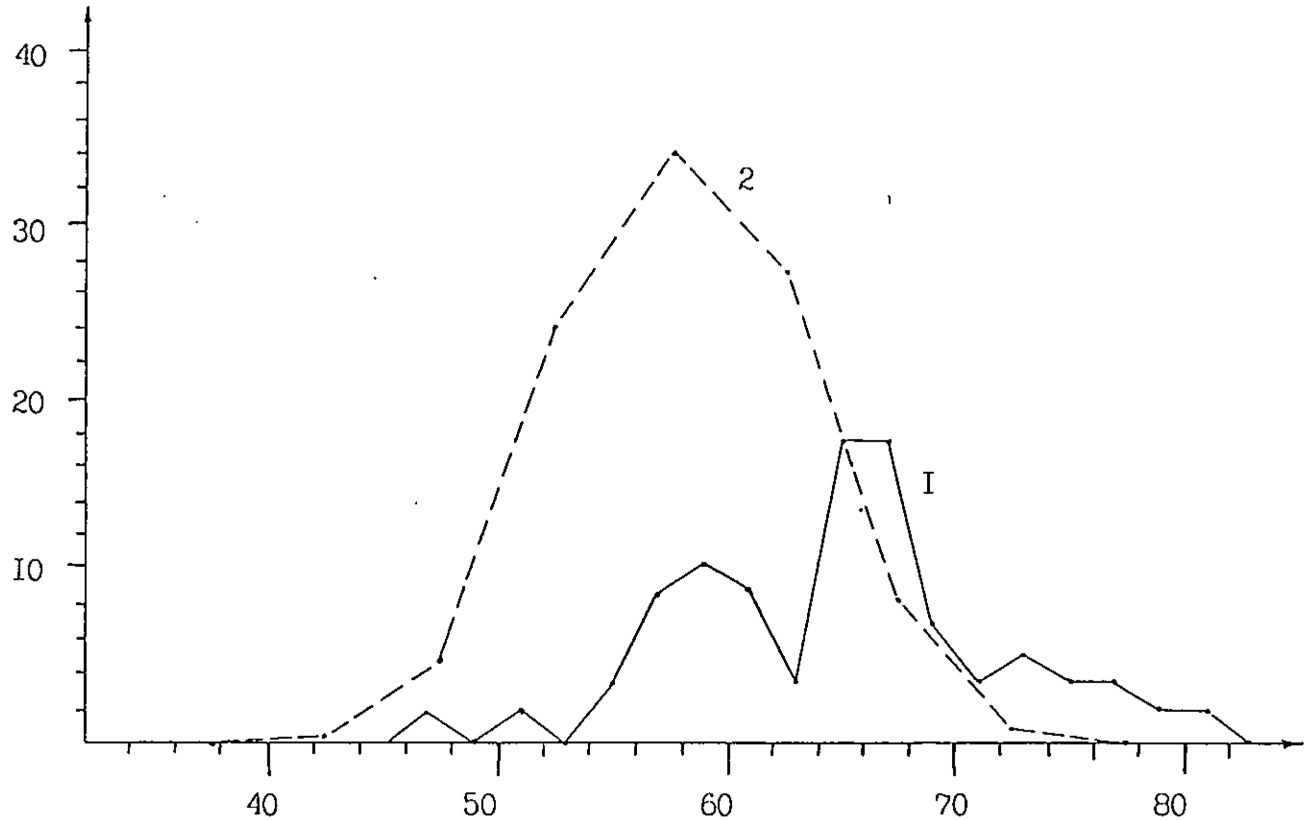


Figure 5. Size composition of walleye pollock in Gulf of Anadyr: 1 - in July 1989; 2 - in late July in end 1930-th years by collection Panin (Andriashev,1954).

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Panel 4: Commercial Fisheries

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Status of Korean Trawl Fishery for Alaska Pollock in the Bering Sea in 1987-1988

Yeong Gong and Young Hee Hur
National Fisheries Research and Development Agency
Republic of Korea

ABSTRACT

Catches from the Korean trawlers were 299 thousand mt in 1988 and 301 thousand mt in 1989. This paper present the changes of the seasonal geographical distribution pattern and those of relative abundance of Alaska pollock in the high sea of the Bering Sea and their length compositions for 1987-1988 from the Korean trawl fishery data.

The fishing ground of Alaska pollock by the Korean trawl fishery in the high sea of the Bering Sea were formed rather dispersed in the central to the southern part in spring season. And in summer season(July to September) fishing ground was formed in the southwest corner of the high sea ; this area has tended to move eastward as time passed till in autumn to winter season(October to January).

Vertical distribution of catch of Alaska pollock were ranged 20-400m. The mean depth of catch was shallower in summer season and deeper in winter season.

The mean and mode of the lengths in the catch of the Korean trawlers have tended to be larger in each year since 1985. There were two modes in spring season(April and May) and one mode in the other seasons in both sexes in 1988. For June and July the proportion of lengths less than 40cm were higher compared to that of the other months.

Seasonal changes of Gonadosomatic Index (GSI) in 1987 and 1988 showed that GSI has increased sharply from October to December. Spawning and spawned individuals were observed from December to February.

INTRODUCTION

Catch of pelagic population of Alaska pollock in the high sea of the Bering Sea has increased since 1986 from the Republic of Korea, Japan, Poland, China and USSR and about 1.5 million tons by about 200 trawlers in 1988. Korean trawl fishery operated in the high sea of the Bering Sea in 1980 for the first time and the catch has increased continuously since 1983 and recorded 301,550 mt in 1989.

This paper present the fishing power of the Korean trawl fishery in the high sea of the Bering Sea and showed the changes of the seasonal geographical and vertical distribution pattern and those of relative abundance of Alaska pollock in the high sea of the Bering Sea with their length compositions for 1987-1988.

RESULT AND DISCUSSION

Catch and Relative Abundance

The annual catch of Alaska pollock by the Korean trawlers in the high sea of the Bering Sea is shown in Table 1. Catches by the Korean trawlers have increased continuously since 1983, and 301,550mt were caught by 41 vessels in 1989. Alaska pollock has been the only target species for the Korean trawlers and no incidental catch have been recorded since the beginning of the fishery in this area.

There were not significant changes in the fishing power such as engine power and vessel size of the Korean trawlers operating in the high seas of the Bering Sea since 1984(Table 2). The fishing gear used in the pollock fishery by the korean trawlers in the high sea of the Bering Sea is midwater trawlers and that has become improved and larger almost once a year. The increasing rate of the area of the net mouth of the gear per year was approximately 20-30%.

The seasonal changes of fishing effort, catch and catch per unit effort (CPUE) of the Korean trawl fishery in the high sea of the Bering sea in 1986 to 1988 are shown in Figures 1,2 and 3.

At the beginning of the Korean trawl fishery in the high sea of the Bering Sea, fishing was limited from December to April or May, with a peak in January and February. In recent years, fishing season was extended throughout the year round with higher catches from December to January in 1986/1987, from mid-October to December in 1987 and 1988. After showing the peaks of catch and CPUE, they showed a sharp decline in February and March. Fishing was conductd again in April and continued to the year round. The peaks of catch and CPUE were not as high as those from the early development of the fishery. On the other hand, the catch proportion and the fishing efforts have increased in summer season with higher CPUE compared to the early years. This phenomenon were also reported by the other fishing countries (Tronski,1989, Sasaki et al 1989).

Geographical Distribution

Since commercial fishing vessels are tended to search and fish highly aggregated schools as far as possible, seasonal changes of geographical distribution of catch and CPUE from the commercial fishing can give an idea of the migration patterns of fish.

Monthly geographical distribution of catch and CPUE of the Korean trawl fishery in the Bering Sea for 1987 and 1988 are shown in Figures 4 and 5. In spring season the fishing ground were dispersed in the central area to the southern part of the high sea. In summer season (July to September)fishing ground was formed in the southwest corner of the high sea. As time passed this area has tended to move eastward till in autumn to wintrer season(October to January).

Vertical Distribution

Seasonal vertical distribution of catch of Alaska pollock in the high sea of the Bering Sea by the Korean trawlers in 1988 are shown in Figure 6. Alaska pollock were caught in the depth range 20-400 m. The mean depth of catch was seasonally fluctuated. In mid-June, the mean depth was shallowest and it has become gradually deeper in advances of months till early February, and again to be shallower till summer.

The water temperature in the depth range of the catch observed by fishermen were mainly 3°C to 4°C(Figure 7).

Size composition

Length compositions of Alaska pollock for the catches of Korean trawlers for 1984-1988 are shown in Figure 8.

Length compositions of the catch range from 30 cm to 70 cm, with the bulk of catches 40-50cm. The lengths of mean and mode of the catch have become larger and larger since 1985. Length compositions of female were slightly larger than those of males in every year.

Monthly length compositions for 1987-1988 are shown in Figure 9. Length composition in 1988 showed a slightly different shape by month. In April to May, two mode are shown in both sexes ; in female 41.5 cm and 47.5 cm, and in male 41.5 cm and 47.0 cm. Except for these two months there are one mode in both sexes. For, June and July the proportion of lengths less than 40 cm were higher compared to that of the other months.

Gonadosomatic Index

Mean gonadosomatic index (GSI) by ten days of Alaska pollock in the high sea of the Bering Sea in 1987 and 1988 sampled from Korean fishing vessels is shown in Figure 10. GSI has increased sharply from October to December. Spawning and spawned individuals were observed from December till February.

Table 1. Annual catch (mt) and CPUE*(mt/hr) of Alaska pollock by Korean trawlers in the high seas of the Bering Sea, 1980–1988

Year	No. of vessels operating	Catch	CPUE
1980		12,509	
1981	0	0	
1982	5	2,934	
1983	25	66,558	10.0
1984	26	80,317	9.3
1985	26	82,444	7.9
1986	30	155,718	9.7
1987	32	241,870	10.8
1988	33	268,600	5.7
1989	41	301,550	

Table 2. Annual changes of the fishing power of the Korean fishing vessels and their fishing gear operating in the high seas of the Bering Sea from 1984–1988

Year	no.of	Engin Power		Gross Registered Tonnage		type of	Range of	Range of area of
	vessels	Range	Average	Range	Average	gear	net height	net mouth*
1984	26	2350–5700	3435	1015–5549	2175	Midwater trawl	20–40 m	
1985	26	2000–6000	3823	1015–5680	2832	"	20–40	
1986	30	2000–6000	3800	1015–5680	2745	"	20–45	
1987	32	2000–6000	3817	1015–5680	2750	"	35–70	
1988	33	2000–6000	3897	1015–5680	2790	"	35–70	1100–4200m^2

The data of area of net mouth are from the fishing net made by Ssayang Fishing net Company of Korea.

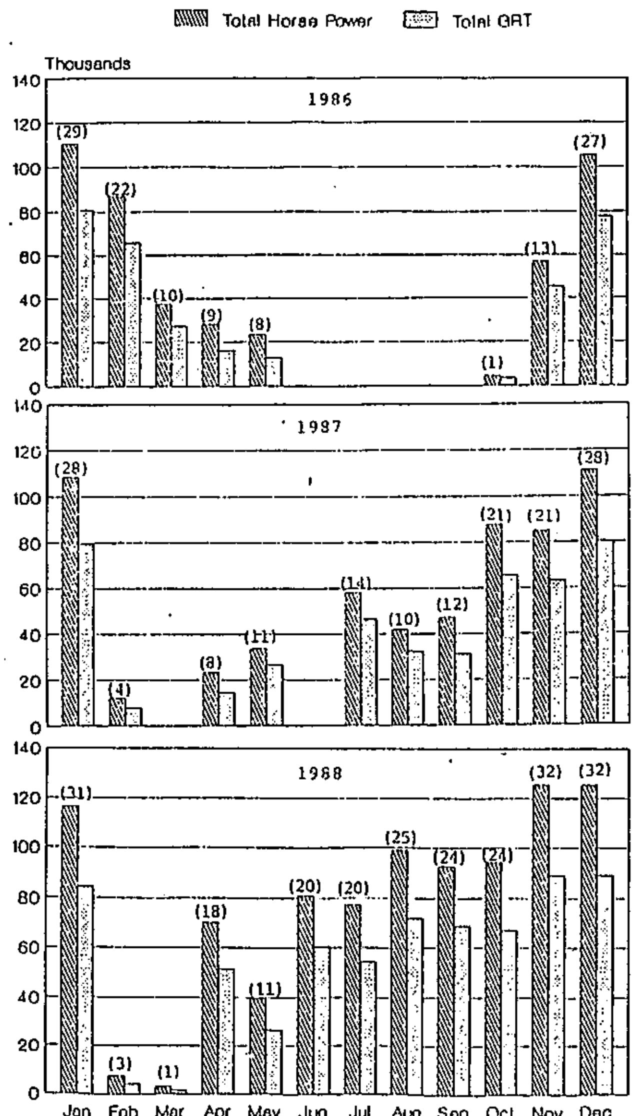


Figure 1. Seasonal changes of fishing power (total GRT & horse power) in the high seas of the Bering Sea in 1986-1988.
Numbers in parenthesis denotes the number of fishing vessels operating

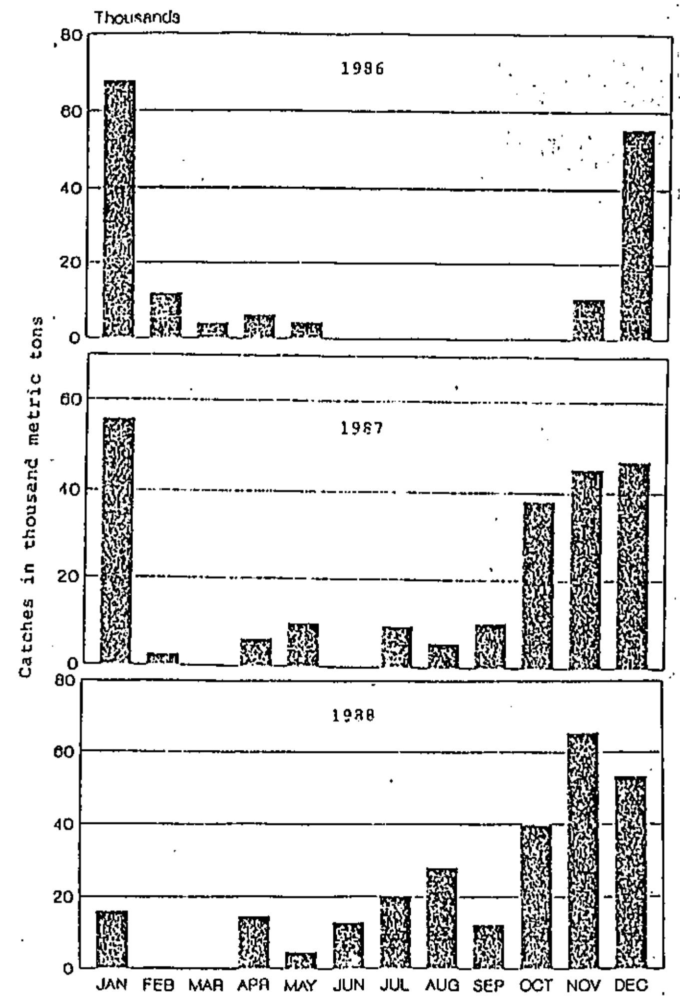


Figure 2. Seasonal changes of catch in the high seas of the Bering Sea in 1986-1988.

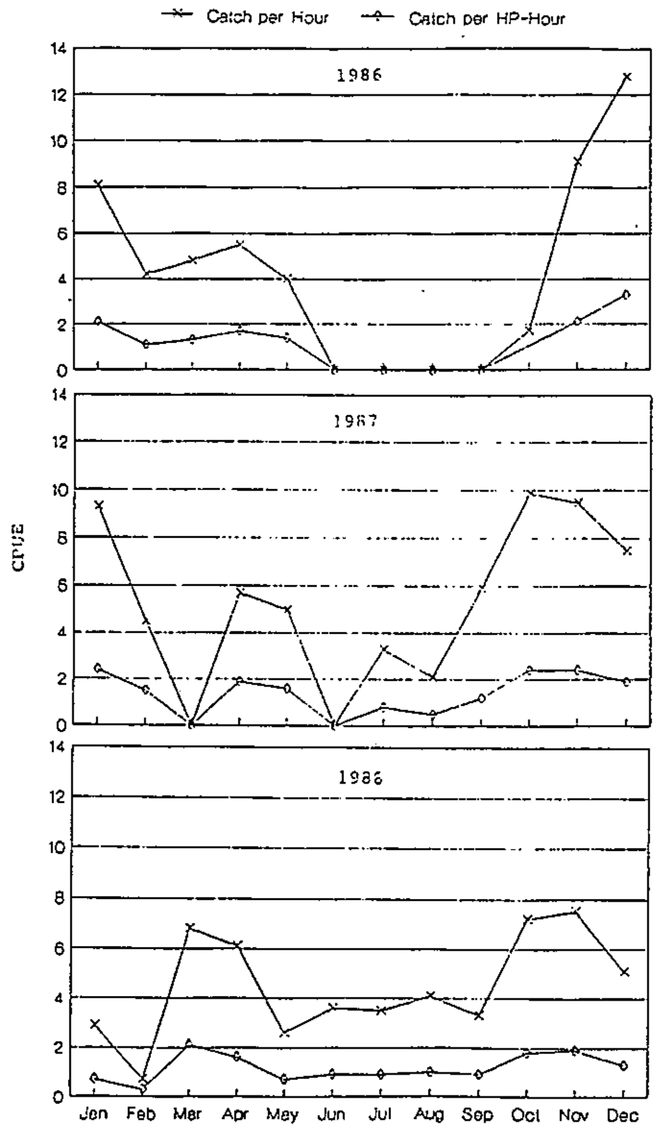


Figure 3. Seasonal changes of catch per unit of effort (CPUE) in the high seas of the Bering Sea in 1986-1988.

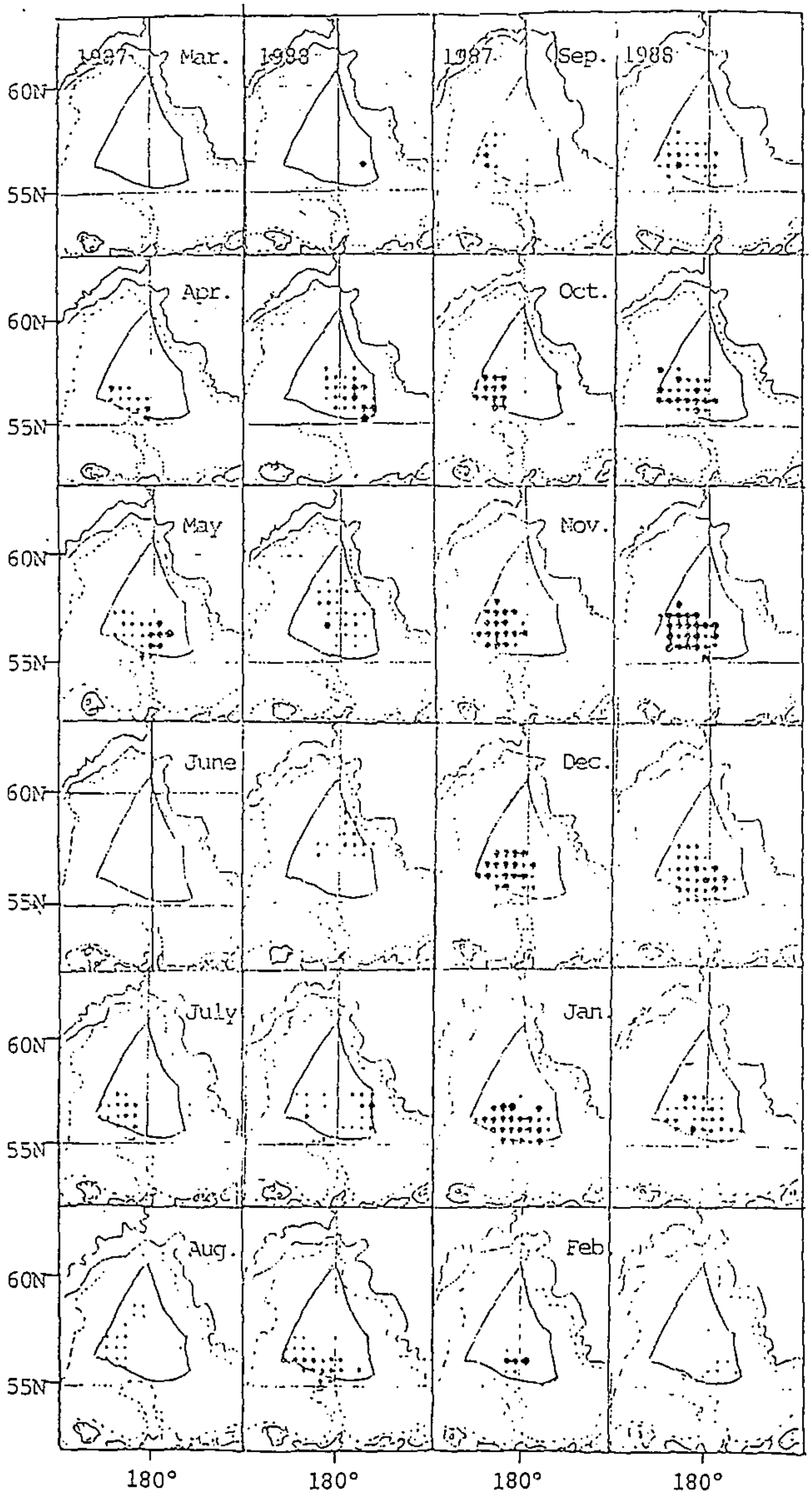


Figure 4. Monthly geographical distribution of catch by the Korean trawlers in the high seas of the Bering Sea, 1987-1988.

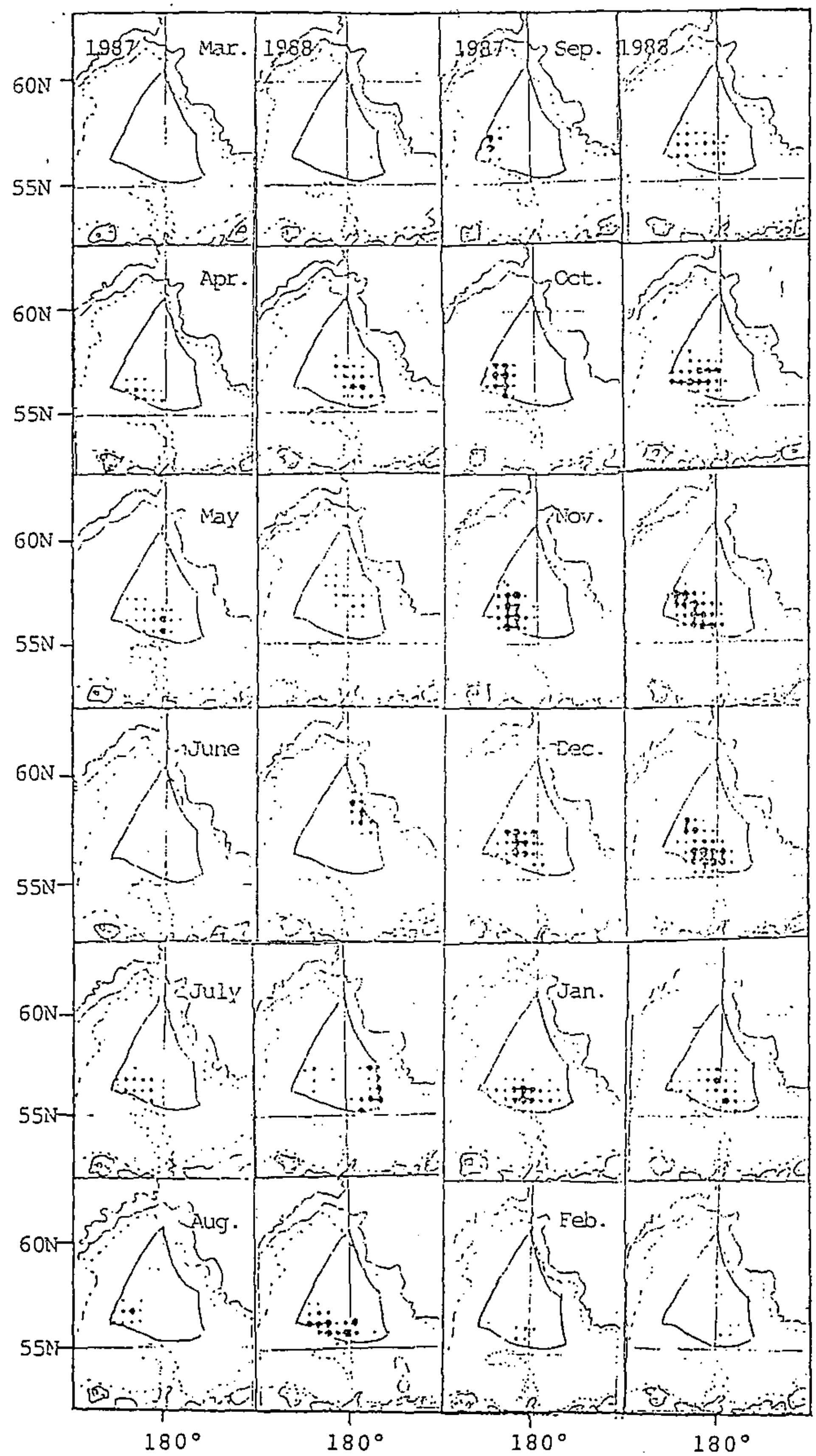


Figure 5. Monthly geographical distribution of CPUE by the Korean trawlers in the high seas of the Bering Sea, 1987-1988.

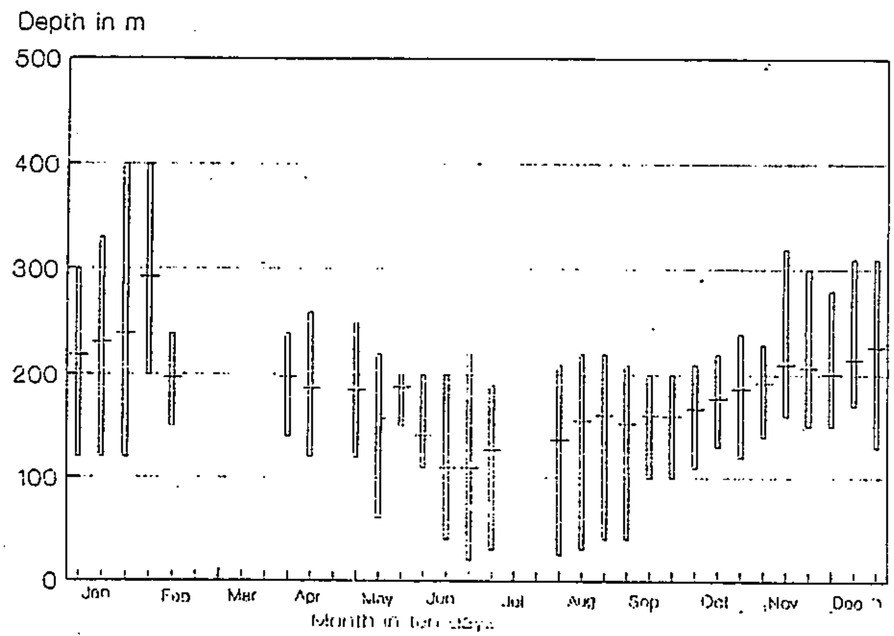


Figure 6. Changes of range and Average depth by ten days of Alaska pollock in the high seas of the Bering Sea based on the Korean trawl fishing operations in 1988.

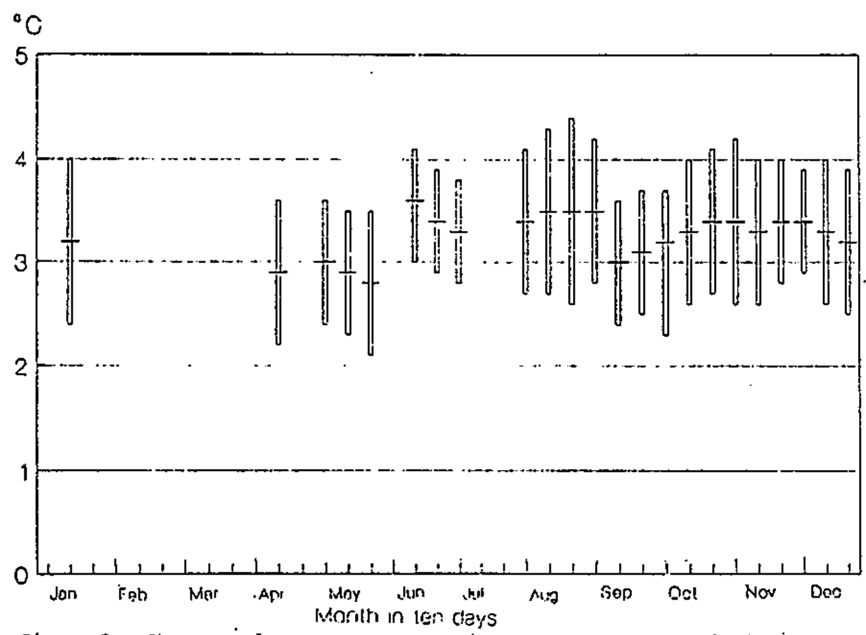


Figure 7. Changes of water temperature(mean & standard deviation) in the layor of the fishing depth by ten days in the high seas of the Bering Sea based on the Korean trawl fishing operations in 1988.

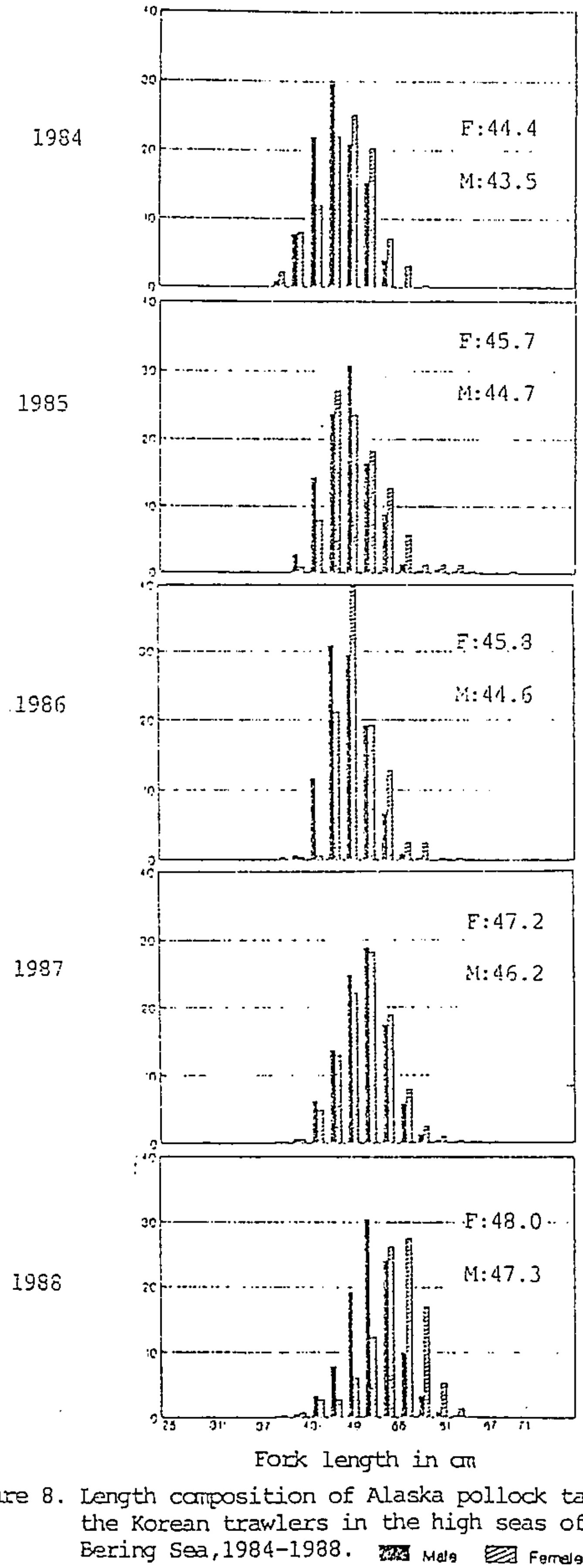


Figure 8. Length composition of Alaska pollock taken by the Korean trawlers in the high seas of the Bering Sea, 1984-1988.

The figures denote mean fork length in cm.

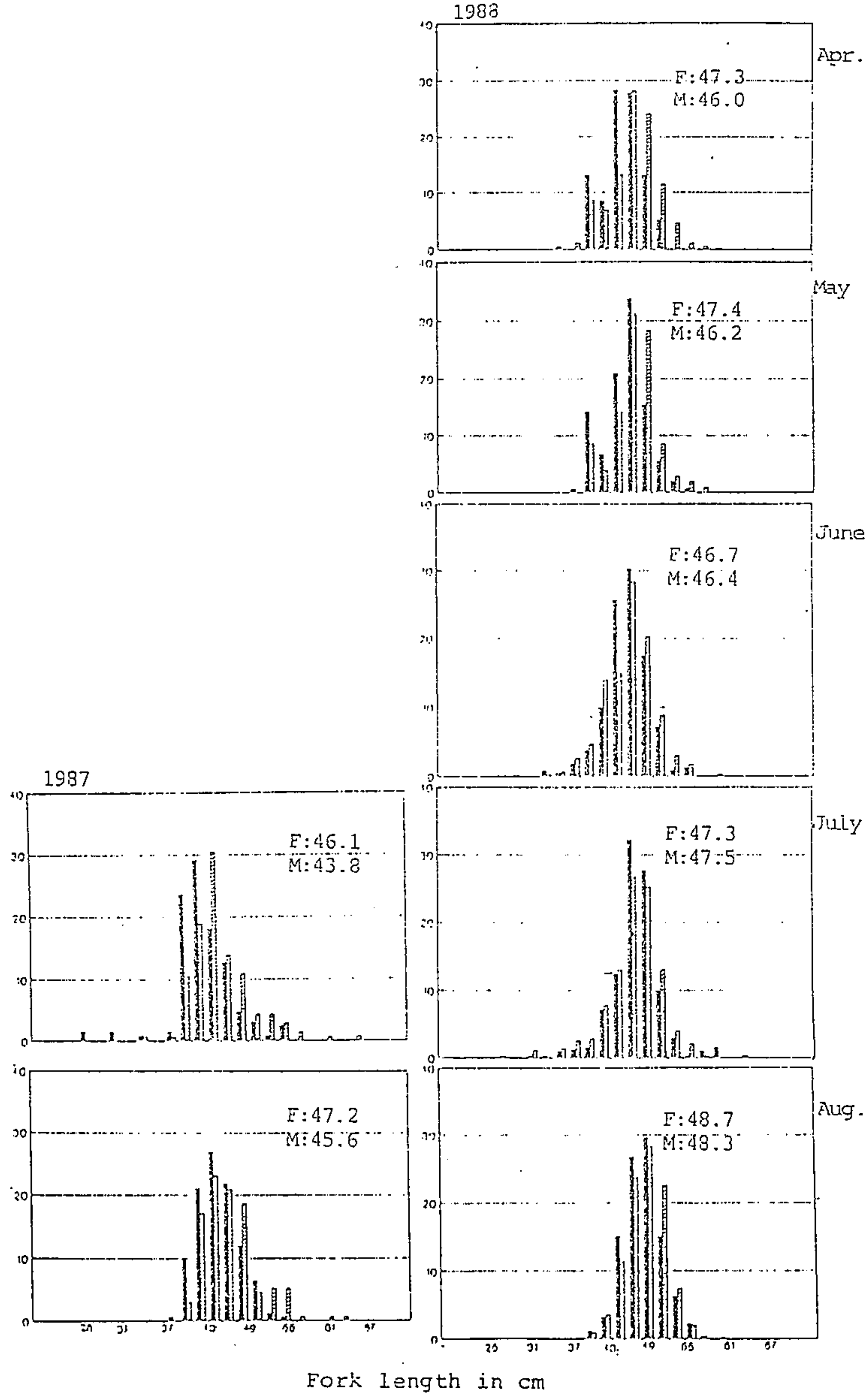


Figure 9-a. Monthly length composition of Alaska pollock taken by the Korean trawlers in the high seas of the Bering Sea, 1987-1988, April-August. Male Female

The figures denote mean fork length in cm.

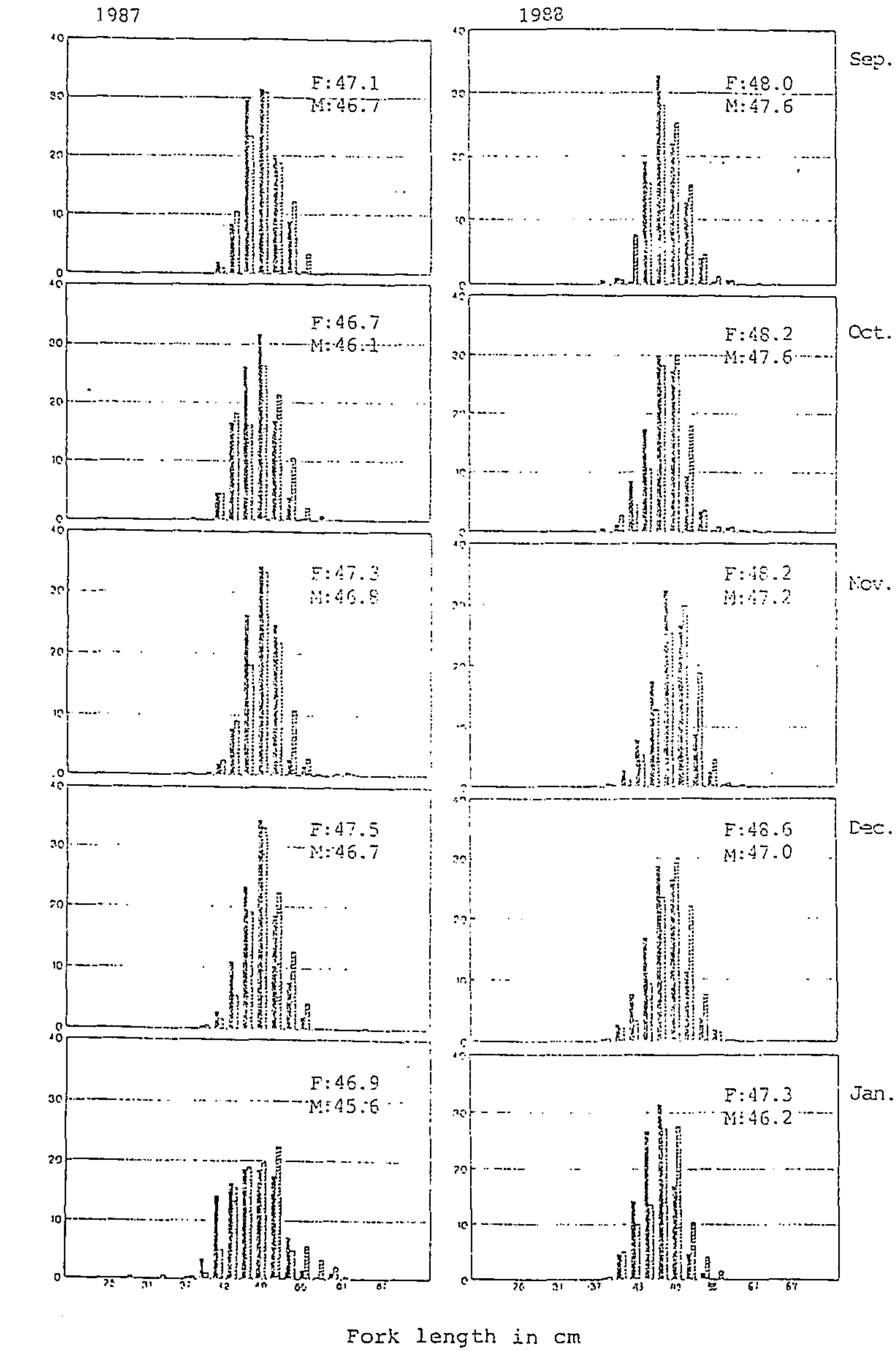


Figure 9-b. Continued, September-January.

Outline of Japanese Trawl Fishery in the International Waters of the Bering Sea (1986 - 1988)

Taku Yoshimura and Takashi Sasaki
National Research Institute of Far Seas Fisheries
Shimizu, Japan

Introduction

Japanese midwater trawl fishery targeted at pelagic and midwater pollock in the Aleutian Basin was started by a limited number of fishing vessels from around 1980. Initially, most of the catch came from the Aleutian Basin of the U.S. 200 miles zone, and catch from the international waters of the Bering Sea was very small. Catch amount of pollock in the international waters of the Bering Sea sharply increased following drastic reductions in catch quota in the U.S. and the U.S.S.R. Notably, catch amount in 1989 saw a dramatic increase over the previous years to approximately 700,000 tons. This paper is intended to present an outline of pollock fishery by Japanese fishing boats in the international waters of the Bering Sea since 1986. There are some cases in which fisheries statistics in this report, including catch, are slightly different from those which have been made available informally. This is due to the fact that these figures, compiled by the fishing industry informally, were used on a provisional basis. But it is to be noted that the figures given in this report is the final and formal statistics of the Fisheries Agency of Japan. However, statistics for 1989 in this paper are preliminary because the data are still in the process of compilation.

Type of fishery and the number of fishing boats

Three types of trawl fishery are now being authorized for Japanese fishing boats in the international waters of the Bering Sea: North Pacific Trawl Fishery, Tenkan Trawl Fishery and Land-based Trawl Fishery. These three types of authorized operation, which have been created out of the process of fisheries regulation in Japan, have different terms and limitations for authorization. However, no substantial difference exists among them when they are seen from the viewpoint of pollock fishery in the international waters of the Bering Sea.

As shown in the table below, the number of vessels authorized to operate in this fishery were 40 North Pacific trawl vessels, 16 tenkan trawl vessels and 54 Land-based trawl vessels in 1986 and 1987. In 1988, however, North Pacific trawl vessels were reduced by one, Tenkan trawl vessels by 2 to 39 and 14, respectively. North Pacific trawl vessels were reduced further by 2 to 37 in 1989. The number of vessels actually engaged in this operation is shown in the parentheses in the table.

Type of fishery	1886	1987	1988	1989
North Pacific Trawl Fishery	40 (28)	40 (34)	40 (36)	37
Tenkan trawl fishery	16 (11)	16 (12)	16 (13)	14
Land-based trawl fishery	54 (54)	54 (54)	54 (54)	54

Although only one vessel is authorized to operate under the same license number, it is possible to have another vessel to take over the license in the middle of fishing season due to the needs of fishing companies. Therefore, the number of vessels actually engaged in fishing exceed that of the licensed vessels when more than one vessel which operated under the same license number is counted as an operating vessel. But the figure used in the table represents the counting of more than one vessels operating under the same license number as one vessel.

There are some 280 tons register among North Pacific trawl vessels but about half of them are large vessels of 2,500 tons or over (Table 1). Tenkan trawl vessels consist of fishing vessels ranging from 280 tons to 550 tons and all of the Land-based trawl vessels are small ones of 350 tons or less.

Fishing effort and catch amount

1) Fishing effort

As shown in the table below, the vessel days of Japanese trawl vessels in the international waters of the Bering Sea saw a gradual increase from 7,265 vessel days in 1986 to 9,061 vessel days in 1988. However, 1989 saw a 7% decline over the previous year to 8,407 days. Overall towing hours increased from 81,311 hours in 1986 to 95,375 hours in 1987 and 109,742 hours in 1988. The towing hours for 1989 have not been made available but are believed to have decreased reflecting the decline in overall vessel days.

Year	Vessel day	Fishing effort in hour
1986	7,265	81,311
1987	8,449	95,375
1988	9,061	109,742
1989	8,407	*

*Data are not available.

2) Catch amount

Catch amount of pollock, as in the following table, reached 700,000 tons in 1986 and rose to a record of 800,000 tons in 1987, but fell to 750,000 tons in 1988 and to 650,000 tons in 1989.

Year	1986	1987	1988	1989
Catch (t)	697,975	803,550	749,982	638,914

In terms of monthly change (Table 2, Fig. 1), catches in January, February and December accounted for 71.4% of the total annual catch in 1986. Catch peaked in January and posted a decline until March and, after a slight recovery in April, dropped sharply in summer from June to August. Bulky catch started in September and showed swift increase until December. The year 1987 also had a similar tendency, but due to a 146% increase in November over the same period of the previous year, the catch in January, February, November and December combined accounted for 77.7% of the total annual catch. Further, catch amount in October also grew 185% from a year earlier. The increasing trend in autumn, observed in 1987, became more conspicuous in 1988, with catch amount in October-December rising 34% from the corresponding period of the preceding year, and accounting for 67.2% of the total annual catch. Conversely, catch amount in January-February dropped 63% from the same period of the previous year. Further in 1988, operations were conducted throughout the year for the first time by a limited number of vessels. This caused the catch in summer to increase drastically, although it remains still small in proportion to the total annual catch. The year 1989 saw a similar tendency as in 1988. But the catch in October-December dropped 29% from the same period of 1988, with the proportion to the total annual catch also declining 55.8%. By contrast, catch amount in April-May saw a dramatic increase from the same period of the preceding years. Specially that in April advanced 52% from a year earlier to 83,000 tons.

CPUE

Pollock fishery in the international waters of the Bering Sea is a relatively new type operation using midwater trawl nets which had not been well known to Japanese trawl fishermen previously. According sd catch amount increases, development of midtrawl nets entered a full-scale phase from around 1984. Fishing efficiency is deemed to have improved annually because midwater trawl nets with new specifications were developed year by year and fishing vessels competed in replacing the conventional nets with new ones. The difference in catch efficiencies widened because net specifications differed due to the vessel size class and engine powers and human capability differed even when the nets with same specifications were applied. It seems virtually impossible to correct these differences and standardize the fishing efficiency.

Therefore, it is inappropriate to use nominal CPUE (catch per one hour towed) as accurate index for stock abundance, but it can be used as an approximate index to determine increasing or decreasing trend of the abundance of fish schools. As shown in the table below, CPUE annually increased until 1986 to reach 8.58 tons/hour in that year. Although the CPUE in 1987 remained at almost the same level from the previous year, that in 1988 fell 19% to 6.83 tons/hour. The corresponding figure for 1989 have not been made available because statistics of towing hours have not been obtained, but the catch per vessel day showed a decline to 76 tons from 83 tons in 1988.

Year	1986	1987	1988	1989
CPUE (t/hour)	8.58	8.43	6.63	

*Data are not available.

The decline in CPUE suggests that the migrating stock size of pollock in the international waters of the Bering Sea decreased in 1988 and 1989 because the catching efficiency of fishing vessels improved year by year due to accumulation of experience of fishermen and improvement of fishing nets. But it is not considered that pollocks take the same migration pattern every year. There might be considerable annual differences as regards migrating period and routes. It is possible to assume that the decline in CPUE in the international waters in 1988 and 1989 was induced by the fact that a larger amount of pollock migrated in the U.S. 200 miles zone south of the international waters as compared with previous years. In any case, it is not possible to determine only on the basis of data obtained from the international waters of the Bering Sea that the abundance of pollock stocks in the whole area of the Aleutian Basin declined.

The monthly changes in CPUE more or less coincided with monthly changes in catch amount, and the months with large catch amount showed higher CPUE (Table 2, Fig. 1).

Distribution of fishing grounds

Distribution of CPUE was plotted by statistical fishing block of 30 minutes of latitude and one degree of longitude in order to examine the distribution of fishing grounds for pollock in the international waters of the Bering Sea (Fig. 2). As mentioned earlier, CPUE--catch per one hour towed--does not correct changes of fishing efficiencies between vessels and years. Therefore, it cannot be said to represent accurately the relative abundance between fishing blocks, but it seems that there is no problem in using CPUE as an approximate index for fishing ground distribution.

The yearly distribution of CPUE in the period from 1986 to 1988 showed a similar tendency on the whole, and a high concentration of CPUE was observed in the western or south-western part of the international waters. Differences from year to year was observed when examined more closely, with 1986 showing the high CPUE also in the northeastern part of the international waters in 1986. Further, high CPUE was observed in slightly north of western area of the international waters in 1988.

In terms of monthly change, high CPUE appeared in the western part of the international waters in October and in a wider area of the international waters in December. High CPUE areas spread in the southern part of the international waters in January and February in 1986 and 1987, but in January 1988, high CPUE was observed only in a limited area of the western part and disappeared in February. CPUE distribution in April, when catch amount slightly recovers each year, showed annual fluctuations and presented no characteristic pattern.

Length composition

Little or no data of length composition of the catch from fishing vessels were made available in 1986. The length compositions of pollock caught in the international waters of the Bering Sea in 1987 and 1988 were more or less the same, with the modes of 46-48 cm for both year and the average length of 48.6 cm in 1987 and 49.1 cm in 1988, thus shwoing that the composition was slightly enlarged in 1988 over the previous year (Fig. 3).

Table 1. Size class in registered gross tonnage of Japanese trawl vessels with license from Japanese Government.

Year	Type of fishery	~300	~350	~400	~500	~1,000	~1,500	~2,500	~3,500	~4,500	4,500~	Total
	North Pacific Trawl Fishery	-	-	1	8	4	3	2	9	11	2	40
1986	Tenkan Trawl Fishery	-	1	1	7	6	-	-	-	-	-	15[a]
	Land-based Trawl Fishery	28	26	-	-	-	-	-	-	-	-	54
	North Pacific Trawl Fishery	2	-	2	8	3	2	2	7	12	2	40
1987	Tenkan Trawl Fishery	2	-	6	4	4	-	-	-	-	-	16
	Land-based Trawl Fishery	32	22	-	-	-	-	-	-	-	-	54
	North Pacific Trawl Fishery	1	1	3	6	4	-	2	7	12	3	39
1988	Tenkan Trawl Fishery	1	-	6	4	3	-	-	-	-	-	14
	Land-based Trawl Fishery	39	15	-	-	-	-	-	-	-	-	54

a One vessel with license did not take part in the fishery.

Table 2. Fishing effort, catch, and CPUE of pelagic pollock by month caught by Japanese trawl fisheries in the International waters of the Bering Sea from 1986 to 1989.

Year		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Effort (hour)	18,849	21,461	8,024	7,458	3,577	75	212	356	1,953	4,121	5,620	9,605
1986	Catch (t)	200,628	139,770	37,148	49,835	24,678	115	686	900	3,984	19,155	62,949	150,127
	CPUE (t/hour)	10.6	6.5	4.6	6.7	6.9	1.5	3.2	2.5	2.0	4.7	11.2	16.5
	Effort (hour)	18,137	14,713	10,407	10,205	7,289	95	120	504	383	5,166	11,310	16,966
1987	Catch (t)	192,267	109,738	43,912	49,117	30,850	136	123	400	382	54,647	155,180	166,790
	CPUE (t/hour)	10.6	7.5	4.2	4.8	4.2	1.4	1.0	0.8	1.0	10.6	13.7	9.8
	Effort (hour)	18,386	6,922	3,644	8,809	6,834	4,048	1,842	2,582	1,507	11,619	18,150	25,399
1988	Catch (t)	95,983	17,033	13,073	54,711	19,792	11,377	6,377	14,960	12,925	119,435	206,441	177,875
	CPUE (t/hour)	5.2	2.5	3.6	6.2	2.9	2.8	3.5	5.8	8.6	10.3	11.4	7.0
	Effort (hour)*												
1989	Catch (t)	64,025	18,376	30,642	83,255	44,918	7,868	2,987	13,240	18,249	56,991	110,615	195,902
	CPUE (t/hour)*												

* Data are not available.

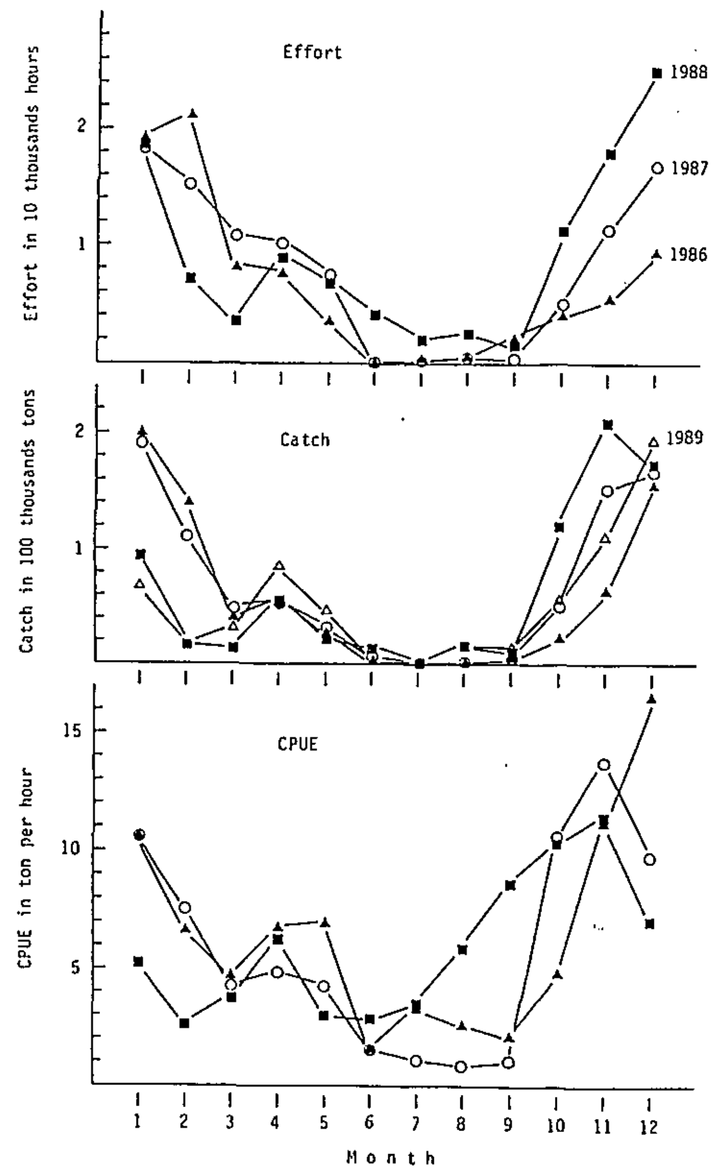


Figure 1. Fishing effort, catch of pollock, and nominal CPUE of pollock by month obtained from Japanese trawl vessels operated in the International Waters of the Bering Sea, 1986-1989.

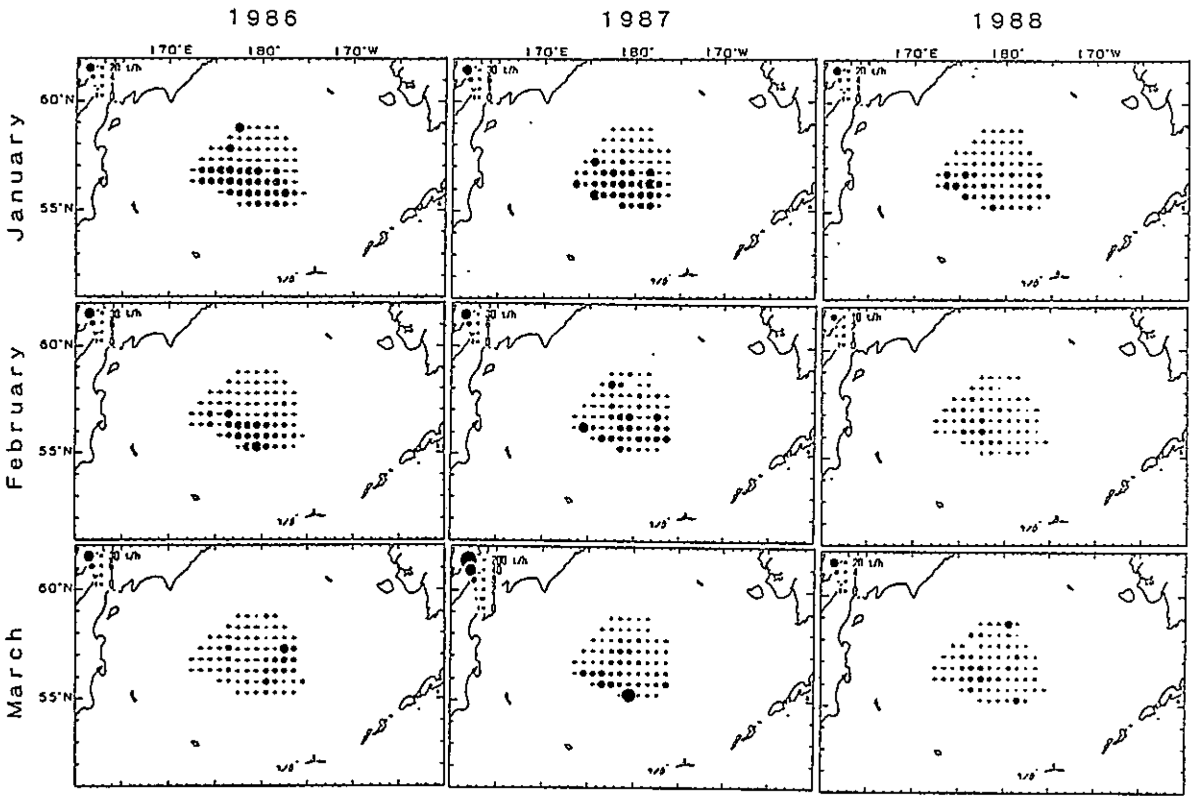
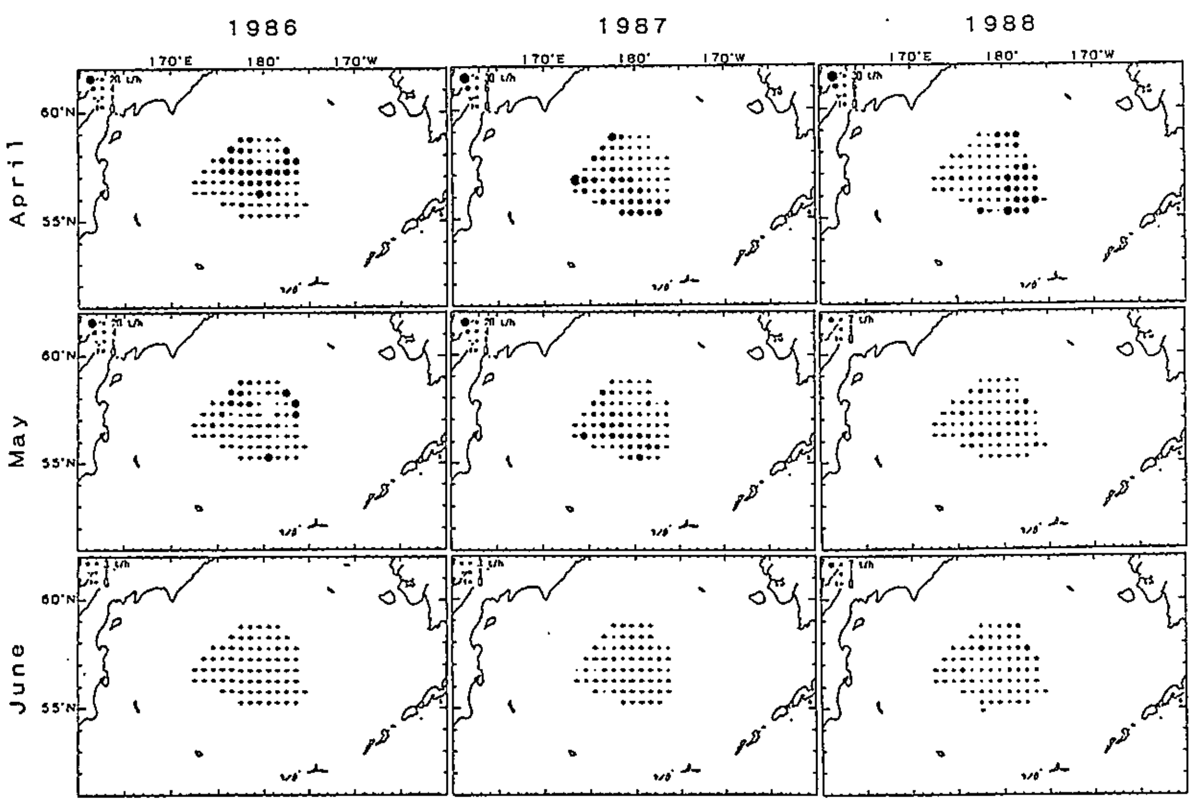


Figure 2. Monthly CPUE distribution of pollock obtained from Japanese trawl vessels operated in the International Waters of the Bering Sea, 1986-1988.



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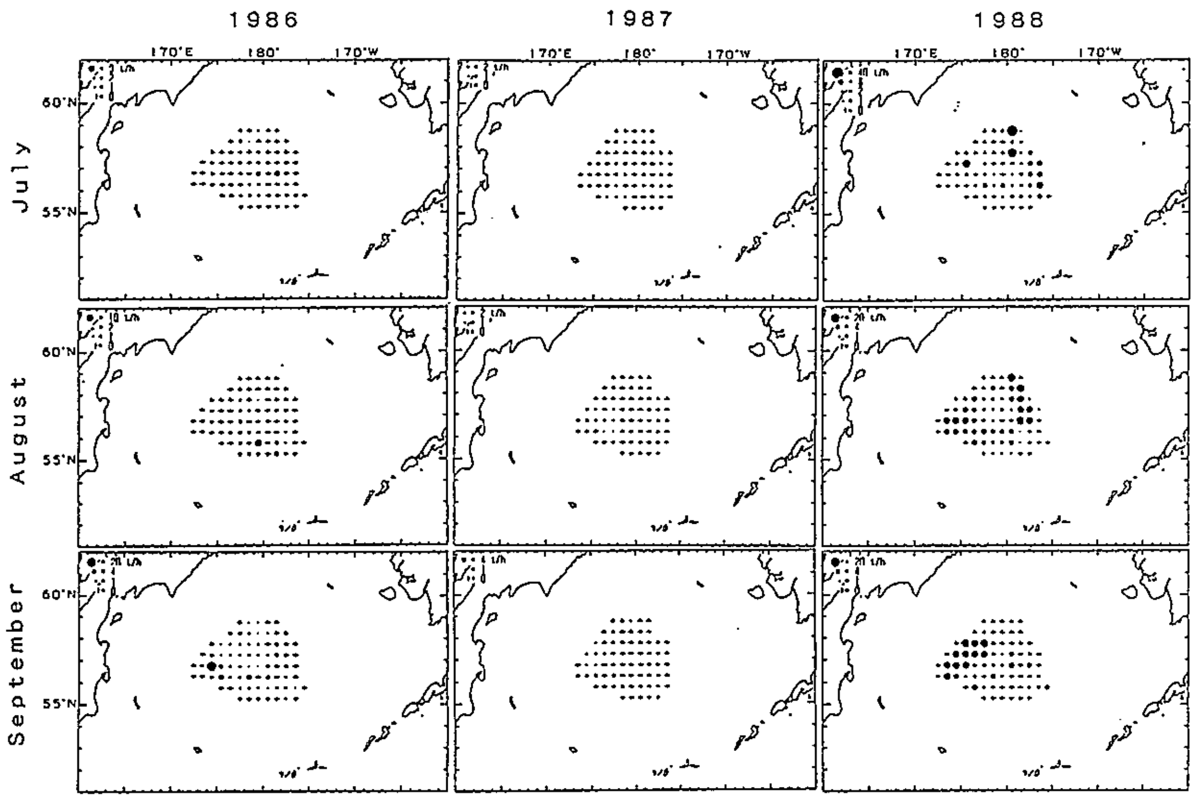

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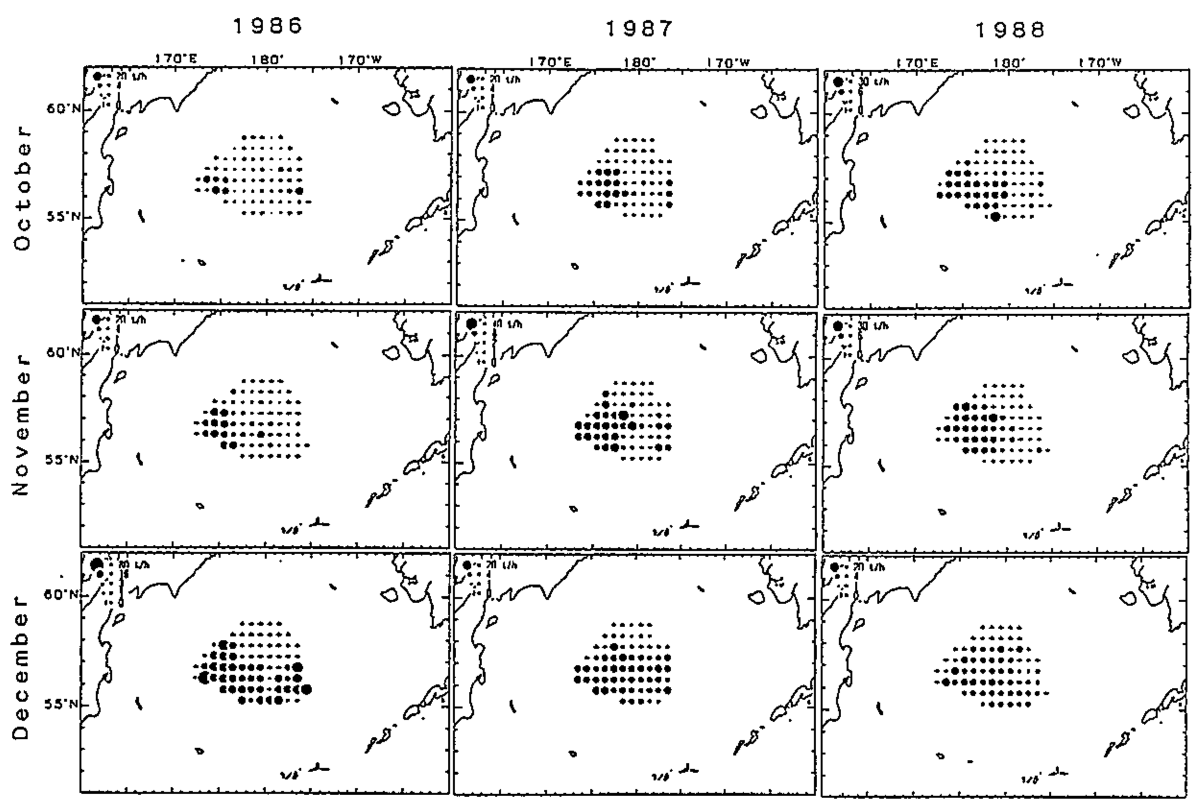

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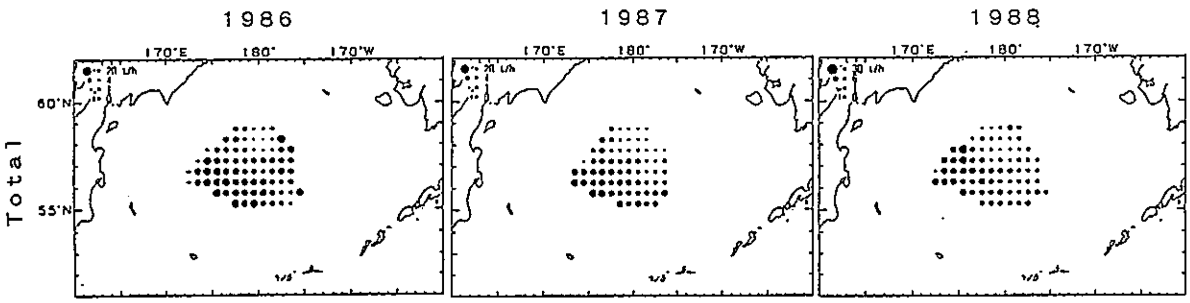

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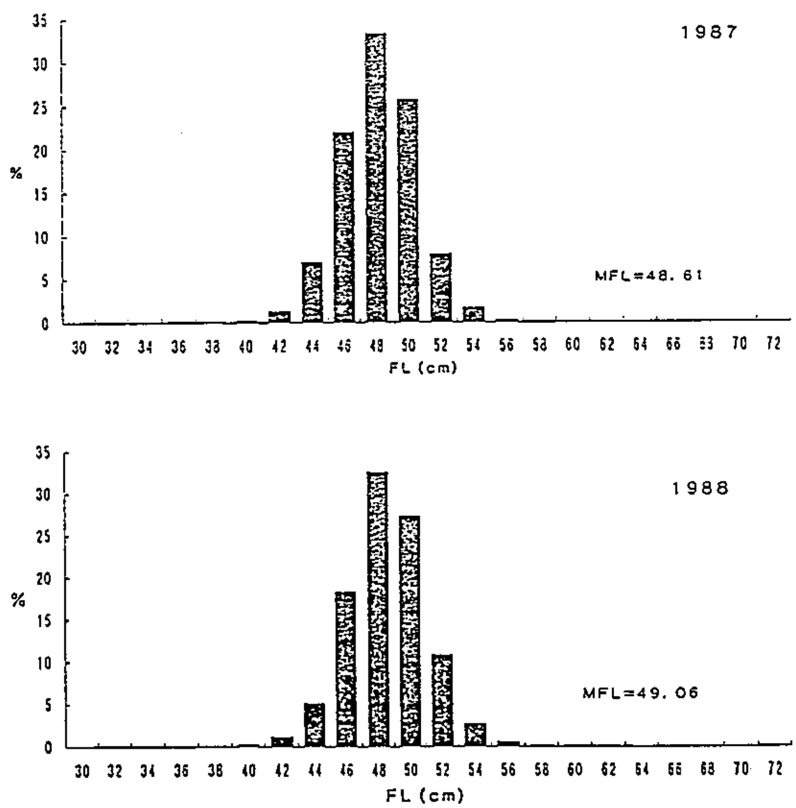

Figure 3. Length composition of pollock caught by Japanese trawl vessels in the International Waters of the Bering Sea in 1987 and 1988.

Biological Information on Walleye Pollock based on Polish catches in the International Waters of the Bering Sea in 1989

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Abstract

Investigation conducted in 1989 covered the period from January to April and from September to November. Poland caught 268.6 tons in 1989, attaining satisfactory catch results during the entire year. Throughout the year the pollock were distributed over a large area of international waters with the most dense concentrations being formed in the central and south-eastern parts of the international waters. In catches in 1989 pollock with a total length of 39-63 cm were found. Mean lengths and weights of pollock were slightly larger in comparison with the previous years. Year classes of 1978 and 1977 dominated in the catches. The share of younger year classes (1981 and 1983) was also prominent during September-November catches. The investigations carried out in 1989 revealed no significant changes in the pollock stock in the international waters of the Bering Sea.

Introduction

Poland has began fishing operation for pollock and biological investigations in international waters of the Bering Sea since 1985. Research materials were collected on Polish fishing vessels engaged in commercial pollock fishery in this area and came from samples taken on board of these vessels. Most information come from first and last months of the year. The methods used and the scope of research remained unchanged since the beginning of Polish investigations in international waters.

In 1989 investigations were carried out in two periods: from January to April and from September to November.

The aim of this paper is to present the results of investigations conducted in 1989, which may contribute to a better understanding of the biology of walleye pollock in the Aleutian Basin.

Catches

In 1985 Poland began fishing operations for pollock in international waters of the Bering Sea and caught 116 thous tons. In the following years the catches continued to increase, reaching almost 300 thous. tons in 1988 and 269 thous. tons in 1989 (Table 1). The Polish fleet fished initially in the first and last months of the year, extending the fishing season in the subsequent years; in 1988 and 1989 Polish vessels were fishing for pollock all year round attaining satisfactory results (Fig. 1).

In 1989 a decline in catches was observed in February and March, which had been caused by the peak of spawning taking place south-east of the international waters at that time. A similar decline in catches in those months was observed in previous seasons although in 1988 and 1989 the disappearance of fish concentrations resulting in not efficient catches was relatively long, lasting six weeks.

In the previous years the best catch rates were attained in the period directly before and after spawning while in the last two years during the period April-July and November-December. In 1989 mean annual CPUE (42.9 t/d) was slightly lower than achieved in 1988 (43.0t/d).

Catch rates attained by the Polish fleet in summer months of 1987-1989 signify that pollock concentrations at that time were not less dense than during winter fishing operations.

The information on distribution and density of pollock concentrations in open waters of the Bering Sea are based on the analysis of movements of the Polish fleet and statistical catch data and presented in fig. 2.

Length composition

Similarly to the previous years pollock with total length ranged from 39 to 63 cm.

The bulk of the stock consisted of specimens with lengths ranging from 46 to 51 cm (about 85%). Fish smaller than 41 cm and larger than 59 cm formed less than 1% of total weight of fish (Fig. 3). Mean lengths of pollock in open waters of the Bering Sea were as follows:

1989	Males	Females
I-IV	47.77 cm	49.28 cm
IX-XI	48.76 cm	49.97 cm

Generally pollock from open waters of the Bering Sea reached greater lengths in 1989 than in the previous years.

Age

The total absence of fish younger than 5 years (Fig.4). was characteristic for Polish catches in 1985-1989. In 1989 the verification of aging of pollock for 1985-1988 years was made according to the interpretation of annual increments in otoliths suggested by the U.S. scientists from NMFS (Seattle). In the 1989 pollock of age 5 to 23 years occurred in the catches (Fig.5,6).

The age-groups 11 and 12 (year classes of 1978 and 1977) predominated, constituting 16.4% and 21.8% of the catch, respectively. The share of these two year classes were higher in the first months of the year than at the end of the year. The share of younger year classes increased in September-November catches. The fishes representing 6 and 8 year classes of 1983 and 1981 consisted of 10.5% and 11.2% catches respectively, which resulted in a distinct decrease of mean age of fish in comparison with January-April 1989.

	Mean age	
1989	Males	Females
I-IV	12.2	12.1
IX-XI	10.5	10.7

Between September and November 1989 pollock in the same age-groups, were characterized by greater mean lengths in relation to pollock caught in the first four months of the year (Fig. 7).

The Polish investigations carried out between September and November 1989 may suggest that the year classes of 1978 and 1977 will be gradually replaced by younger fish.

Weight of fish

In 1989 pollock reached weights ranging from 340 to 1790 g (Table 2). The bulk of the stock consisted of specimens with weights of 540-1190 g. In the period September to November mean weights were greater than in the first four months of the year

Analysis of weight-length relationship calculated from formula $W = K * L^n$ indicated that in smaller length classes males weighed slightly more than females. In the 45-48 cm length classes in January to April and in the 44-47 cm length classes in September to November the weights of both sexes became equal. In the highest length classes, females weighed more than males.

Pollock occurring in international waters in 1989 were characterized, as in the previous years, by a wide range of weight in the same length classes. Mean weights of pollock in 1989 were slightly higher than those in the previous years.

Gonads maturity

. The gonads of pollock in 1989 matured relatively slowly between September and November, their development becoming rapid in January. (Table 3). First males ready for spawning were found in February, while the females at the beginning of March. In April a large part of pollock had gonads completely spent (about 40%) and in resting stage (about 53%). Just like in the previous years, males matured earlier in 1989 than females. The process of gonads maturation in males was extended in time, while the gonads of females matured more quickly within a short time.

Male-to-female sex ratio

In 1989, as in the previous years, male-to-female sex ratio in open waters were changing with time (Fig. 9). Females predominated distinctly in the spawning and post-spawning period. Their greatest abundance was observed in March (84%). In April the share of males slowly increased to 54%. Between September and November males were more numerous than females. The ratio of males and females in the stock was similar to that in the years 1985-1988.

Feeding

During the whole study period in 1989 a very low feeding intensity of pollock was observed (Table 4). The fish with empty stomachs predominated (Fig. 10). The lowest feeding intensity of pollock was observed before spawning (over 96% of fish with empty stomachs). After spawning feeding intensity slowly increased. Empty stomachs were more frequently encountered in males than in females.

Pollock caught in 1989 was characterized by a low condition coefficient K = 0.547 - 0.731 (Fig. 11). The best condition was visible in fish in the pre-spawning period between November and January, and the worst in March and April.

Conclusions

Catch rates fluctuated throughout the whole year and the mean CPUE in comparison with 1988 year was slightly lower.

The dominant year classes continued to be 1977 and 1978 and age studies revealed that the pollock stock was supplemented with younger year classes.

Catch rates and the stable age structure of the stock show that stock condition was not affected by the fishery.

The presence of spawning pollock in international waters of the Bering Sea may suggest that at least a part of the stock undertakes spawning within the boundaries of those waters.

YEAR	1985		1986		1987		1988		1989	
MONTHS	catch (t)	CPUE (t/df)	catch (t)	CPUE (t/df)	catch (t)	CPUE (t/df)	catch (t)	CPUE (t/df)	catch (t)	CPUE (t/df)
JANUARY	3 407	48.7	32 290	59.1	41 107	54.1	40 944	42.1	29 392	36.2
FEBRUARY	16 954	55.8	21 169	45.5	32 146	44.1	9 676	11.0	4 167	11.3
MARCH	10 031	42.3	18 937	41.3	13 715	26.8	9 309	14.5	7 488	23.5
APRIL	18 456	51.4	26 644	62.8	31 292	57.4	49 678	67.3	32 677	58.7
MAY	30 855	63.9	17 852	46.4	30 338	49.9	15 177	30.4	39 955	63.4
JUNE	18 161	50.2	4 939	26.7	24 512	45.8	37 791	64.2	32 849	54.7
JULY	94	47.0	339	21.2	16 157	68.5	28 836	62.3	23 428	40.2
AUGUST	-	-	6	6.0	-	-	19 431	51.8	12 464	41.1
SEPTEMBER	-	-	-	-	-	-	5 839	42.6	8 768	37.5
OCTOBER	-	-	2 201	44.9	-	-	7 414	54.5	16 418	32.0
NOVEMBER	-	-	13 514	41.2	13 342	47.8	29 342	60.6	26 113	43.3
DECEMBER	17 916	58.9	25 358	45.4	27 709	39.5	46 277	46.4	34 851	47.3
TOTAL	115 874	54.5	163 249	47.7	230 318	47.0	298 714	43.8	268 570	42.9

Table 1. Polish catches and catch rates of pollock in international waters of the Bering Sea.

	1989 I - IV								1989 IX - XI							
	MALES				FEMALES				MALES				FEMALES			
LENGTH (cm)	no	mean weight	range from -	to	no	mean weight	range from -	to	no	mean weight	range from -	to	no	mean weight	range from -	to
39					2	432.5	420	445								
40	4	420.0	340	500					2	415.0	410	420	1	500.0	500	500
41	2	412.5	405	420	1	520.0	520	520	5	512.0	470	580				
42	6	555.8	460	690	2	445.0	410	480	31	519.0	450	600	1	510.0	510	510
43	11	555.0	420	630	5	488.0	430	545	27	552.2	390	630	14	548.6	460	600
44	26	595.0	465	735	14	596.8	500	765	35	611.4	440	780	18	603.3	550	690
45	54	628.6	490	780	19	581.3	480	725	66	645.0	520	1250	28	628.9	560	720
46	93	670.5	500	870	46	644.9	460	900	91	699.5	570	870	24	673.8	590	770
47	158	688.6	540	895	85	680.6	490	910	115	765.4	470	910	48	741.0	620	830
48	149	718.0	505	965	125	723.4	530	970	178	811.9	630	950	58	796.6	680	900
49	110	747.8	580	995	150	771.5	540	1010	170	848.0	580	1000	70	856.6	760	980
50	65	772.7	640	905	159	801.9	580	1110	137	897.3	760	1050	97	917.5	790	1050
51	32	806.9	710	915	104	834.7	590	1190	90	922.0	610	1150	94	958.1	810	1100
52	9	900.6	780	1165	57	905.1	650	1150	53	973.4	620	1170	78	1009.5	880	1210
53	10	968.5	810	1205	28	920.9	710	1125	26	1039.2	830	1240	69	1065.5	950	1210
54	7	915.0	750	1130	21	995.0	710	1270	13	1073.1	900	1300	53	1144.7	960	1310
55	1	990.0	990	990	11	1015.5	730	1245	11	1114.5	900	1310	38	1152.6	1000	1330
56					9	1162.2	800	1530	1	1190.0	1190	1190	26	1254.2	1050	1390
57					4	1248.8	1060	1400	1	1240.0	1240	1240	13	1281.5	1140	1400
58					3	1241.7	1170	1350					4	1362.5	1310	1400
59					3	1356.7	1020	1545								
60					1	1590.0	1590	1590					1	1680.0	1680	1680
61					1	1545.0	1545	1545					1	1510.0	1510	1510
62					1	1535.0	1535	1535					1	1790.0	1790	1790
63					1	1680.0	1680	1680								
	737	709.6	340	1205	850	789.5823	410	1680	1052	809.7528	390	1310	736	938.2472	460	1790

Table 2. Mean weight-at-length of pollock from Polish catches in international waters of the Bering Sea in 1989.

MONTHS / MATURITY STAGE	MALES									FEMALES									MALES AND FEMALES								
	I	II	III	IV	V	VI	VII	VIII	n	I	II	III	IV	V	VI	VII	VIII	n	I	II	III	IV	V	VI	VII	VIII	n
JANUARY	-	4.0	4.6	80.2	11.2	-	-	-	303	-	3.8	67.0	28.3	0.9	-	-	-	318	-	3.9	36.6	53.6	6.0	-	-	-	621
FEBRUARY	-	1.5	2.0	51.7	43.8	1.0	-	-	201	-	4.1	23.7	71.8	0.4	-	-	-	245	-	2.9	13.9	62.8	20.0	0.4	-	-	446
MARCH	-	-	-	-	-	-	21.1	78.9	19	-	58.4	-	-	-	3.0	6.9	31.7	101	-	49.2	-	-	-	2.5	9.2	39.2	120
APRIL	-	36.4	-	-	-	-	13.2	50.4	258	-	72.3	-	-	-	0.9	0.4	26.3	224	-	53.1	-	-	-	0.4	7.3	39.2	482
MAY																											
JUNE																											
JULY																											
AUGUST																											
SEPTEMBER	-	18.1	73.5	8.1	0.3	-	-	-	298	-	10.2	87.9	1.4	0.5	-	-	-	215	-	14.8	79.5	5.3	0.4	-	-	-	513
OCTOBER	0.3	15.5	76.2	7.9	-	-	-	-	290	-	10.0	84.6	5.4	-	-	-	-	280	0.2	12.8	80.4	6.7	-	-	-	-	570
NOVEMBER	-	6.9	61.1	30.9	1.1	-	-	-	252	-	6.2	72.7	20.2	0.8	-	-	-	242	-	6.5	66.7	25.8	1.0	-	-	-	504
DECEMBER																											

Table 3. Gonads maturity (Maier scale) in pollock from Polish catches in international waters of the Bering Sea in 1989.

MONTHS / STOMACH FULLNESS DEGREES	MALES						FEMALES						MALES AND FEMALES					
	0	1	2	3	4	n	0	1	2	3	4	n	0	1	2	3	4	n
JANUARY	97.2	1.6	0.4	0.4	0.4	254	97.5	1.8	0.4	-	0.4	285	97.4	1.7	0.4	0.2	0.4	539
FEBRUARY	98.8	1.3	-	-	-	160	94.5	4.0	1.0	0.5	-	201	96.4	2.8	0.6	0.3	0.0	361
MARCH	46.7	26.7	13.3	6.7	6.7	15	40.0	30.6	23.5	4.7	1.2	85	41.0	30.0	22.0	5.0	2.0	100
APRIL	41.6	26.6	17.3	8.9	5.6	214	29.8	27.1	16.5	10.1	16.5	188	36.1	26.9	16.9	9.5	10.7	402
MAY																		
JUNE																		
JULY																		
AUGUST																		
SEPTEMBER	80.5	16.8	1.3	0.3	1.0	298	66.5	26.0	4.7	2.3	0.5	215	74.7	20.7	2.7	1.2	0.8	513
OCTOBER	73.4	20.3	4.5	1.0	0.7	290	6.0	2.4	1.0	0.4	0.1	280	67.0	21.9	7.4	2.6	1.1	570
NOVEMBER	89.7	5.0	3.8	1.1	0.4	262	76.4	12.4	8.3	2.1	0.8	242	83.3	8.5	6.0	1.6	0.6	504
DECEMBER																		

Table 4. Degree of stomach fullness in pollock from Polish catches in international waters of the Bering Sea in 1989.

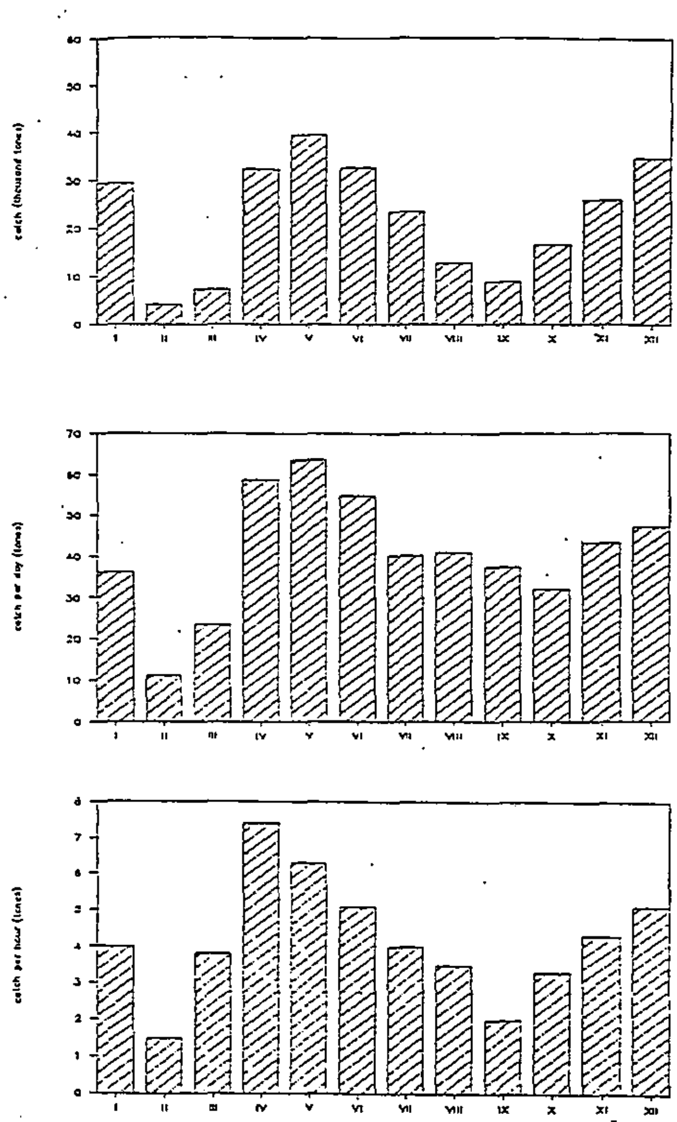

Fig. 1. Catches, fishing effort and CPUE of Polish fleet fishing for pollock in international waters of the Bering Sea in 1989

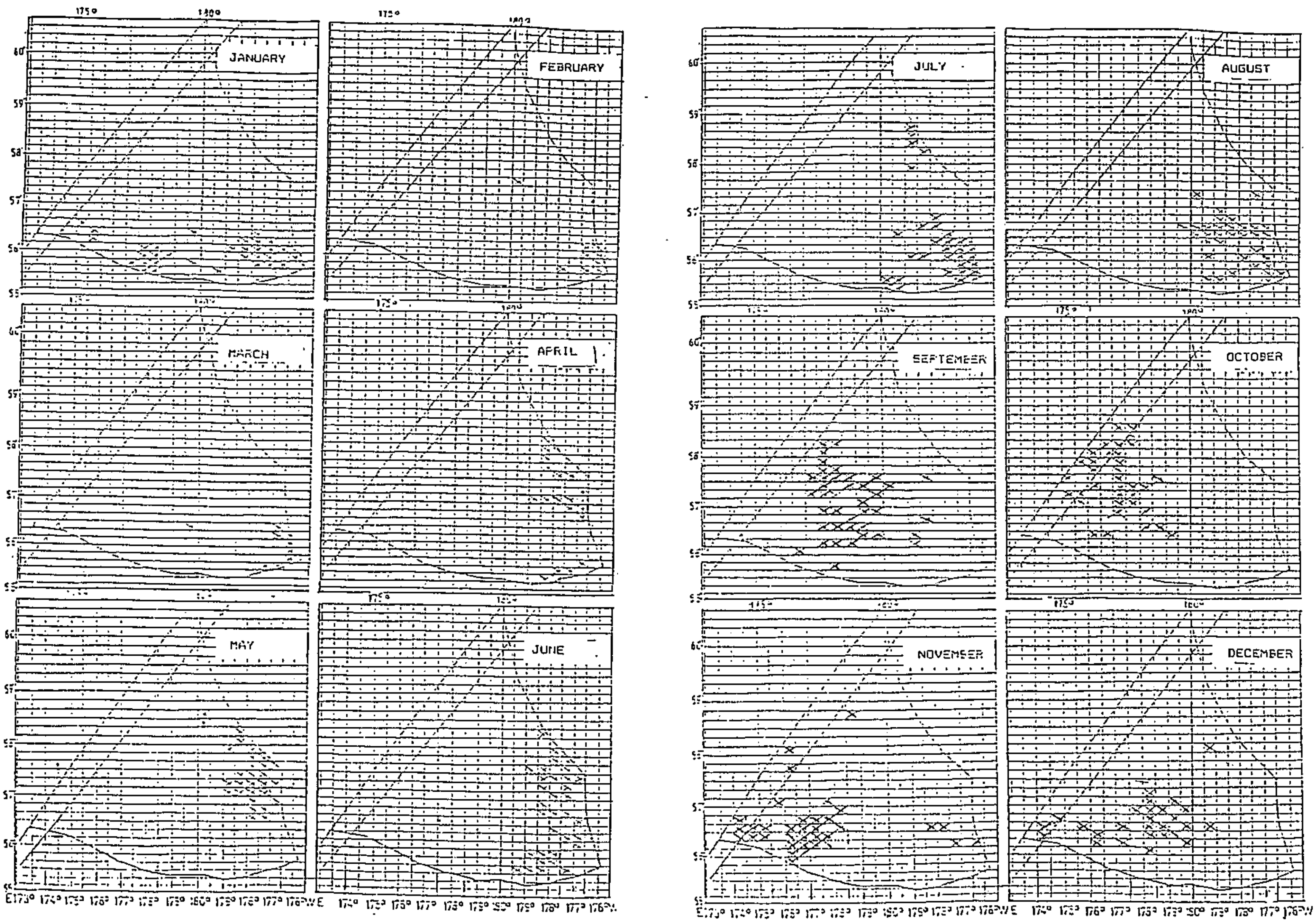

Fig. 2. Distribution of pollock from Polish catches in international waters of the Bering Sea in 1989

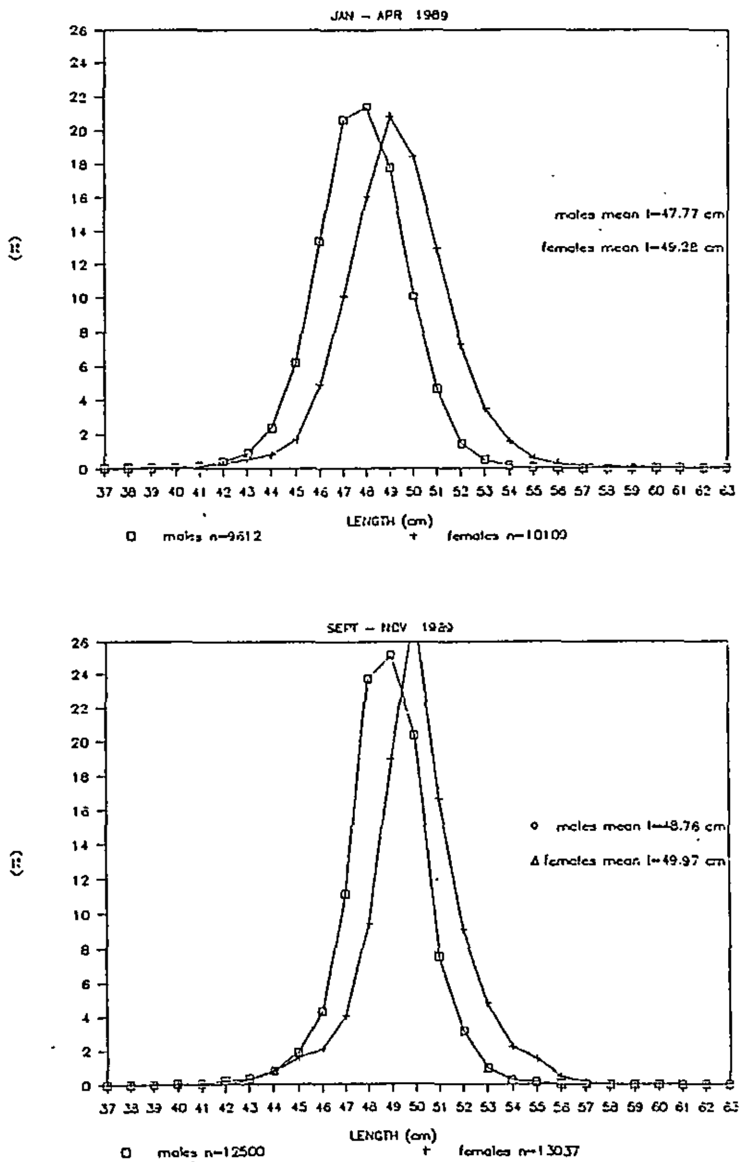

Fig. 3. Length composition of pollock in international waters of the Bering Sea in 1989 (January–April, [illegible]

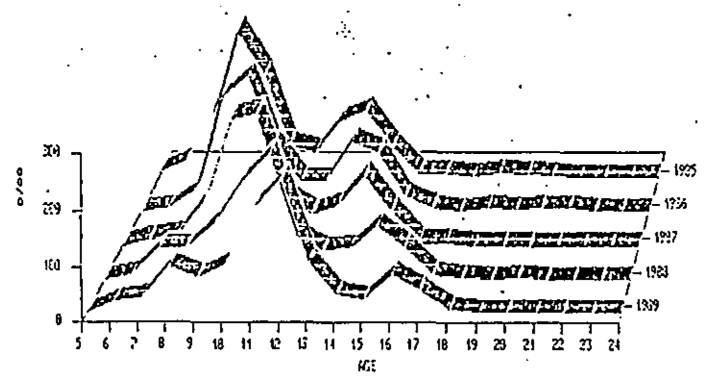

Fig. 4. Age composition of pollock from Polish catches in international waters of the bering Sea in 1985–1989

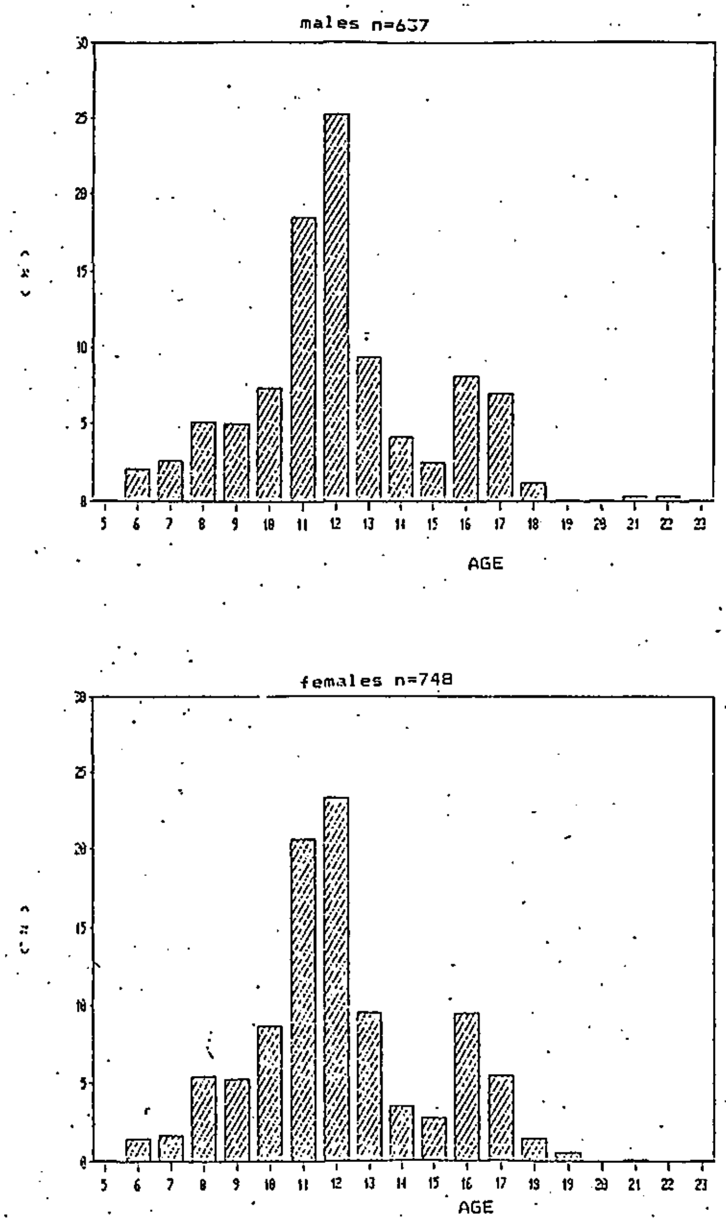

Fig. 5. Age distribution of pollock caught in international waters of the Bering Sea in January-April 1988

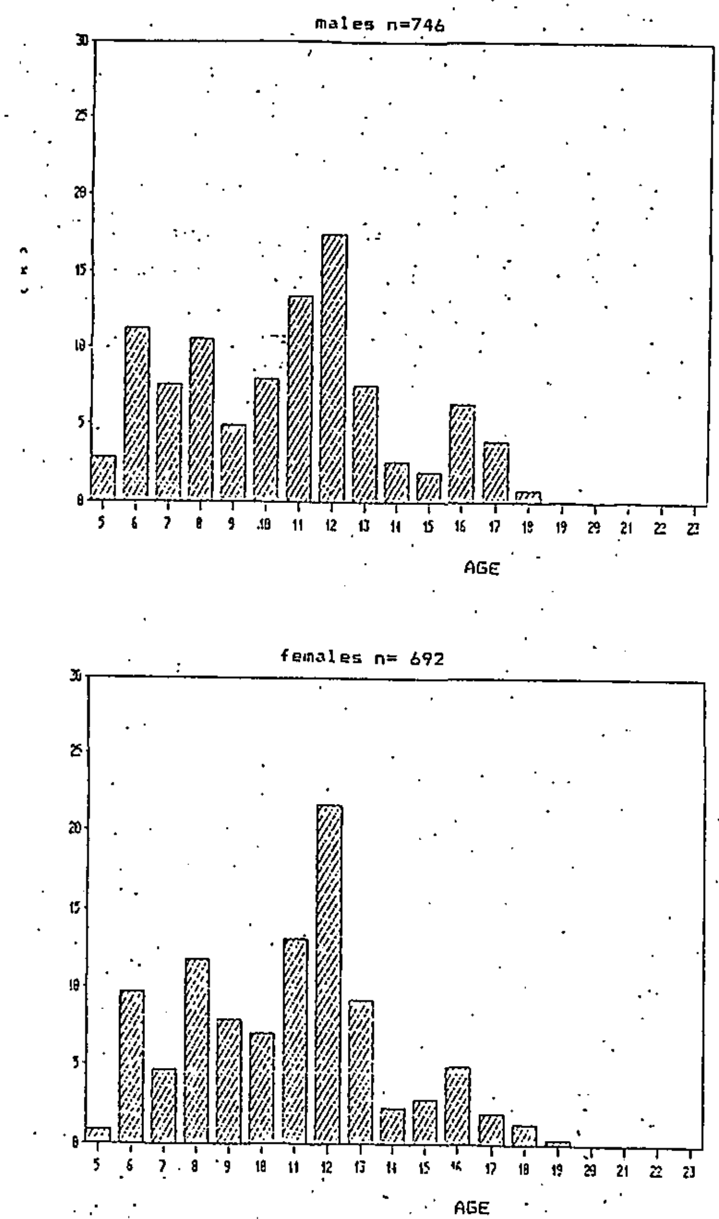

Fig. 6. Age distribution of pollock caught in international waters of the Bering Sea in September-November 1988

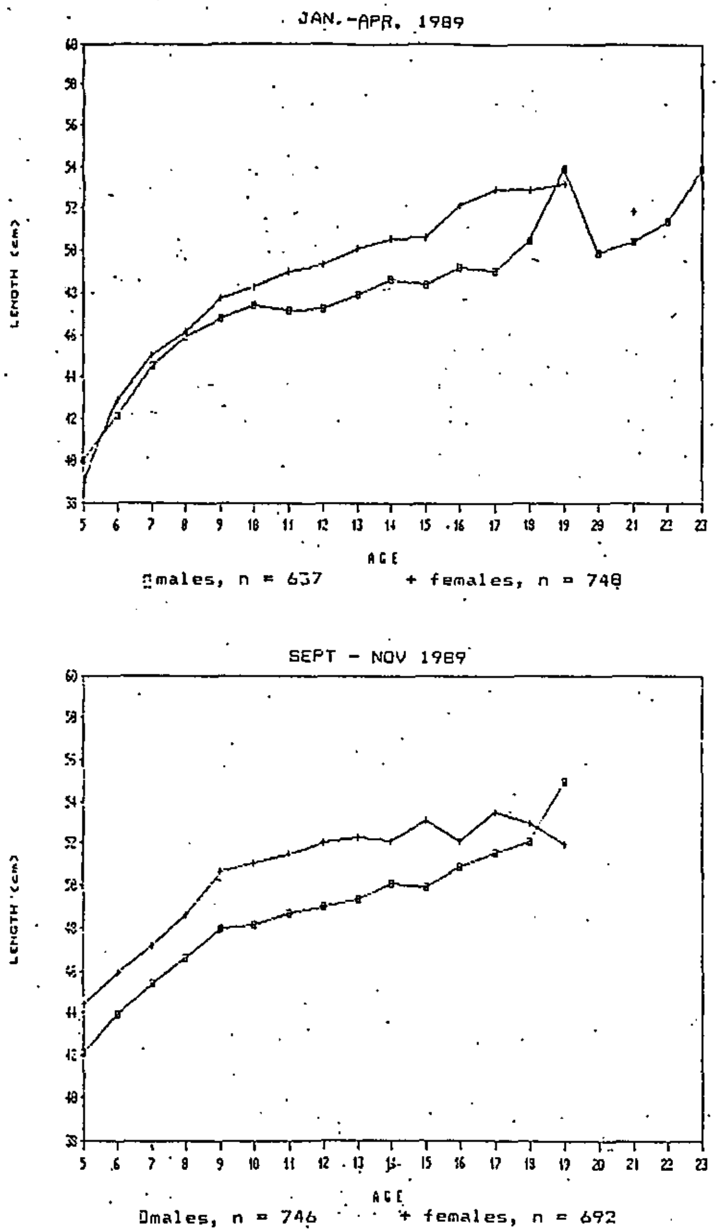

Fig. 7. Mean length-at-age of pollock caught in international waters of the Bering Sea in 1989

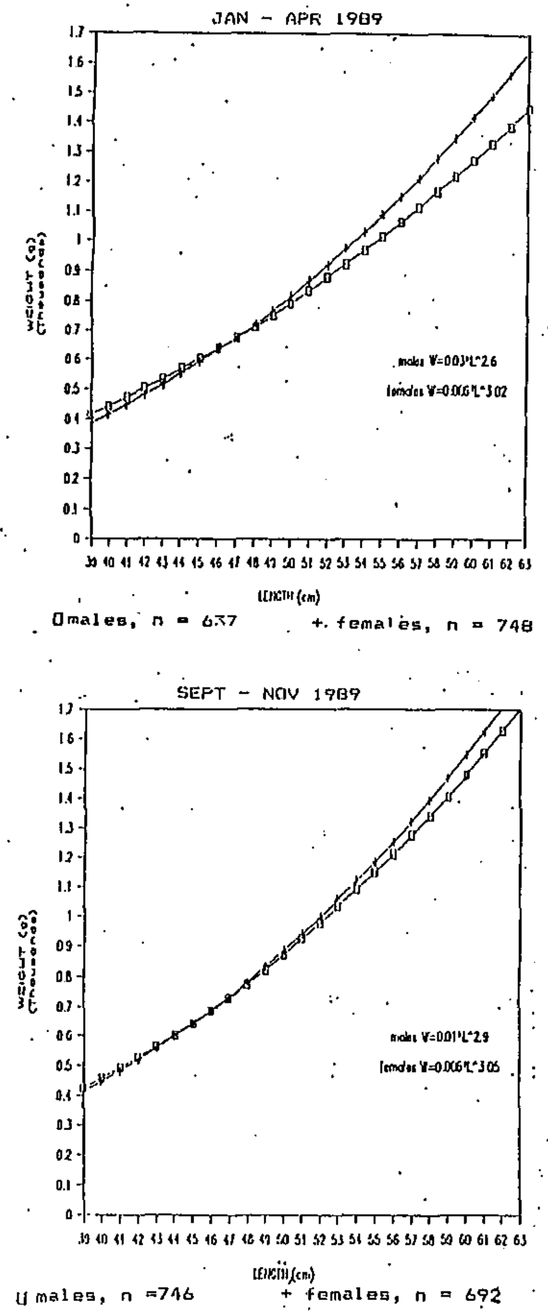

Fig. 8. Length-weight relationship of pollock in 1989.

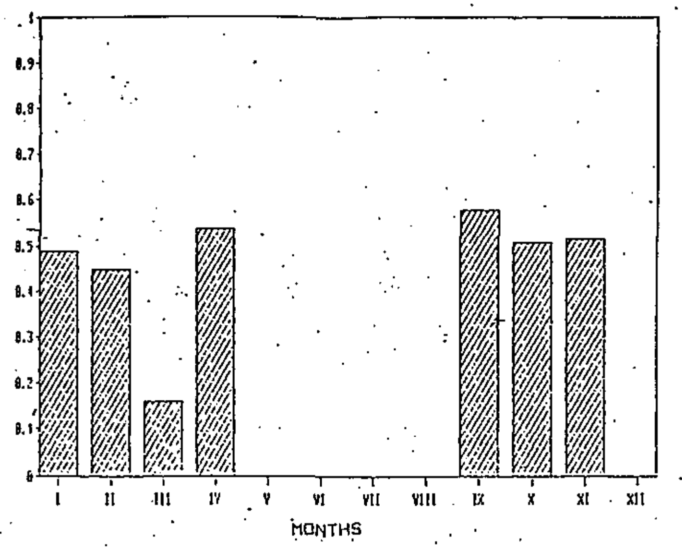

Fig. 9. Male-to-female ratio of pollock caught in international waters of the Bering Sea in 1989.

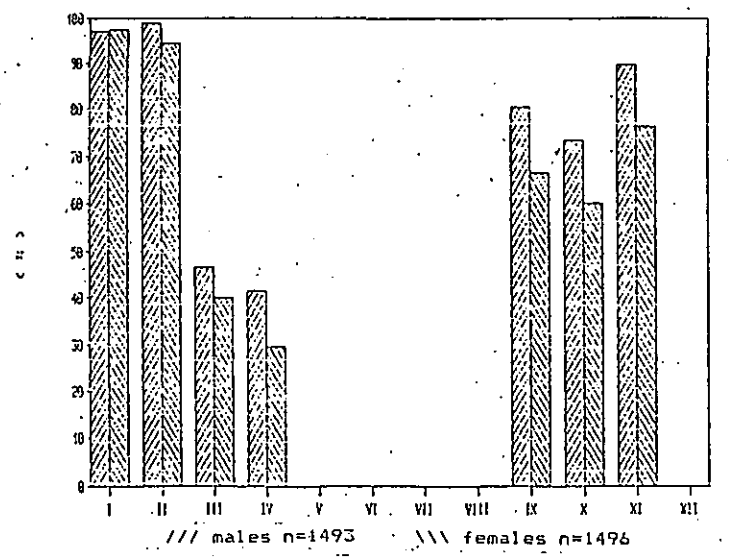

Fig. 10. Percentage share of non-feeding pollock in catches made in international waters of the Bering Sea in

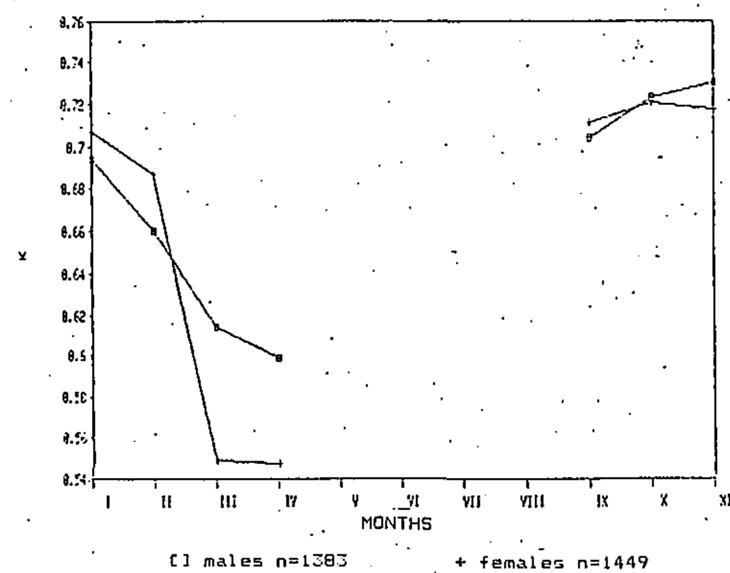

Fig. 11. Condition (k=(W/L^3)*100) of pollock in international waters of the Bering Sea in 1989.

Panel 5: Stock Assessment

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The Fishery and State of Stocks of the Most Important Species of fish in the Bering Sea

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TINRO, Vladivostok, U.S.S.R.

The Bering sea, particularly the eastern part, is unique and highly-productive body of water. Penetration of warm Alaska current, quite extensive shelf and intensive vertical mixing make favourable oceanological conditions for living organisms which inhabit this area, - they are: fish, invertebrates, mammals, birds. First references to the Bering sea fishery have more then a hundred year old history, nevertheless, drastic development of fishery started in the late 50s - early 60s this century. That time the major fishery occured over the eastern Bering sea shelf and ~~commercial~~ slope.

Fish catch increased 35 times only for 5 years and was estimated to be 500 thnd t (Stock assessment..., 1989). Rapid decline in catches, observed in the mid 60s, was caused by too intensive fishery of yellow-fin sole, rockfish and Greenland turbot. Pollock catches' significance increased drastically in the late 60s; therefore, the catch increased ten times from 1964 through to 1971 and was estimated to be 1744 thousand tons. The maximum catch of pollock was 1874 thousand tons in the eastern Bering sea it was reached in 1972. The history of fisheries shows that the eastern Bering sea was one of the main fishing ~~areas~~ [grounds] in the North Pacific prior to the introduction of 200-mile economic zone by the US government. The fishery is regulated here by quotas when this area turned out tobe under the US jurisdiction. The U.S.S.R. fishermen were particularly in a difficult situation, who practically lost the possibilities to be engaged in fishery that in its turn was a stimulus for development of the western Bering sea shelf. The catch of fish has been increased more than 1,5 times in the last ten years. The increase in catches was due to pollock, cod and flatfishes (Table 1).

The Aleutian Islands are a particular locality in the US 200-mile zone. The catch almost reached 150 thnd t (table 2) in the mid 80s, notwithstanding the fact that compared to the eastern Bering sea, much less fish are caught in this area. The fishery is primarily based on pollock as in the eastern Bering sea, nevertheless, ~~one-finned greenling~~ [atka mackerel] is the next abundant species. There are practically no flatfishes in catches.

The large-scale fishery started in the western and north-western Bering sea in the mid 70s when the Soviet fishermen had been forced out of the US zone. This area has essential significance in the fishery in the last 10 years. It should be noted that access to the shelf of the Navarin area is limited by severe, ice and meteorological conditions, due to this fact there is practically no fishery here in the winter period. There was a tendency towards increase in last years. Pollock is the main object of fishery, cod are also significant (tabl.3), the ~~rest~~ [others] species - herring, saffron cod, flounder and halibut are relatively significant.

Intensive fishery started to be conducted in the mid 80s in the central Bering sea, located beyond the limits of the USSR and US 200-mile economical zones. The main reason of developing a new fishing area, as we think, is that Japan is forced out of the US zone. If Japan's catch was 900 thnd t in the eastern Bering sea in 1976, the quota was about 350 thnd t in 1986.

Table I

The catch of the main fishes in the eastern part of the Bering Sea I979–I988 (thd.t.)

Year	Pollack	Cod	Sablefish	Rockfishes	Yellowfin sole	Arrowtooht flounders Greenland tourbot	other flatfishes	other species	total
I979	9I3,9	33,8	I,4	3,7	99,0	42,9	I9,7	38,8	II53,2
I980	958,3	45,9	2,2	I,4	87,4	62,6	20,4	34,6	I2I2,8
I98I	973,5	52,0	2,6	I,5	97,3	66,4	23,4	35,6	I252,3
I982	956,0	55,0	3,2	0,9	95,7	54,9	23,8	I8,2	I207,7
I983	982,4	83,2	2,7	0,7	I08,4	53,6	30,4	I5,5	I276,9
I984	I098,8	II0,9	2,3	2,0	I59,5	29,3	44,3	8,5	I455,6
I985	II79,8	I32,7	2,3	0,9	227,I	22,0	7I,2	II,5	I647,5
I986	II88,4	I30,6	3,5	0,8	208,6	I4,5	76,5	I0,5	I633,4
I987	I237,6	I44,5	4,2	I,9	I8I,4	I0,9	50,8	8,6	I639,9
I988	I228,0	I92,7	3,2	I,9	223,2	II,5	74,2	I2,2	I746,9

except Pacific Halibut

Table 2. The Catch of the main species of fishes in Aleutian Islands region in I979–I988 (I000 t.)

Year	Pollack	Cod	Sablefish	Perches	Halibuts	Atka mackerel	other species	Total
I979	9,5	5,6	0,8	I0,0	I2,8	22,3	I2,9	73,9
I980	58,2	5,8	0,3	4,4	8,3	I5,5	I3,0	I05,5
I98I	55,5	I0,5	0,5	4,0	8,0	I6,7	7,3	I02,5
I982	58,0	II,5	0,9	3,8	8,7	I9,5	5,2	I08,5
I983	59,0	9,9	0,7	I,7	7,9	II,6	3,7	94,5
I984	8I,8	22,2	I,0	0,9	3,3	36,0	I,7	I46,9
I985	58,7	I2,7	I,4	0,6	0,I	37,9	2,0	II3,4
I986	46,6	I0,3	3,0	0,4	2,3	32,0	I,5	96,I
I987	28,7	I3,2	3,8	I,6	3,2	30,I	I,2	8I,8
I988	43,0	5,2	3,4	2,5	I,5	2I,7	0,4	77,7

except Pacific halibut

Table 3. The Catch of the main species of fishes in Western and North-Western parts of the Bering Sea in I979-I988 (I000 t.)

Year	Pollack	Cod	Flatfishes	Saffron cod	Herring	Halibut Arrowtooht flounder Greenland tourbot	Total
I980	880,4	9,2	II,I	I3,0	II,7	2,9	928,3
I98I	805,0	I7,9	3,2	I4,I	I4,3	6,4	860,9
I982	928,3	52,I	7,4	I3,6	I2,0	2,9	I0I6,3
I983	980,0	55,3	I5,2	I4,4	I6,0	2,2	I083,I
I984	756,0	90,8	9,2	I5,2	I9,4	2,0	892,6
I985	662,0	92,4	I5,2	II,3	33,9	2,7	8I7,5
I986	878,5	I08,5	I8,5	8,9	2I,2	4,8	I040,4
I987	946,5	69,I	I5,2	9,0	I9,8	3,9	I063,5
I988	I435,0	57,0	I4,I	I0,3	I5,3	2,5	I534,2
I989	II5I,0	7I,7	I3,5	6,8	7,9	2,I	I252,7

Rapid development of the Bering sea neutral waters by fishermen of Japan,South Korea and Poland led to the fact that their total catch exceeded 1,0 mln.t (Table 4) in 1986. The main reason of so called "boom" is related to uncontroled fisheries,high demand for "surimi" and pollock eggs. Moreover, at present the fishery is carried out by the USSR,Romania,Taiwan,Western Germany and Norway as well in the open part of the Bering sea.Therefore, the actual catch is likely to exceed 1,5 mln.t

Table 4

Pollock catch in the open waters of the central Bering sea in 1980-1988 (thnd t)

Year	Countries					Total catch thnd.t
	Japan	Taiwan	South Korea	Poland	the U.S.S.R	
1980	2,4	-	12,5	-	-	14,9
1981	0,2	-	0	-	-	0,2
1982	1,2	-	2,9	-	-	4,1
1983	4,1	-	66,6	-	-	70,7
1984	100,9	-	80,3	-	-	181,0
1985	136,5	1,6	82,4	115,8	-	336,0
1986	698,0	3,2	155,7	163,2	41,0	1061,0
1987	802,6	4,1	241,9	230,3	158,0	1437,0
1988	749,2	17,4	266,7	[illegible]	[illegible]	1439,0

Summarizing the above-said it is necessary to note that large-scale development of two new fishing areas - Navarinskiy (north-west part of the sea) and central areas ("Neutral"waters) has been marked in the last decade. In recent years catch is based on pollock and has reached quite significant meaning - about 4 mln.t

No doubts that successful fishery is strictly related to the state of stocks. Contemporary studies of US scientists showed that there is no concern about the state of pollock, cod and flatfishes' stocks that inhabit the eastern Bering sea (Wespestad, 1989; Sample, Bakkala, 1989; Thompson, 1989, Bakkala, Wilderbuer, 1989; Walters, Wilderbuer, 1989; Walters, Wilterbuer, 1989). Nevertheless, recruitment of pollock of 1986-1988 is marked below the average level that will undoubtedly affect the fishery' efficiency. The author's forecast (Bulatov, 1988), based on climatee-oceanological phenomena, shows that the stocks of pollock will decline starting in 1990.

The fishery is also based on pollock catches in the USSR zone. At present there are no serious symptoms that would indicate the expected rapid fall of stocks of important commercial species of fish, inhabiting the western and north-western Bering sea.

The fishery is exclusively based on pollock in the area of the Bering sea, located beyond the limits of the USSR- and US 200-mile exclusive economical zones. The lack of any documents and agreements, regulating the fishery in this area, led to the fact that the problem had the political character. Nevertheless, its topicality will to a considerable extent, depend on the state of pollock stock in near future.

Soviet scientists have been conducting annual pelagic surveys in fall since 1986. The south-eastern Bering sea was taken as a control area, limited by 165°E from the west and by the US zone boundary from the east. Distribution of pollock is represented in the figure. The following fact should be taken into consideration.: two pollock aggregations have been observed in all periods of observations. Distinctive peculiarity of 1989 was rapid decline of the area where high catches were marked.

The stock of pollock was determined by 1987-1989 trawl surveys' data. The biomass assessment was conducted by Aksyutina's formula (1968) :

$$P = \frac{Q \cdot X}{q \cdot k}$$

where P - biomass, tons;

X - mean arithmetic catch in the south-western part and neutral waters, t;

Q - area of surveys, km^2;

q - mean area of one hour trawling, km^2;

k - fishing coefficient (taken to be 0,4).

The results showed that in compared area the pollock biomass declined more than 3 times compared to that of 1988. This decline of stocks has been expected earlier (Bulatov, Sobolevskiy, 1989). Drastic increase of pollock average size was taking place in the south-western Bering sea during the last years: 45,1cm (1986), 46,2cm (1987), 47,5cm (1988), 48,3cm (1989), it is related to the fact that 1-2 very strong year-classes are leaving the commercial part of population.

Alarming situation, due to decline of pollock stocks in the eastern and central Bering sea, will result not only in aggravation of commercial situation but it will negatively affect the entire Bering sea ecosystem. Due to this fact there is a necessity to have an international body or adopt International legal documents that could regulate the pollock fishery in the open waters of the Bering sea.

TABLE 5. The Alaska pollock biomass in the South-Western Bering Sea and high seas in 1987 - 1989.

Source of information		Standard trawl survey at Soviet research vessels			
South-Western part (the USSR zone)	Period of observation	Sep 1987	Oct 1987	Nov-Dec 1988	Nov 1989
	Biomass, thou tons	1280	1950	371	296
High seas (international waters)	Period of observation	Aug 1987	Oct 1987	Oct-Nov 1988	Nov 1989
	Biomass, thou t	295	1132+	2802	658
Total, thousand tons		1575	3082	3173	954

+ - Only the southern part was investigated.

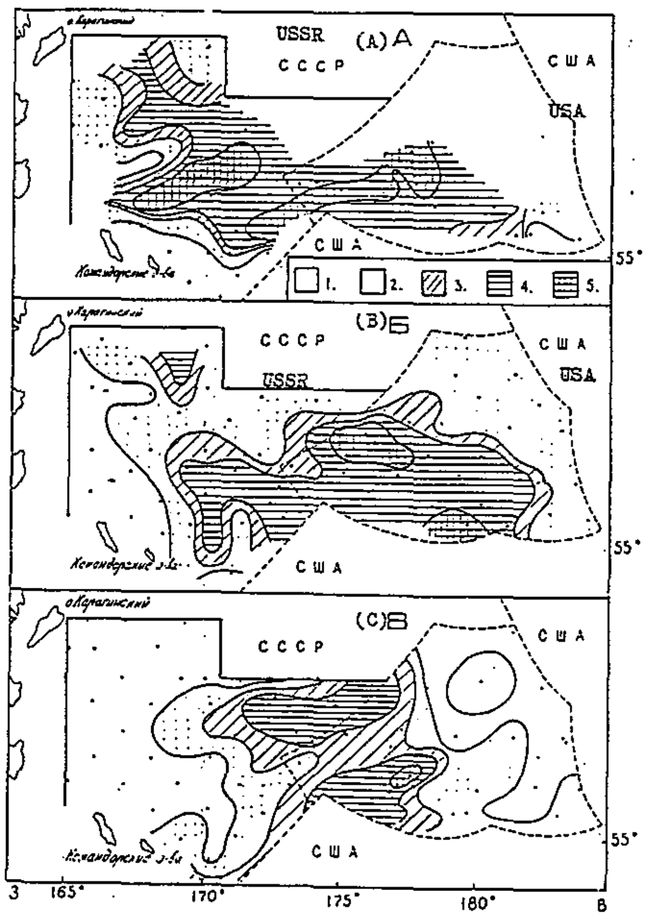

Fig.1. Distribution of Alaska pollock in the Doughnut Hole area and the South-Western Bering Sea in autumn 1987 - 1989.
LEGEND: A,B,C - 1987, 1988, 1989 correspondingly.
1.less than 0.1 t; 2. 0.1 - 0.5 t; 3. 0.5 - 1.0 t;
4. 1.0 - 5.0 t; 5. more than 5.0 t/hour.

Stock Assessment of Walleye Pollock in the Bering Sea under Assumption of Three Stocks

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ABSTRACT

Stock assessment in the Bering Sea was conducted on the assumption that pollock in the Bering Sea consisted of three stocks. The continental shelf stock in the eastern area and the continental shelf stock in the western region spawn, develop, grow and migrate on the continental shelf and continental slope of the eastern and western Bering Sea, respectively. It was assumed that pollock stocks of the Aleutian Basin spawn in the Aleutian Basin, young fish move to surrounding continental shelf, develop and grow there, and they move again to the Basin when they reach age 5 or 6.

Body weight by age, life span, age at maturity, natural mortality coefficient (M) and age at recruitment, etc. were estimated from the results of the multi-vessel trawl surveys conducted by Japan and Japan-U.S.cooperative ground fish trawl surveys, etc., in order to obtain the equilibrium yield (EY) of each stock. To obtain the value of M of pollock of 4 years old and older for the eastern continental shelf stock, an estimate of Z (0.45) was obtained from the decline of individuals of age 6 or older under the Japan-U.S. cooperative survey, and the estimates of M values of 0.38 and 0.29 were obtained by subtracting the two values of F which was obtained from the two methods, from Z. M for 3 year-old fish was fixed at 0.88 and 0.79, and age at recruitment was set 3 or 4 on the basis of age composition by year of the catch. For the Basin stock, the value of M was the same as that of the continental shelf stock and for age at recruitment, it was assumed that 50% of age 5 fish and 100% of age 6 fish were available for the fishery. For the continental shelf stock in the western area, it was assumed that these parameters are the same as those for the continental shelf stock in the eastern area. Recruitment was obtained as a relative value by stock. Recruitment of the western continental shelf stock was fixed to be 1/4 of the eastern continental shelf stock. The rate of the Basin stock to that of the eastern continental stock was obtained by subtracting the numbers of population (back-calculated from age 6 fish) of the continental stocks from the number of population of age 4 fish on the continental shelf of the eastern Bering Sea, and, 2.96 and 2.29, the rates of the Basin stock throughout the Bering Sea to the eastern continental shelf stock was obtained by adding with the Basin stock in the other areas. The former corresponded to the case when M is 0.38 (Case I) and the latter to the case when M is 0.29 (Case II).

Furthermore, the F values by age and numbers of population by age and by year-class were estimated by cohort analysis. The revised U.S. data were used for the numbers of pollock caught. The value of fishing mortality coefficient F_T in terminal age T was calculated from the numbers of population of the oldest age obtained from the Japan-U.S. cooperative survey.

Virgin biomass and MSY were calculated using the mean value of numbers of population of age 3 fish obtained from cohort analysis. Virgin biomass of the continental shelf stock in the eastern area was 12.08 million t (recruited at the age of 3 years old) and 10.40 million t (recruited at the age of 4 years old) in Case I, and 12.28 million t (recruited at the age of 3 years old) and 11.12 million t (recruited at the age of 4 years old) in Case II. Virgin biomasses of the Basin stocks were 16.53 million t in Case I and 14.10 million t in Case II. MSY was assumed to be obtained when the biomass of spawners became half of the virgin biomass. The value of F at this time was fixed to be F_{opt}. Maximum sustainable yields of the continental shelf stocks in the eastern area were 1.14 million t (recruited at the age of 3 years old) and 1.19 million t (recruited at the age of 4 years old) in Case I and 930,000 t (recruited at the age of 3 years old) and 990,000 t (recruited at the age of 4 years old) in Case II. Although the maximum sustainable yields of the Basin stocks were 2.90 million t in Case I and 1.88 million t in Case II, as they are caught on the continental shelf at the age of 3 to 4 years old, taking it into consideration, MSYs were 2.66 to 2.75 million t in Case I and 1.65 to 1.75 million t in Case II.

On the assumption that the equilibrium yield is obtained at the time of F_{opt}, EY in 1990 was estimated by extrapolation. I obtained the numbers of population at age in 1987 from the number of population of age 3 fish and the value of Z obtained by cohort analysis and then obtained the numbers of population in 1990 using the value of F corresponding to the catches from 1987 to 1989. By using the value of F_{opt} for the numbers of population in 1990, equilibrium yields of the continental shelf stocks in the eastern area were 1.66 to 1.92 million t in Case I and 1.27 to 1.44 million t in Case II, and EYs of the Basin stocks were 3.58 to 3.96 million t in Case I and 2.26 to 2.54 million t in Case II. Judging from the conditions of recruitment in recent years, age at recruitment from 1988 to 1990 was considered to be 4 years old. Assuming that the value of F by year would be constant among ages, the value of EY was calculated, and fixed this as the allowable catch. The values of allowable catch in 1990 for the continental shelf stocks in the eastern area were 1.95 million t in Case I and 1.47 million t in Case II, and those for the Basin stock were 3.87 million t in Case I and 2.44 million t in Case II. The value of allowable catch for the continental shelf stock in the western area were 490,000 t in Case I and 370,000 t in Case II. The values of allowable catch by area are as follows (10,000 t):

STOCK		EASTERN CONTINENTAL SHELF STOCK		BASIN STOCK		WESTERN CONTINENTAL SHELF STOCK		TOTAL	
AREA	CASE	I	II	I	II	I	II	I	II
Eastern continental shelf/ continental slope		95	147	70	36	0	0	265	183
Basin and Aleutian Islands region		0	0	299	199	0	0	299	199
Western continental shelf/ continental slope		0	0	18	9	49	37	67	46
TOTAL		195	147	387	244	49	37	631	428

The total allowable catch in 1990 (4.28-6.31 million t) was considerably greater than the actual catch in 1987 (3.64 million t).

CONTENTS

1. Introduction

Pollock (Theragra chalcogramma) are widely distributed not only on the continental shelf but also throughout the Bering Sea including the Basin, and the biomass is tremendous (Laevastu and Larkins 1981, Lynde 1984, Maeda 1971, Smith 1981, Sobolebskiy et al. 1988). Many pollock are caught in the U.S. 200 miles zone, U.S.S.R. 200 miles zone and in international waters. In addition, although the resource management of pollock in the U.S. and U.S.S.R. 200 miles zone are conducted by the U.S. and U.S.S.R. independently, the structure of resource management in the international waters is not completed yet.

Information on stocks of pollock in the Bering Sea is presently not sufficient. Stock assessment of pollock is conducted here on the assumption that there are three stocks, which is based on the information obtained in the past.

It is known that the spawning grounds of pollock in the Bering Sea are divided roughly into three areas (Hinckley 1987, Stepanenko 1989). These are the continental shelf of the Western Bering Sea, Aleutian Basin and the continental shelf of the eastern Bering Sea. In addition, the spawning season occurs in April and May on the continental shelf of the western Bering Sea, February and March in the Aleutian Basin, and April to August in the eastern Bering Sea (Hinckley 1987, Stepanenko 1989, Teshima et al. 1988). For growth of pollock, there is a difference between the Aleutian Basin and the continental shelf of the eastern Bering Sea, pollock in the Aleutian Basin grow slower than pollock on the continental shelf of the eastern Bering Sea (Okada and Yamaguchi 1985, Traynor and Nelson 1985). It is known that the abundance of pollock of age 1 to 3 fish is very low in the Aleutian Basin.

From the above information, it is assumed that three stocks (the eastern continental shelf stock, western continental shelf stock, and Basin stock) exist in the Bering Sea. The eastern continental shelf and western continental shelf stocks are assumed to spawn, develop, grow and migrate on the continental shelf and continental slope in the eastern and western areas, respectively. Furthermore, the Basin stock is assumed to spawn in the Aleutian Basin and develop and grown on the continental shelf and continental slope of both the eastern and western areas, and Aleutian Islands region from juvenile to the age of 4 years old, and move to the Aleutian Basin from the age of 5 years old to the age of 6 years old, and some pollock remain in the Aleutian Islands region.

Pollock is generally known as bottom fish, however, the ecological characteristics of this species in the Bering Sea are somewhat pelagic in character and the major food is zooplankton such as euphasids and copepods. On the continental shelf and upper continental slope in the eastern Bering Sea, large sized pollock eat their own young fish, and this cannibalism is remarkable. Also, there is evidence that changes of biomass of pollock depend largely on the strength of the year-classes (Bailey et al. 1986, Sasaki 1987). Factors which determine the strength of the year-class are still unknown. However, there is no doubt that cannibalism is an important cause of mortality of young pollock (Dwyer et al. 1987, Livingston et al. 1986, Mito 1988a, 1989). In analyzing the stock, it is necessary to consider the yearly changes in the strength of the year-classes and mortality due to cannibalism.

Management of pollock stocks by the U.S. within the U.S. 200 miles zone is conducted so that optimum yield (OY) of pollock is set at the upper limit of the catch. OY of pollock in the eastern Bering Sea and Aleutian Islands region was set at 1.2 million t and 100,000 t, respectively, from 1984 to 1986, 1.2 million t and 88,000 t in 1987 (Bakkala 1987), 1.3 million t and 45,000 t in 1988, and 1.34 million t and 13,000 t in 1989.

2. History of the fishery

Table 1 shows the yearly change of catch of pollock in the eastern Bering Sea and Aleutian Islands region. A full-scale fishery for pollock was initiated in 1964, the catches increased dramatically year by year, and reached a peak of 1.84 million t in 1972. After that, because the average size of the fish declined remarkably, a catch limitation was introduced through bilateral treaties between Japan and the U.S., and between the U.S. and the U.S.S.R. (Takahashi). As a result, the catch decreased and was 1.25 million to in 1978. Since 1977, the concerned area has been incorporated into the U.S. 200 miles zone and the allowable catch or optimum catch was established and the catches in the eastern Bering Sea were 0.88 to 1.00 million t from 1977 to 1983 and 1.18 to 1.24 million t from 1985 to 1988. In the Aleutian Islands region, the statistics have been taken from 1977, the catches ranged from 6,000 t to 9,000 t during 1977 to 1979, and 56,000 to 61,000 t during 1980 to 1983. Although the largest catch (78,000 t) was reached in 1984, it decreased to 46,000 t in 1986, and further decreased to 29,000 t in 1987 and again increased to 43,000 t in 1988.

Catches by country in the international waters of the Aleutian Basin are as follows (t).

Year	Japan	Korea	Poland	China	Total
1980	2,401	12,059	-	-	14,460
1981	221	0	-	-	221
1982	1,298	2,934	-	-	4,232
1983	4,096	66,558	-	-	70,654
1984	100,899	80,317	-	-	181,216
1985	136,475	82,444	115,874	-	334,793
1986	697,967	155,718	163,249	3,218	1,020,152
1987	803,549	241,870	230,318	4,127	1,279,864
1988	749,981	268,600	298,700	17,400	1,334,681

Since 1980, the catches increased dramatically and reached from 1.02 million and 1.33 million t in 1986 and 1988.

Within the U.S.S.R. 200 miles zone, only the U.S.S.R. catches pollock. Catches from 1980 to 1987 were 930,000, 890,000 t, 1.02 million t, 970,000 t, 790,000 t, 710,000 t, 940,000 t and 1.11 million t respectively (Proceedings of the International Scientific Symposium on the Bering Sea Fisheries (1989)). In addition, catches during 1986 and 1987 included pollock which were caught in international waters.

Therefore, the catch for the entire Bering Sea was 3.2 million t in 1986 and 3.64 million t in 1987.

3. Stock abundance

Table 2 shows the yearly changed of CPUE for the Japanese trawlers which conducted fishing for pollock as a target species on the continental shelf and continental slope of the eastern Bering Sea. CPUE decreased from 1973, and showed no marked fluctuations from 1975 to 1981. However, CPUE increased dramatically since 1982 and CPUE in 1986 was about two times that in 1975 to 1981, and was the highest value in the history of the fishery. However, because this CPUE value was based on the fisheries which were conducted under various regulations, it was not considered that this CPUE value directly reflected abundance of the stocks.

The following table shows CPUE (catch/towing time) for the Japanese midwater trawlers which conducted fishing for pollock as a target species in the international waters of the Aleutian Basin (Sasaki and Yoshimura 1987).

Year	North Pacific Trawl	Landbased Dragnet	Total
1980	0.4 t/hour	0.3 t/hour	0.4 t/hour
1981	-	0.3	0.3
1982	-	0.5	0.5
1983	2.1	0.5	1.0
1984	3.0	5.0	4.0
1985	5.4	4.3	4.8
1986	12.3	6.3	8.6
1987	11.7	5.6	8.4
1988	9.2	4.6	6.8

CPUE values increased, as the catches increased dramatically, and CPUE in 1987 was almost the same value as that in 1986. However, CPUE decreased slightly in 1988 from the previous year. In 1986 and in 1987 when the intensive fishery was initiated in the international waters, the CPUE values of the North Pacific Trawlers exceeded the CPUE values of their bottom trawl which conducted fishing on the continental shelf and continental slope in the eastern Bering Sea, and it was estimated that density of pollock in the international waters was fairly high.

4. Biomass

From 1976 to 1984, the multi-vessel trawl surveys for pollock were conducted twice a year, May to June (spring) and August to September (autumn) on the continental shelf of the eastern Bering Sea by the Japanese catcher boats attached to the surimi motherships. The biomass of pollock estimate from the fall multi-vessel trawl surveys (Table 3) ranged from 7.8 million t to 13.1 million t from 1976 to 1983 (Yamaguchi and Okada 1984). However, the biomass in 1984 was estimated to be 6.6 million t, the lowest on record (Teshima and Okada 1985). Those surveys were almost never conducted in depths of 80 m and shallower, and covered only a part of the school of fishes distributed in the midwater, so it may not be said that the estimated biomass obtained was for the whole eastern Bering Sea (Sasaki 1987).

The Japan-U.S. cooperative groundfish stock survey was conducted on the continental shelf and the upper continental slope in 1979, 1982 and 1985. The biomass of pollock estimated from these surveys is shown in Table 3 (Bakkala et al. 1985 a, b. Walters et al. 1988). In addition to this, Table 3 also shows the estimated biomass by the U.S. on-bottom trawl surveys conducted on the continental shelf (Bakkala et al. 1986, Wespestad and Traynor 1988). The biomass of pollock by three Japan-U.S. cooperative surveys ranged from 8.94 million t to 10.66 million t. It indicated that the volume of pollock distributed in the midwater was greater than that of pollock distributed near the bottom. In 1988, the Japan-U.S. cooperative groundfish stock survey also was conducted, and the estimated biomass of pollock distributed near the bottom on the continental shelf and continental slope in the eastern Bering Sea was 7.51 million t (Bakkala, personal communication). In addition, the temporary estimated biomass of pollock in the midwater was 4.7 million t (Traynor, personal communication). In the Bering Sea side of the Aleutian Islands from 165 degrees to 170 degrees W which included the eastern Bering Sea for the purpose of management of stocks, the Japan-U.S. cooperative groundfish stock trawl surveys were conducted in 1980, 1983 and 1986 (Bakkala et al. 1986, Long et al. in press, Ronholt et al. 1986, Wakabayashi et al. 1988). From them, the biomass of pollock was estimated to be 57,000 t in 1980, 283,000 t in 1983, and 102,000 t in 1986. As pollock distributed in the midwater were not included in these estimates, the values are underestimated. The proportion of pollock obtained by the on-bottom trawl surveys of three Japan-U.S. cooperative surveys in the eastern Bering Sea averages 43%. When the average biomass of three surveys in the concerned area was divided by this value, it was about 340,000 t. This value was 3.5% of the average biomass obtained by three cooperative surveys in the eastern Bering Sea.

In the Aleutian Islands region, the biomass of pollock by the Japan-U.S. cooperative trawl survey was 315,000 t in 1980, 544,000 t in 1983, and 517,000 t in 1986. In the same way as the southern area of the eastern Bering Sea when the average biomass in three surveys is divided by 0.43, the biomass of pollock 1.07 million t.

Since 1983, Japan has conducted an hydro-acoustic survey in the Aleutian Basin, and estimated the biomass of pollock. In the winter of 1983, the estimated value of 1.14 million to was obtained in only the southern Aleutian Basin (260,000 km^2) (Okada 1986). In the summer of 1985, in the offshore area of the Pribilof Islands (140,000 km^2), the biomass of pollock was estimated to be 5.24 million t (Onoda et al. 1986). In the summer of 1987, in the areas of 78% of the international waters (170,000 km^2) the biomass of pollock was estimated to be 9.1 million t (Fisheries Agency of Japan 1988). The area which these surveys covered were different and did not cover the entire area of the Aleutian Basin. When the average density obtained by three surveys is applied to the entire area, the biomass of pollock was 38.0 million t, as the area of the Basin at depths of 1,000 m and deeper was 1.19 million km^2 (Gershanovish 1963) at the average density of 32 t/km^2. The reliability of the estimated biomasses obtained by the hydro-acoustic survey in the summer of 1987 was discussed at an INPFC working group, and was considered that the results could not be used as they were because of several issues involved, such as that these results were still on the threshold level in the process of analysis. In the summer of 1988 and the winter of 1989, the Japan-U.S. cooperative surveys were conducted using the hydro-acoustic survey system developed by the National Research Institute of Fisheries Engineering in the

Aleutian Basin, except in U.S.S.R. waters. The provisional values on stock size obtained from the survey in the summer of 1988 was 620,000 t (National Research Institute of Fisheries Engineering, personal communication), and in the summer of 1989, the Japan-U.S. cooperative survey was conducted using the system in the Aleutian Basin and the continental shelf of the eastern Bering Sea, excluding the U.S.S.R. waters.

Although the biomass of pollock spawners was estimated from the egg/larvae surveys of pollock which had been conducted by the U.S.S.R. from 1984 to 1987, the average value was 8.5 million t in the U.S. waters and 2.1 million t in the U.S.S.R. waters (Bulatov 1989). The U.S.S.R. conducted the stock surveys with midwater trawl nets in 1986 and 1987, and the biomass of pollock was estimated to be 5.53 million t in 1986 and 6.97 million t in 1987 (Sobolebskiy et al. 1989).

5. Body length and age composition

Fig. 1 shows the length composition of pollock caught by the Japanese trawlers on the continental shelf and continental slope in the eastern Bering Sea. Fig. 2 shows the age composition of pollock caught by the concerned countries in the same area. As the Japanese catches accounted for 57 to 67% of the total at that time, it was considered that the length composition reflected almost all the age compositions. Scales were used for age determination. In 1976 to 1981, the fish ages 2 to 4 (mainly age 3) which ranged in size from 26 cm to 40 cm in length were dominant. Since 1982, the ages 3 to 5 fish (mainly age 4) which ranged from 34 cm to 46 cm in length were dominant. The size of pollock as a target for fishing became larger.

Figs. 3 and 4 show the length composition and age composition of pollock stocks estimated by the multi-vessel trawl surveys which were conducted by the Japanese catcher boats attached to the motherships on the continental shelf in the eastern Bering Sea, respectively. In 1976 and 1977, among the fish 2 to 3 years old which ranged from 24 cm to 38 cm in length were dominant, in 1978 age 3 fish, which ranged from 30 cm to 40 cm in length, and in 1979-80, ages 1 to 3 fish which ranged from 16 cm to 36 cm were dominant. Age 3 fish which ranged from 28 cm to 38 cm in length in 1981, and for ages 3 to 5 fish which ranged from 30 cm to 44 cm in length from 1982 to 1984 were dominant.

Wespestad and Traynor (1988) estimated the age composition of pollock caught on the continental shelf and upper continental slope in the eastern Bering Sea using the otoliths (Fig.5). Fish 2 to 4 years old with age 3 fish as the central figure were dominant from 1976 to 1981, age 4 fish in 1982 and ages 4 to 7 fish dominant since 1983. Although the age composition was almost the same as that which was estimated by the Japanese scientists, the proportion of older fish was higher than that estimated by Japan. This is considered to be caused by the difference in the age characteristics used for age determination. That is to say, otoliths may be better for determining the age of older fish than scales.

In the length of pollock stock estimated by the Japan-U.S. cooperative ground fish survey conducted in the Aleutian Islands region in 1980, modes were observed at 33 cm, 40 cm and 49 cm in length, and there were many individuals ranging from 31 cm to 51 cm in length. In the age composition, age 3 fish were dominant (Ronholt et al. 1986). In the length composition of pollock estimated by the Japan-U.S. cooperative survey in 1983, modes were observed at 46-47 cm, and there were many individuals ranging from 43 cm to 51 cm in length (Wakabayashi et al. 1988). In the length composition of pollock estimated by the Japan-U.S. cooperative survey in 1986, the modes were observed at 30 cm, 38 cm, and 50 cm in length (Long et al. in press).

From the survey which was conducted in the Aleutian Basin in the summers from 1977 to 1979, the estimated length composition of pollock ranged mainly from 42 cm to 52 cm, and the modes were observed at 46 cm to 48 cm, and differences by survey year were quite small (Okada 1986). In the survey in the summer of 1987, modes were observed at 46 cm to 48 cm, and the body length ranged mainly from 42 cm to 52 cm (Fisheries Agency of Japan 1988). In the Japan-U.S. cooperative survey conducted in the summer of 1988, the modes were observed at 47 cm to 48 cm in length for male fish and at 49 cm to 51 cm in length for female fish, and the body length ranged mainly from 43 cm to 56 cm. As compared with the results of surveys obtained in the past, the mode was about 2 cm larger (Yoshimura 1989). In addition, in the surveys conducted in the winter of 1983, modes were observed at 44 cm to 46 cm, and the body length ranged mainly from 40 cm to 50 cm, and it was somewhat smaller than that of pollock obtained in the summer (Yamaguchi 1984). In the length composition of pollock caught by the Japanese landbased dragnet trawlers in the winter of 1987, modes were observed at 45 cm to 47 cm in length, the body length ranged mainly from 43 cm to 51 cm, and mode was about 1 cm larger that of pollock caught in the winter of 1983 (Sasaki and Yoshimura 1987). In the Japan-U.S. cooperative survey which was conducted in the winter from 1988 to 1989, a mode was observed at 48 cm for male, 50 cm for female, and the body length mainly ranged from 43 cm to 55 cm, the mode was about 3 cm larger that obtained in the winter of 1987 and was almost the same as that obtained in the summer of 1988 (Teshima, personal communication). However, the difference of body length by these results were small, and it is considered that size of pollock in the Aleutian Basin scarcely changed by season and age. In the age composition of pollock, according to the results of age determination which was conducted by the Japanese scientists in the surveys conducted in the summer of 1979, ages 5 to 7 fish were dominant (Okada and Yamaguchi 1985). In the results obtained by the surveys conducted in the winter of 1983, ages 5 to 7 fish were dominant, and the individuals of 3 years old and younger did not appear (Yamaguchi 1984). In the age composition obtained from the age determination which was conducted by the U.S. scientists in the surveys in the summer of 1979, the results differed from the results by Japan, and ages 9 and 10 fish were dominant (Traynor and Nelson 1985). According to the results on age determination by the U.S. for the catches in the Aleutian Basin, ages 9 to 10 fish in 1983, ages 6 to 8 fish in 1984, ages 7 to 10 fish in 1985, ages 7 to 9 fish in 1986, ages 8 to 9 fish in 1987, and age 10 fish in 1988 were dominant, respectively. Since 1984, the 1978 year-class was the most abundant in the catches (Dawson 1989).

6. Characteristics of the stocks

(1) Growth and life span

For the studies on growth of pollock on the continental shelf and upper continental slope in the eastern Bering Sea, there are studies by Yamaguchi and Takahashi (1972), and Smith (1981) etc. The reports on the U.S.groundfish surveys in 1975, 1976 and 1986 and the reports of the Japan-U.S. cooperative

groundfish stock surveys in 1979, 1981, 1982 and 1985 also showed growth curves (Bakkala et al. 1985 a, b, Halliday and Sassano in press, Kaimmer et al. 1976, Sample et al. 1985, Smith and Bakkala 1982, Walters et al. 1988). The body length by age was calculated by these growth curves by sex, and the mean value was obtained. When this mean value was applied to the growth curve of von Bertalanfly using a program developed by Motonaga and Ishioka (1988) (Application of growth curve of von Bertalanfly (finite difference drawing method), collective volume of program on stock analysis using personal computer, Edition by the Mathematical Ecology and Statistics Division, Tokai Regional Fisheries Research Laboratory), the growth curves were as follows:

Male: $Lt = 70.4\ (1 - e^{-0.189\ (t + 0.211)})$
Female: $Lt = 77.1\ (1 - e^{-0.166\ (t + 0.295)})$

In the Aleutian Islands region, the following growth curves were obtained as the results of the Japan-U.S. cooperative groundfish stock survey in 1980 (Ronholt et al. 1986).

Male: $Lt = 53.17\ (1 - e^{-0.3155\ t})$
Female: $Lt = 56.32\ (1 - e^{-0.3234\ t})$

In the Aleutian Basin, the growth curves were obtained based on age determination by Japan and the U.S. during the surveys conducted in the summer of 1979 (Okada and Yamaguchi 1985, Traynor and Nelson 1985). As both the growth curves were not applied to the growth curve of von Bertalanfly, they were applied here using the program of Motonaga and Ishioka (1988) in the same manner as that conducted for pollock on the continental shelf. As the adaptation which applied to the U.S. data was not so good, it was shown by the equation obtained from the Japanese data.

Male: $Lt = 52.3\ (1 - e^{-0.330\ (t + 0.110)})$
Female: $Lt = 54.8\ (1 - e^{-0.302\ (t + 0.131)})$

The growth of pollock obtained from these equations was similar to the growth of pollock in the Aleutian Islands region.

Conversion to body weight was calculated using the relationship between length and weight equation by Smith (1981).

$W = 0.0075\ L^{2.977}$

Body length and body weight by age and by stock of pollock obtained by the above equation are as follows (unit: body length cm, body weight g):

	EASTERN CONTINENTAL SHELF STOCKS				BASIN STOCKS			
	MALE		FEMALE		MALE		FEMALE	
AGE	length	weight	length	weight	length	weight	length	weight
3	32.0	227	32.5	237	33.5	260	33.5	260
4	38.6	398	39.3	418	38.8	402	39.0	406
5	44.1	590	45.1	629	42.6	531	43.2	542
6	48.6	789	50.0	855	45.3	638	46.2	657
7	52.4	984	54.1	1,084	47.2	724	48.4	752
8	55.5	1,168	57.6	1,308	48.7	790	50.1	826
9	58.0	1,336	60.6	1,519	49.7	840	51.3	883
10	60.2	1,486	63.1	1,716	50.4	877	52.2	927
11	61.9	1,619	65.3	1,895	50.9	905	52.9	959
12	63.4	1,735	67.1	2,056	51.3	925	53.4	984
13	64.4	1,835	68.6	2,199	51.6	939	53.8	1,002
14	65.6	1,921	69.9	2,326	51.8	950	54.0	1,015
15	66.4	1,994	71.0	2,436	51.9	958	54.3	1,025
16	67.1	2,055	72.0	2,533	52.0	963	54.4	1,032
17	67.6	2,107	72.8	2,617	52.1	967	54.5	1,038
18	-	-	-	-	52.1	970	54.6	1,041

These values were considered to be the body length and body weight of pollock of eastern continental shelf stocks at August 1 which was almost the mean value of middle day of the periods when the seven surveys were conducted. It was considered to be the body length and body weight of pollock at July 1 for the Basin stocks.

From the results of age determination using the otoliths obtained by the U.S. surveys and Japan-U.S. cooperative surveys which were conducted on the continental shelf and continental slope in the eastern Bering Sea, the oldest fish was 17 years old, and that was assumed to be the life span of pollock. It was 18 years old in the Aleutian Basin.

For age at maturity, I used the relationship between body length and maturity rate of pollock on the continental shelf and continental slope in the eastern Bering Sea (Smith 1981), and for female pollock about 30% matured at age 3, about 70% matured at age 4, about 90% matured at age 5 and individuals at age 6 were 100% mature. For simplicity, it is assumed that age 3 fish are all immature and individuals at age 4 are 100% mature. It was assumed that individuals at age 5 are 100% mature for the Basin stocks.

The sex ratio for males and females is assumed to be 1:1, and the mean body weight of male and female pollock is used for body weight.

(2) Natural mortality coefficient

The natural mortality coefficient (M) of pollock on the continental shelf and upper continental slope in the eastern Bering Sea is described in detail by Sasaki (1985). As a result, it is considered that 0.4 or 0.5 is a reasonable value. Also, Wespestad and Traynor (1987), assuming a natural

mortality coefficient for pollock stocks of 0.3, made a stock assessment with various analytical methods.

Mito (1988) estimated the value of M using the populaion number by age obtained by the Japan-U.S. cooperative groundfish stock surveys, and obtained the value of 0.45 for pollock of age 4 and older fish on the continental shelf and upper continental slope in the eastern Bering Sea. However, it is assumed that fish ages 4 to 5 are from both the eastern continental shelf stocks and the Basin stocks. Therefore, when I estimated the total mortality coefficient Z of the eastern continental shelf pollock stocks using the estimated population number of ages 6 to 10 fish, I obtained the mean value of 0.45. This was obtained from fish of 1972-1976 year-classes.

In order to obtain the value of M from the value of Z, I estimated the fishing mortality coefficient (F). First, data from the Japanese fall multi-vessel trawl surveys were used and this case was termed as Case I. The average number of pollock of ages 6 to 8 of 1972-1976 year-classes were 734 million fish, and when I converted this values to the value at January 1, it was 990 million fish. The average numbers of pollock caught of ages 6 to 8 fish in the same year-class according to age determination by Japan were 56 million fish. Therefore, the rate of exploitation was 0.057. The value of F was obtained by the following equation:

$$F = 0.057 \cdot \frac{0.45}{(1 - e^{-0.45})} = 0.07$$

Therefore, the value of M was M = 0.45 - 0.07 = 0.38. This value of M is applicable to age 4 and older fish.

Case II was based on the results of the Japan-U.S. cooperative surveys. After calculation by applying Z 0.45 to estimated stock numbers, the average number of fish of 6 to 9 years old of 1972-1976 year-classes was estimated at 1,244 million fish. And this value, when converted into the value as of January 1, was 1,617 million fish. The U.S. age assessment results with some modifications were used as the number of catch. The average catch of fish aged 6 to 9 in the 1972-1976 year-classes was 206 million fish. Therefore, the rate of exploitation was 0.127 and the value of F was approximately 0.16, with the value of M standing at 0.29.

The value of M for age 3 fish is considered to be considerably higher than that for age 4 and older fish because predation mortality by cannibalism is high. In this paper, 0.88 (Case I) and 0.79 (Case II) were used by adding mortality coefficient of 0.5 estimated by Mito (1989).

The value of M for the Basin stock is assumed to be the same as that for the eastern continental shelf stock. But the values of M for age 3 and older fish are fixed at 0.38 (Case I) and 0.29 (Case II), because age 3 fish of the Basin stock is not eaten by cannibalism.

(3) Age at recruitment and amount of recruitment

With respect to the age at which pollock recruit to the population on the continental shelf and upper continental slope in the eastern Bering Sea, it was described as 3 years old (Sasaki 1987, Wespestad and Traynor 1987, Yamaguchi and Okada 1984). In this report, the age at recruitment by year class was determined by comparing with the number of ages of 3 and 4 fish which were caught in each year-class. That is to say, I set age 4 fish as the age at recruitment up to the 1969 year-class, and age 3 fish as the age at recruitment from the 1970 year class to the 1977 year-class, and age 4 fish as the age at recruitment from the 1978 year class to the 1984 year-class. And then, for the 1985 year-class and after, I set age 3 or 4 fish as the age at recruitment, and conducted stock analyses both ways. For the Basin stocks, I assumed 50% recruited at age 5 and 100% recruited at age 6. However, it is assumed that pollock that remain on the continental shelf are also caught at age 3 to 5.

For recruitment of pollock, Sasaki (1985) estimated the population numbers of age 3 fish on the basis of numbers of individuals of age 4 fish obtained from the Japanese fall multi-vessel trawl surveys by the catcher boats attached to the trawl motherships for the case of natural mortality coefficient of 0.4, 0.5 and 0.6. In the case of the M value of 0.4, the population numbers of age 3 fish ranged from 7 billion to 20 billion fish, and at the time of the M value of 0.6, the population numbers of age 3 fish ranged from 8.4 billion to 24.1 billion fish. Wespestad and Traynor (1987) estimated that the population number of age 3 fish between the 1978 year-class and 1982 year-class ranged from 1.8 billion to 15.1 billion fish.

In this report, the estimation of recruitment of the eastern continental shelf pollock stocks was conducted from the population number by age obtained by the Japan-U.S. cooperative groundfish stock surveys. The year-classes used were from the 8 year-classes from 1972 to 1979. On the assumption that the Z value is 0.45, when I estimate the numbers of individuals of age 6 fish, the results are as follows (unit: million fish):

YEAR-CLASS	AGE 6	7	8	9	10
1972	514 ←	328 ←	209 ←	133 ←	85
		225			
1973	498 ←	317 ←	202 ←	129	
	506				
1974	684 ←	436 ←	278		
1975	411 ←	262 ←	167 ←	107 ←	68
	417 ←	266			
1976	390 ←	248 ←	158 ←	101	
	578				
1977	999 ←	637 ←	406		
1978	3,792 ←	2,418			
1979	3,261				

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The values enclosed with the rectangles were the values obtained from the surveys. In the case when there were two estimated values in the same year-class, I used the larger value, the mean value from the 1972 year-class to the 1979 year-class was 1.34 billion fish. When I convert this value to the value at January 1, it is 1.75 billion fish. From this, the numbers of individuals of ages 5 and 4 fish were 2.74 billion fish and 4.30 billion fish, respectively.

The amount of recruitment of the Basin stock was calculated in the following. As Case I, the numbers of individuals by age estimated by the Japanese fall multi-vessel trawl surveys were used. The number of fish by age according to year-class are as follows: (unit: million fish)

YEAR-CLASS	AGE 3	4	5	6	7	8
1970				580	350	85
1971			1,082	650	212	222
1972		6,207	1,932	655	268	124
1973	10,547	4,677	1,461	331	331	70
1974	14,036	4,075	892	829	135	26
1975	4,301	3,790	2,314	286	64	41
1976	10,905	5,386	665	251	193	73
1977	22,108	6,626	2,027	521	429	
1978	21,739	11,681	6,008	1,505		
1979	5,993	11,203	2,582			
1980	8,869	5,339				

The average number of age 4 fish in the 1972-1979 year-classes was 6.71 billion fish. The value of Z obtained from the number of individuals of 4 age fish as of September 1 and that of individuals of age 6 as of January 1 was 1.01. From the value of Z, the number of age 4 fish as of January 1 was calculated as 13.14 billion. 8.84 billion fish (13.14 billion minus 4.30 billion fish) is considered to be the Basin stock on the continental shelf of the eastern Bering Sea.

As Case II, the number of fish by age estimated by the Japan-U.S. cooperative surveys was used. The year-classes in which the number of individuals of age 4 or 5 fish and that of individuals of age 6 fish can be compared are as follows (unit: million fish):

YEAR-CLASS	4 YEARS OLD AUG. 1	5 YEARS OLD AUG. 1	6 YEARS OLD JAN. 1
1974		1,313	888
1975	1,598		541
1977		3,591	1,296
1978	11,967		4,931

The average of the values of Z for four year-classes by weighting periods is 0.92. The number of age 4 fish as of January 1, obtained from this value of Z and the number of age 6 fish, was 11.05 billion fish. Therefore, the number of fish in the Basin stock is 6.75 billion fish.

Age 4 fish of the Basin stock are distributed on the continental shelf and upper continental slope in the western Bering Sea and Aleutian Islands region in addition to this. Even in the western Bering Sea, the Basin pollock stock is assumed to exist at the same rate with that in the eastern Bering Sea, and all pollock stocks in the Aleutian Islands region are assumed to the Basin stock. Assuming that the biomasses of spawners in each region are 8 for the eastern, 2 for the western, and 1 for the Aleutian Islands, the numbers of individuals of age 4 fish of each stock are as follows (unit: 100 million fish):

STOCK		EASTERN CONTINENTAL SHELF STOCK		BASIN STOCK		WESTERN CONTINENTAL SHELF STOCK		TOTAL	
AREA	CASE	I	II	I	II	I	II	I	II
Eastern continental shelf		43	43	88	68	0	0	131	110
Western continental shelf		0	0	22	17	11	11	32	28
Aleutian Islands region		0	0	16	14	0	0	16	14
Total		43	43	127	98	11	11	181	152

That is to say, age 4 fish of the Basin stocks is 12.7 billion fish and 9.8 billion fish.

Assuming that the Z value of age 3 fish of the eastern continental shelf stock is 0.95 and that of the Basin stock is 0.45, the numbers of individuals of age 3 fish at January 1 were 11.1 billion for the eastern continental shelf stock and 19.9 billion (Case I) and 15.4 billion (Case II) for the Basin stock. The numbers of recruits as age 4 fish of the eastern continental shelf stock are 4.6 billion fish (Case I) and 5.0 billion fish (Case II). Also the numbers of recruits as age 5 fish of the Basin stock are 4.7 billion fish (Case I) and 4.3 billion fish (Case II) and as age 6 fish 6.4 billion fish (Case I) and 6.5 billion fish (Case II).

7. Cohort analysis

Cohort analyses are conducted by the U.S. scientists for pollock on the continental shelf and upper continental slope in the eastern Bering Sea (Wespestad and Traynor 1988, Wespestad 1989). However, as it is considered that at least two stocks are included in ages 3 to 5 fish, it is necessary to analyze each stock separately. In this report, I conducted cohort analysis on that particular eastern continental shelf stock.

I used the data of Wespestad and Traynor (1988) and Wespestad (1989) as the numbers caught by year and by age. When I obtained the catch weight by multiplying the numbers caught by body weight by age, this catch was different from the value reported as the catch statistics. Therefore, the number of fish caught by year were corrected to be in accord with the reported catch. Furthermore, as the Basin pollock stock was included in ages 3 to 5 fish, it was omitted. That is to say, for ages 3 fish, I multiplied by 0.445 in Case I and 0.512 in Case II, and for age 4 fish by 0.327 in Case I and 0.389 in Case II, and for age 5 fish 0.389 in Case I and 0.560 in Case II (Table 4).

As the M value, 0.88 (Case I) and 0.79 (Case II) was used for age 3 fish, and 0.38 (Case I) and 0.29 (Case II) was used for age 4 and older fish. The calculations were conducted using two programs: Ishioka's program (1988) (Calculation of cohort analysis which used the sequential substitution method) and Shimamoto and Ishioka's program (1988) (Cohort calculation of a single year-class (back calculation method), Collective volume of programs on stock analysis using personal computer, Edition by the Mathematical Ecology and Statistics Division, Tokai Regional Fisheries Research Laboratory).

At first, the population number of the oldest age (age 10 fish) was obtained from the numbers of individuals of ages 4 to 12 fish (converted to the value of January 1) which was estimated by the Japan-U.S. cooperative groundfish stock surveys and Z = 0.45. By this, in the 1967 year-class to 1978 year-class, the population number of age 10 fish on January 1 were obtained, and in the 1979 year-class to 1981 year-class, the population numbers of ages 9 to 7 fish were obtained (Unit: million fish):

YEAR-CLASS	AGE 4	5	6	7	8	9	10	11	12
1967							138 ←		56
1968							214 ←	137	
1969							160		
1970						163	122 ←		50
1971					124		119 ←	76	
1972				293			110		
1973			658 →			168 →	→ 109		18
1974					361 →		→ 147	32	
1975				346 →			→ 90		
							88		
1976			752 →			131 →	→ 124		
1977					528 →		→ 215		
1978				3,144 →			→ 815		
1979			4,240 →				→ 701		
1980		3,007 →				→ 497 (Case I)			
		3,415 →				→ 564 (Case II)			
1981	669 →				→ 111 (Case I)				
	796 →				→ 132 (Case II)				

The F value and population numbers by age of the 1967 year-class to 1981 year-class were calculated by inputting these population numbers to Ishioka's program (1988). For the 1961-66 year-classes, F and the population numbers were calculated through the program of Shimamoto and Ishioka (1988), by using F value of age 8 fish of the previous year-class as F_T. For 1982-1983 year-classes, the average F value for age 5-6 fish in the 1967-1981 year-classes was used as F_T.

Table 4 shows F values and population numbers by age of each year-class for both Case I and Case II. The average number of individuals of age 3 fish in the 1964-1983 year-classes was 12.09 billion in Case I and 7.93 billion in Case II. Further, the amount of recruitment has been on an increasing trend in recent years, and the average population number in 1974-1983 year-classes was 14.04 billion fish in Case I and 9.05 billion fish in Case II.

8. Estimation of virgin biomass

For the numbers of recruit at age 3 from the eastern continental shelf stocks, the mean value of the 1972-1979 year-classes was 11.1 billion fish. However, as the 1978 year-class which was very dominant was included in these year-classes, it is assumed that these numbers of recruits were more than the average number of recruits. Also, in contrast with this, it was considered that the estimated value obtained by this survey was an underestimate. Therefore, the virgin biomass was estimated using, as the average number of pollock recruited, the population numbers of age 3 fish in 1964-1983 year-classes obtained from the cohort analysis. The value of M for age 3 fish was set at 0.88 (Case I) and 0.79 (Case II) and that for age 4 and older fish at 0.38 (Case I) and 0.29 (Case II). The virgin biomass on August 1 was calculated by converting the numbers of individuals on January 1 into the number of individuals on August 1 and by multiplying body weight by age. The virgin biomass of the eastern continental shelf stock in Case I was 12.08 million t for recruits at age 3 and 10.40 million t for recruits at age 4. The corresponding values for Case II were 12.28 million t and 11.12 million t, respectively.

For Basin stock, the numbers of individuals of age 3 fish as of January 1 are assumed at 1.792 times in Case I and 1.386 times in Case II as compared with the eastern continental shelf stock. Age at recruitment is 50% at the age of 5 and 100% at the age of 6. Virgin biomass can be obtained by converting the number of individuals into the value as of July 1 and multiplying by body weight by age. The figures obtained were 16.53 million t in Case I and 14.10 million t in Case II.

When the average population number for 1974-1983 year-classes is used as the recruitment amount, the virgin biomass for Case I comes out as 1.161 times and that for Case II is 1.141 times. It is considered to be difficult to estimate the virgin biomass, because of a large yearly fluctuation of the strength of year-class for pollock. That is to say, the average recruitment is unlikely to be obtained. The virgin biomass described here is an approximate standard.

9. Reproduction

It is important to clarify the relationship between the number of eggs and the number of recruits in order to forecast the fluctuation of biomass. I considered here the reproduction from the population numbers by year and by age of the eastern continental shelf stocks obtained by the cohort analysis.

As it is considered that the number of eggs are almost proportional to the biomass of spawners, the biomasses of ages 4 to 9 fish on August 1 are set as an index of the number of eggs. For the number of recruits, the biomass of age 3 fish was used (Fig. 6). And then, the program of Kato (1988) was applied to the reproduction curve of Ricker-type (Application of Ricker-type reproduction curve by Gauss-Newton method. Collective volume of programs on stock analysis using personal computer. Edition by the Mathematical Ecology and Statistics Division, Tokai Regional Fisheries Research Laboratory). Equations for the curve were as follows:

Case I: $R = 1.708\ E\ e^{-0.003457E}$
Case II: $R = 1.493\ E\ e^{-0.004436E}$

The curve did not fit well, because the points varied widely.

The curve does demonstrate that the more the spawners decrease, the more the number of recruit increase.

10. Estimation of MSY

It is considered that we can achieve MSY by adjusting the fishing intensity to maintain the biomass of spawners at the level of maximum recruits. However, as mentioned before, an obvious relationship was not recognized in the reproduction of pollock.

On the assumption that maximum recruits is obtained when the biomass of spawners reached more than half of the virgin biomass, I could set the value of F at that time at half of the virgin biomass for the optimum fishing mortality coefficient (F_{opt}). That is to say, when the value of F reached F_{opt}, the MSY would be achieved.

F_{opt} and MSY for the eastern continental shelf stock was as follows:

	CASE I		CASE II	
	F_{opt}	MSY	F_{opt}	MSY
At the time recruited at the age of 3 years old	0.157	1.14 million t	0.133	930,000 t
At the time recruited at the age of 4 years old	0.214	1.19 million t	0.170	990,000 t

The exploitation rates at these times vis-a-vis the biomass on August 1 were 0.169 for 3 year-old recruits and 0.228 for 4 year-old recruits for Case I and 0.140 for 3 year-old recruits and 0.178 for 4 year-old recruits for Case II.

Furthermore, in the case of the Basin stock, because half of the age 5 fish were not yet recruited, and they were presumed to be spawners, the value of F_{opt} was considerably high, with 0.387 in Case I and 0.289 in Case II, and

MSY was 2.90 million t in Case I and 1.88 million t in Case II, and exploitation rate for the biomass on July 1 was 0.395 for Case I and 0.293 for Case II. However, since ages 3 to 5 fish of the Basin stock were still caught on the continental shelf, the actual age of recruitment was 3 years old or 4 years old. The value of F_{opt} at these times was 0.139 when recruited at the age of 3 years old and 0.181 when recruited at 4 years old in Case I and 0.130 when recruited at 3 years old and 0.165 when recruited at 4 years old in Case II. MSY was 2.66 million t when recruited at the age of 3 years old and 2.75 million t when recruited at the age of 4 years old in Case I, and 1.65 million t when recruited at the age of 3 years old and 1.75 million t when recruited at the age of 4 years old in Case II. The exploitation rates vis-a-vis the biomass on July 1 were 0.151 for 3 year-old recruits and 0.198 for 4 year-old recruits for Case I and 0.132 for 3 year-old recruits and 0.168 for 4 year-old recruits for Case II.

In the same way as the virgin biomass, MSY is also an approximate standard.

11. Estimation of equilibrium yield

Assuming that the biomass is maintained when the fishing intensity is provided by the value of F_{opt}, I estimated the equilibrium yield (EY) of the eastern continental shelf stock and Basin stock in 1990.

For the eastern continental shelf stock, I used the population numbers of ages 3 to 10 fish of 1987 which was obtained from cohort analysis. The population numbers of age 11 and older fish were obtained from the population numbers of age 10 fish prior to the 1986 and the Z value of 0.45. The population numbers up to 1990 were estimated by extrapolation. The number of recruits of age 3 fish was obtained by the same method as the Wespestad and Traynor's method (1987). That is to say, at first, I obtained the relationship between the estimated numbers of age 1 fish obtained from the U.S. stock surveys and the numbers of age 3 fish obtained from cohort analysis, and estimated the number of recruits from the 1984 year-class to the 1987 year-class. The numbers of individuals from the 1978 year-class to 1983 year-class were as follows (Unit: billion fish):

YEAR-CLASS	AGE 1 FISH BY U.S. SURVEY	AGE 3 FISH ESTIMATED IN REPORT	
		CASE I	CASE II
1978	8.2	38.06	23.72
1979	-	23.96	14.13
1980	1.0	14.22	9.88
1981	0.8	4.65	3.47
1982	3.7	24.18	15.30
1983	0.3	4.94	3.16

This relationship was shown in Fig. 7. On the assumption that an exponential relation was formed here, the following equations were obtained:

Case I : $y = 9.57\ x^{0.6643}$
Case II : $y = 6.44\ x^{0.6376}$

Where, x is the population number of age 1 fish (1 billion fish) by the U.S. surveys and y is the number of recruits of age 3 fish (1 billion fish) estimated in this report. A coefficient of correlation was 0.925-0.933 and I can say that there was a positive correlation with the percentage of risks of 5%. The number of recruits from the 1984 year-class to 1987 year-class obtained from these equations were as follows (Unit: 1 billion fish):

YEAR-CLASS	AGE 1 FISH BY U.S. SURVEY	NO. OF RECRUITS AT THE AGE OF 3 YEARS OLD	
		CASE I	CASE II
1984	4.0	24.04	15.59
1985	2.2	16.16	10.65
1986	0.3	4.30	2.99
1987	1.0	9.57	6.44

The catch on the continental shelf and continental slope of the eastern Bering Sea in 1987 was 1.24 million t. Also, as the number of fish caught of age 3 years were fairly few, I regarded as pollock recruited at the age of 4 years old. The value of F which provided the catch of 1.24 million t was 0.087 for Case I and 0.111 for Case II. The biomass on August 1 was 9.18 million t for Case I and 8.14 million t for Case II. Of the catch of 1.24 million t, the eastern continental shelf stock was 0.84 million t for Case I (67% of the total) and 0.94 million t for Case II (76% of the total). The population number of eastern continental shelf stock on January 1, 1988 using the values of F and M, were obtained as follows (unit: million fish):

AGE	CASE I	CASE II
3	16,160	10,650
4	9,971	7,075
5	1,271	944
6	4,171	3,305
7	489	489
8	894	898
9	1,066	964
10	945	933
11	135	144
12	53	62
13	26	34
14	30	41
15	15	23
16	10	17
17	8	14

The catch in 1988 was 1.23 million t. In Case I, the value of F=0.052 corresponded to the catch when fish were recruited at the age of 3 years old

and the value of F=0.067 did so when fish were recruited at the age of 4 years old. In Case II, the value of F was 0.073 when recruited at the age of 3 years old and 0.091 when recruited at the age of 4 years old. The biomass of eastern continental shelf stock on August 1 was 12.63 million t when recruited at the age of 3 years old and 10.36 million t when recruited at the age of 4 years old in Case I, and 10.65 million t and 9.06 million t in Case II, respectively. Similarly, I obtained the population numbers on January 1, 1989, established the catch as 1.34 million t, and the corresponding value of F was 0.067 when recruited at the age of 3 years old and 0.071 when recruited at the age of 4 years old in Case I, and was 0.089 and 0.094 in Case II, respectively. The biomass of eastern continental shelf stock on August 1 was 11.19 million t, 10.57 million t, 9.82 million t, and 9.35 million t, respectively. And then, I could calculate the population numbers by age on January 1, 1990. The following table shows the number of individuals (million fish) and biomass (thousand t) by age on August 1 for both Case I and Case II. For Case I, an F_{opt} value of 0.157 was used for fish recruited at age 3 and 0.214 for fish recruited at age 4. The corresponding values for Case II were 0.133 and 0.170.

AGE	CASE I				CASE II			
	RECRUITED AT AGE 3 FISH		RECRUITED AT AGE 4 FISH		RECRUITED AT AGE 3 FISH		RECRUITED AT AGE 4 FISH	
	NO. OF INDIV.	BIOMASS	NO. OF INDIV.	BIOMASS	NO. OF INDIV.	BIOMASS	NO. OF INDIV.	BIOMASS
3	5,226	1,213	-	-	3,759	873	-	-
4	1,219	497	1,261	514	970	396	1,038	423
5	2,975	1,813	3,019	1,840	2,403	1,464	2,517	1,534
6	3,027	2,488	2,873	2,361	2,632	2,163	2,518	2,069
7	368	399	366	379	351	363	336	347
8	1,266	1,567	1,202	1,487	1,230	1,522	1,176	1,455
9	148	212	141	201	182	260	174	248
10	271	434	258	412	334	535	320	512
11	324	569	307	540	359	630	343	603
12	287	544	272	516	347	658	332	629
13	41	83	39	78	54	108	51	103
14	16	34	15	33	23	49	22	47
15	8	18	8	17	13	28	12	27
16	9	21	9	19	15	35	15	34
17	5	11	4	10	9	20	8	19

In Case I, the biomass was 9.90 million t and EY was 1.66 million t when recruited at age 3 fish and the biomass was 8.41 million t and EY was 1.92 million t when recruited at age 4 fish. In Case II, the biomass was 9.10 million t and EY was 1.27 million t when recruited at age 3 fish and the biomass was 8.05 million t and EY was 1.44 million t when recruited at age 4 fish.

For the Basin stock, EY estimated on the assumption that the number of recruits by year-class is proportioned to that of the eastern continental shelf stock. The number of recruits at the age of 3 was 1.792 times larger than that of the eastern continental shelf stock for Case I and 1.386 times larger for Case II. The population number by age on January 1, 1987 was calculated by multiplying the number of recruits of each year-class by the survival rate obtained from the value of Z included the fishing mortality on the continental shelf at ages 3 to 5 fish. Although a fair amount of pollock was caught in the international waters from 1983 to 1986, the fishing mortality was not included here for age 5 and older fish of Basin stock. The catch of pollock in the international waters in 1987 was 1.26 million t. Because the Basin stocks were caught on the continental shelf at ages 4 to 5 fish, the catches of whole stock were 1.67 million t to 1.80 million t. The corresponding value of F was 0.065 in Case I and 0.087 in Case II. Also, the total biomass of the Basin stock on July 1 (age 4 and older fish) was 25.32 million t in Case I and 18.03 million t in Case II. The population numbers by age on January 1, 1988 were obtained from these values of F and M. The catch of pollock in the international waters in 1988 was assumed to be 1.30 million t. Although few differences were observed in the value of F between recruitment at age 3 and age 4 on the continental shelf, this was a negligible amount. It was 0.074 in Case I and 0.097 in Case II. The biomasses (age 3 and older fish and age 4 and older fish) were 34.03 million t and 27.89 million t in Case I and 22.45 million t and 19.19 million t in Case II. The catch of pollock in the international waters in 1989 was also assumed to be 1.30 million t. The corresponding value of F was 0.076 to 0.077 in Case I and 0.102 to 0.103 in Case II, and the biomasses (age 3 and older fish and age 4 and older fish) were 28.73 million t and 27.30 million t in Case I and 19.50 million t and 18.76 million t in Case II. The population numbers by age of January 1, 1990 was obtained and then EY was obtained by applying F_{opt} of 0.139 for 3 year-old recruits and 0.181 for 4 year-old recruits in Case I and 0.130 for 3 year-old recruits and 0.165 for 4 year-old recruits in Case II to the population numbers by age of January 1, 1990. The numbers of individuals and biomasses of the Basin stock on July 1 were as follows (unit: million fish and 1,000 t):

AGE	CASE I				CASE II			
	RECRUITED AT AGE 3 FISH		RECRUITED AT AGE 4 FISH		RECRUITED AT AGE 3 FISH		RECRUITED AT AGE 4 FISH	
	NO. OF INDIV.	BIOMASS	NO. OF INDIV.	BIOMASS	NO. OF INDIV.	BIOMASS	NO. OF INDIV.	BIOMASS
3	13,111	3,411	-	-	7,224	1,880	-	-
4	3,768	1,530	3,916	1,591	2,296	933	2,464	1,001
5	9,234	5,001	9,451	5,119	5,693	3,083	5,985	3,242
6	9,394	6,176	9,039	5,943	6,200	4,076	5,966	3,922
7	1,180	887	1,145	861	812	611	790	594
8	3,869	3,195	3,785	3,126	2,843	2,348	2,791	2,305
9	482	425	471	416	452	400	444	392
10	1,042	966	1,019	945	1,000	927	982	910
11	1,226	1,176	1,199	1,151	1,092	1,048	1,072	1,028
12	1,268	1,247	1,240	1,220	1,262	1,241	1,239	1,218
13	251	251	246	264	280	280	275	275
14	84	86	83	84	100	101	98	99
15	43	44	42	43	57	59	56	57
16	46	47	45	46	67	69	66	68
17	30	31	29	30	49	50	48	50
18	18	19	18	18	31	32	31	32

In Case I, the biomass when recruited at the age of 3 years old was 24.49 million t and EY was 3.58 million t, and the biomass when recruited at the age of 4 years old was 20.84 million t and EY was 3.96 million t. In Case II, the biomass when recruited at the age of 3 years old was 17.14 million t and EY was 2.26 million t and the biomass when recruited at the age of 4 years old was 15.19 million t and EY was 2.54 million t.

12. Allowable catch

I considered the equilibrium yield on the eastern continental shelf stock and the Basin stock in 1990 in the previous section. In this section, I consider the propriety of equilibrium yield and propose the allowable catch by area.

In this report, I estimated EY on the assumption that there are three stocks of pollock in the Bering Sea. Sasaki (1988) compiled the information of studies on pollock stocks in the Bering Sea. According to this, on the continental shelf in the eastern Bering Sean, there are two hypotheses, a single stock hypothesis (Takahashi and Yamaguchi 1972) and a two stocks hypothesis which assumes two stocks exist: the northwestern stock and southeastern stock on a border of the Pribilof Islands (Maeda 1971, 1972), and in the two stocks hypothesis, it is estimated that the spawning grounds of the northwestern stock are on the continental slope and open sea areas (Maeda and Hirakawa 1977). Lynde et al. (1986) assumed two "units" existed which differ in the process of reproduction in the eastern Bering Sea and Aleutian Basin, and considered that eggs and larvae of stocks which use the Aleutian Basin as the major spawning ground are transported to the continental shelf in the eastern Bering Sea and stay in waters north of the Pribilof Islands until the ages of 3 to 4 years old, and move to the Basin as they grow older. Yamaguchi (1984) considered that most of immature young fish and well grown fish among older fish out of pollock which inhabited the Basin in the winter season return to the continental shelf during the summer season and most older fish still remain in the Basin. Hinckley (1987) considered that there are at least three independent spawning stocks: Aleutian Basin stock, northwestern continental slope stock and a stock inhabiting the southeastern continental shelf and slope area and the northwestern continental shelf. Sasaki and Yoshimura (1988) assume that pollock which inhabit the Basin during the winter are the stock which grew in different areas of the continental shelf, moved to the Basin, and mingled with one another. Based on the results of tagging (Yoshida 1979), Sasaki (1988) indicates that there are some relationships among the stock on the continental shelf in the Asian side, the stock of the Basin, and the stock in the eastern Bering Sea. According to the above information, Sasaki (1988) described that because none of the hypotheses were based on decisive evidence and were still a matter of conjecture, it is necessary to clarify collectively the structure of pollock population throughout the Bering Sea in order to determine the origin of pollock in the Basin.

Like this, because there is no obvious evidences on the separation of pollock stocks in the Bering Sea, Dawson (1989) set up several working hypotheses on the relationship between pollock in the Aleutian Basin and pollock in other areas. In the consideration of stock in this report, the separation was based on the unit of reproduction and based on the condition that there is almost no exchange of genes among the other stocks. Because there is no evidence that the individuals originating in each spawning ground return to the same spawning ground as spawner, it has not been confirmed that pollock in each area are distributed independently as a single stock from other stocks. However, obvious differences are observed in the spawning grounds, spawning season, and growth of pollock in the Aleutian Basin and pollock on the eastern continental shelf. Therefore, it is necessary at least to separate pollock in the Basin and pollock on the eastern continental shelf when assessment is being conducted.

In this report, on the assumption that there are three separate stocks, the eastern continental shelf stock, the western continental shelf stock, and the Basin stock, EY of the eastern continental shelf stock and the Basin stock was estimated from the population numbers, body weight by age, and the values of M and F_{opt}. Among these parameters, it is assumed that the population number has the widest fluctuation in the estimated value. The population number by year and by age were obtained from the number of recruits at age 3 fish by year-class and the value of Z. The number of recruits of the eastern continental shelf stock was estimated by cohort analysis. In this cohort analysis, F and the population number by year and by age was calculated using two values of M. In both Case I and Case II, the number of individuals at the oldest age (here 10 years old) was obtained using the estimated value obtained from the Japan-U.S. cooperative surveys. It is considered that the estimated value by the Japan-U.S. cooperative surveys is an underestimate (Mito 1988b). Therefore, the population numbers obtained through cohort analysis are considered to be underestimate. The number of individuals of the Basin stock was obtained by subtracting the number of individuals of age 4 fish of the eastern continental shelf stock (calculated from the number of individuals of ages 6 fish and the value of Z 0.45) from the number of individuals of age 4

fish which inhabit the eastern continental shelf. For the number of individuals of age 4 fish on the continental shelf in Case I, the estimated value by the Japanese fall multi-vessel trawl surveys was used, and as the number of individuals of age 6 fish, the estimated value by the Japan-U.S. cooperative surveys was used. For the number of individuals of age 4 fish, the estimated value by the Japanese multi-vessel trawl surveys is greater than that by the estimated value by the Japan-U.S. cooperative surveys, and the number of individuals of age 6 fish was vice versa. The area surveyed by the Japanese multi-vessel trawl surveys was smaller than that surveyed by the Japan-U.S. cooperative surveys, and pollock in the midwater were not caught. Therefore, it is considered that the estimated biomass obtained from the Japanese multi-vessel trawl surveys is considerably underestimated. In Case II, the values for the year-classes of 1974, 1975, 1977 and 1978, which had been obtained in the Japan-U.S. cooperative surveys, were used as the number of individuals of age 4 or 5 on the continental shelf. These values which enable comparisons with those of age 6 fish were available for only four year-classes, and were not sufficient to obtain the Z value which include emigration of the Basin stock. In this analysis, the Z value of 0.92 was calculated as a weighted average. If the unweighted average Z value of 1.194 is used, the number of Basin stock recruits is 2.18 times higher than the corresponding number using the weighted average.

The value of F estimated in the cohort analysis varied greatly by age, even in the same year. In this report, the value of F by age of pollock in the Bering Sea is assumed to be constant in the same year. It is considered that the dispersion of the value of F at the time of analysis includes the differences occurred when the numbers of fish caught by age were estimated. Thus, I set up here the populations, of which the values of F by age are the same by year.

At first, for the eastern continental shelf, the value of Case I was used as the numbers of individuals of age 3 fish by year-class. In the catch in the eastern Bering Sea, the Basin stock of ages 3 to 5 fish is included. It is assumed that this amount is proportioned to the amount of the same year-class of continental shelf stocks. That is to say, the proportion of Basin stock in age 3 fish was 1.248 times of the continental shelf stock and, with the corresponding figures for age 4 and 5 fish standing at 2.058 times and 1.029 times, respectively. Using these rates and adding the catch of the Basin stock, the corresponding catch to F was calculated, and was ascertained if it was in accord with the actual catch, and the value of F by year was determined. Furthermore, the value of F was set to be the third decimal place, and the value which provided the catch nearest to the actual catch was applied. I set up the age of 3 years old as age at recruitment in the year which the value of F of age 3 fish obtained by the cohort analysis was more than 0.035, and the age of 4 years old in the year which the value of F of age 3 fish obtained by the cohort analysis was less than 0.035. Table 5 shows the population numbers by year and by age obtained. Also, the value of F, the corresponding catch and biomass on August 1 are as follows:

YEAR	AGE OF RECRUITMENT	F	CATCH OF CONTINENTAL SHELF STOCK	CATCH INCLUDING BASIN STOCK	BIOMASS
	(YEARS OLD)		(10,000 T)	(10,000 T)	(10,000 T)
1964	4	0.033	11	17	326
1965	4	0.046	15	23	317
1966	4	0.057	18	26	297
1967	4	0.089	31	55	336
1968	4	0.085	36	70	404
1969	4	0.062	40	86	615
1970	4	0.091	67	126	698
1971	4	0.144	106	175	699
1972	3	0.130	108	184	781
1973	3	0.158	111	175	660
1974	3	0.181	107	159	552
1975	3	0.149	82	129	509
1976	3	0.140	72	126	477
1977	3	0.097	49	88	473
1978	3	0.113	53	94	443
1979	3	0.117	54	91	429
1980	3	0.101	54	97	495
1981	4	0.126	53	98	396
1982	4	0.046	40	96	828
1983	4	0.043	48	100	1,070
1984	4	0.057	67	109	1,125
1985	4	0.087	90	118	989
1986	4	0.063	72	119	1,099
1987	4	0.085	85	124	954
1988	4	0.066	73	122	1,062
1989	4	0.070	79	133	1,076
1990	4	0.214	195	262	853

For the year of 1990, the catch when F=0.214 which provides EY is shown. That is to say, this is EY in 1990, 1.95 million t for the eastern continental shelf stock and 2.62 million t as EY for pollock on the continental shelf and upper continental slope in the eastern Bering Sea was obtained. This was 30,000 t greater than EY in Case II obtained by the previous section. When the population number of age 3 fish in Case II is used as the recruitment amount, EY of the eastern continental shelf stock was 1.47 million t and that for the stock on the continental shelf and continental slope of the eastern Bering Sea was 1.80 million t, both larger by 30,000 t than EY obtained in the previous section.

Secondly, for the Basin stock, the population numbers by year and by age were obtained using the same method (Table 5). In this calculation the catch in the international waters in 1988 and 1989 was assumed to be 1.30 million t. The following are the values of F and the corresponding catch and biomass in Case I:

YEAR	F	CATCH IN INT'L WATERS	CATCH INCL.ON CONTINENTAL SHELF	BIOMASS IN BASIN	BIOMASS AT AGE 4 YRS AND OLDER
		(10,000 T)	(10,000 T)	(10,000 T)	(10,000 T)
1981	0.000	0	64	710	1,213
1982	0.000	0	79	771	2,477
1983	0.004	8	77	1,395	3,034
1984	0.008	19	74	2,052	3,045
1985	0.014	32	68	2,161	2,590
1986	0.054	101	167	1,860	2,902
1987	0.070	127	177	1,775	2,380
1988	0.079	130	200	1,637	2,677
1989	0.081	130	205	1,600	2,650
1990	0.181	299	387	1,617	2,032

In 1990, the catch at F=0.181, e.g. EY is 2.99 million t. EY including the catch on the continental shelf is 3.87 million t. It is 80,000 t to 100,000 t fewer than EY in Case I obtained in the previous section. When the population number of age 3 fish in Case II as the recruitment amount, EY in 1990 was 1.99 million t in the Aleutian Basin and 2.44 million t, when fish caught on the continental shelf was included. These are 100,000 t fewer than EY in Case II as obtained in the previous section.

Fig. 8 shows the yearly fluctuations of pollock biomass of age 3 and older fish on the continental shelf and upper continental slope in the eastern Bering Sea estimated here. In addition to this, Fig. 8 also shows the yearly fluctuations of biomass of ages 3 to 9 fish estimated by the cohort analysis of Wespestad (1989) and the biomass estimated by the U.S., Japan and the Japan-U.S. cooperative surveys. Peak of the biomasses was in 1969 and 1982, and they resulted from the 1965 year-class and 1978 year-class which were dominant year-classes. It can be said that the entire biomass has a tendency to increase.

When the eastern continental shelf stock was applied to the reproduction curve of Ricker again, the following equation was obtained:

Case I: $R = 0.789\ E\ e^{-0.001683E}$

Case II: $R = 0.591\ E\ e^{-0.001844E}$

Although dispersion of points vary widely, the maximum biomass of recruits is obtained when 5.94 million t (Case I) and 5.42 million t (Case II) of the biomass of spawners of age 4 and older fish, and it is predicted that age 3 fish of 1.72 million t for Case I and 1.18 million t for Case II are recruited. When it is converted into the population numbers of age 3 fish on January 1, 12.4 billion fish in Case I and 8.1 billion fish in Case II. These are 3% (Case I) and 2% (Case II) larger than the average recruitment amount for 1964-1983 year-classes obtained from the cohort analysis. The biomass of spawners are equivalent to 57% of the virgin biomass in Case I and 49% in Case II. According to this curve, the biomass of spawners for which recruitment amount over the average for 1964-1983 year-classes, as obtained from the cohort analysis, are within a range of 4.69-7.41 million t in Case I and 4.51 6.45 million t in Case II. Thus, a large amount of recruitment in a considerably wide range of the biomass of spawners can be expected, i.e. the stability of pollock stock is considered to be high.

As mentioned above, I have estimated the virgin biomass, MSY, and EY, etc. of the eastern continental shelf stock and Basin stock. In addition to this, although I also estimated the western continental shelf stock, I assumed that growth, life span, M, and age at recruitment of the western continental shelf stock is the same as those of the eastern continental shelf stock. And then, on the assumption that the number of recruits of the western stock is a quarter of that of the eastern stock and fluctuation of the year-classes remains the same, the estimated virgin biomass is 2.60 million t for Case I and 2.78 million t for Case II when recruited at the age of 4 years old. MSY is 300,000 t for Case I and 250,000 t for Case II at the time recruited at the age of 4 years old. EY in 1990 is 490,000 t for Case I and 370,000 t for Case II.

I can assume that the allowable catch by stock in 1990 is equal to EY when recruited at the age of 4 years old. The allowable catch by area in 1990 are as follows (unit: 10,000 t):

STOCK		EASTERN CONTINENTAL SHELF STOCK		ALEUTIAN BASIN STOCK		WESTERN CONTINENTAL SHELF STOCK		TOTAL	
AREA	CASE	I	II	I	II	I	II	I	II
Eastern continental shelf/ continental slope		195	147	70	36	0	0	265	183
Basin and Aleutian Islands region		0	0	299	199	0	0	299	199
Western continental shelf/ continental slope		0	0	18	9	49	37	67	46
Total		195	147	387	244	49	37	631	428

Total allowable catch in 1990 was set at 4.28-6.31 million t, a level considerably higher than of the actual catch of 3.64 million t in 1987.

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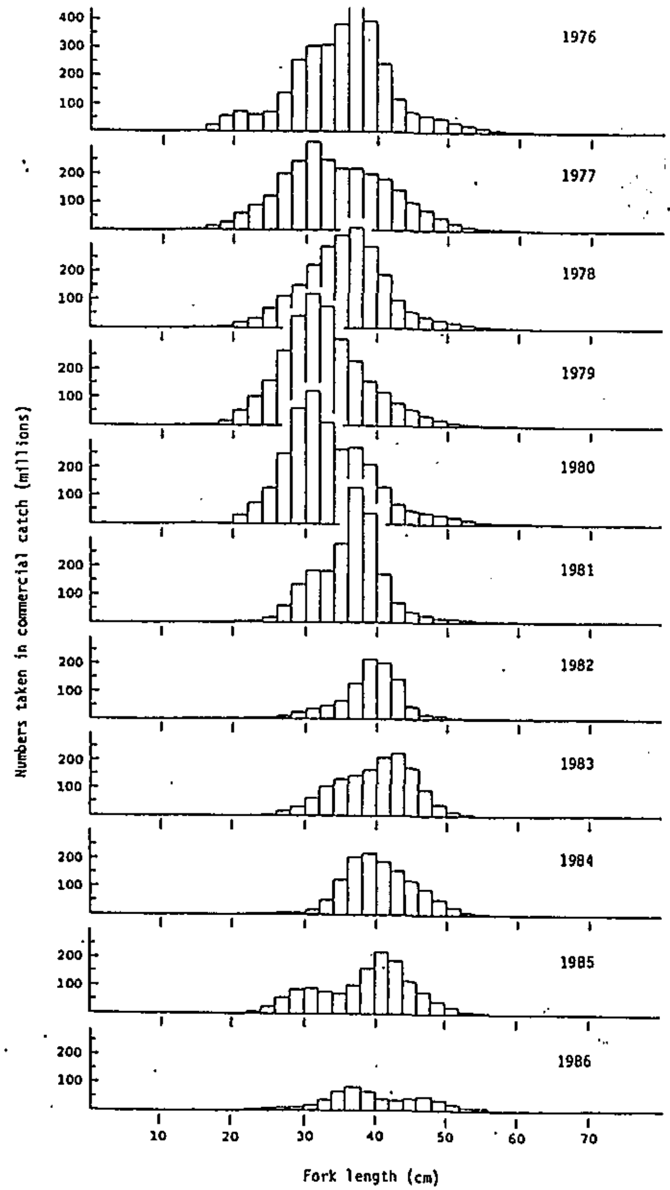

Fig.1. Size composition of pollock taken in Japanese commercial catch by surimi mothership and surimi factory trawl fisheries in the eastern Bering Sea continental shelf and slope. Data in 1982 are taken from surimi mothership fishery only (Size composition, 1976-1985, from Sasaki(1987)).

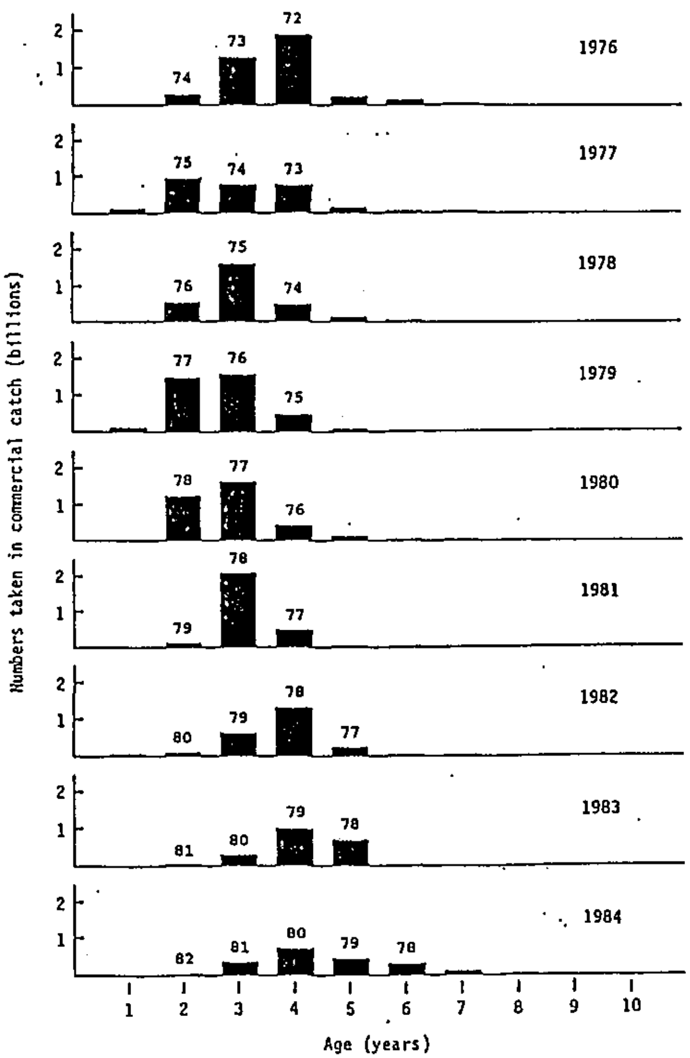

Fig.2. Age composition of pollock taken in commercial catches by all nations in the eastern Bering Sea continental shelf and slope for the years 1976-1984. Numbers above the bars indicate the year-classes

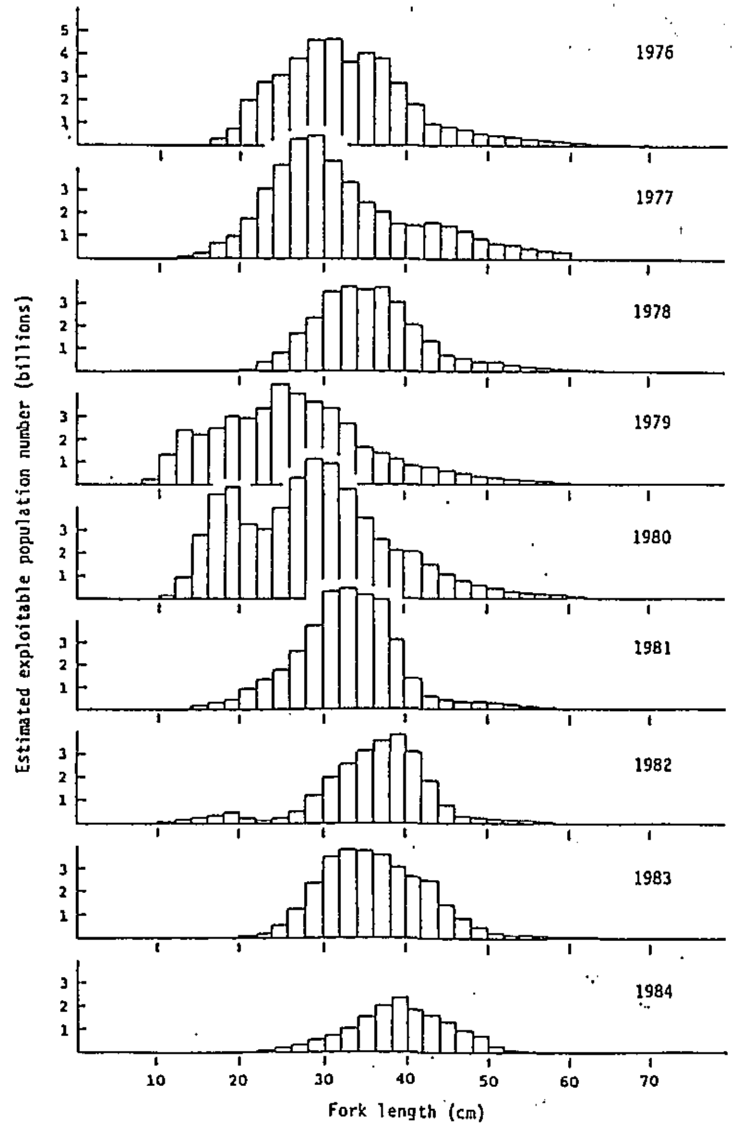

Fig.3. Size composition of exploitable population of pollock in the eastern Bering Sea continental shelf, obtained from Japanese multi-vessel trawl surveys in fall for the years 1976-1984. (Sasaki 1987).

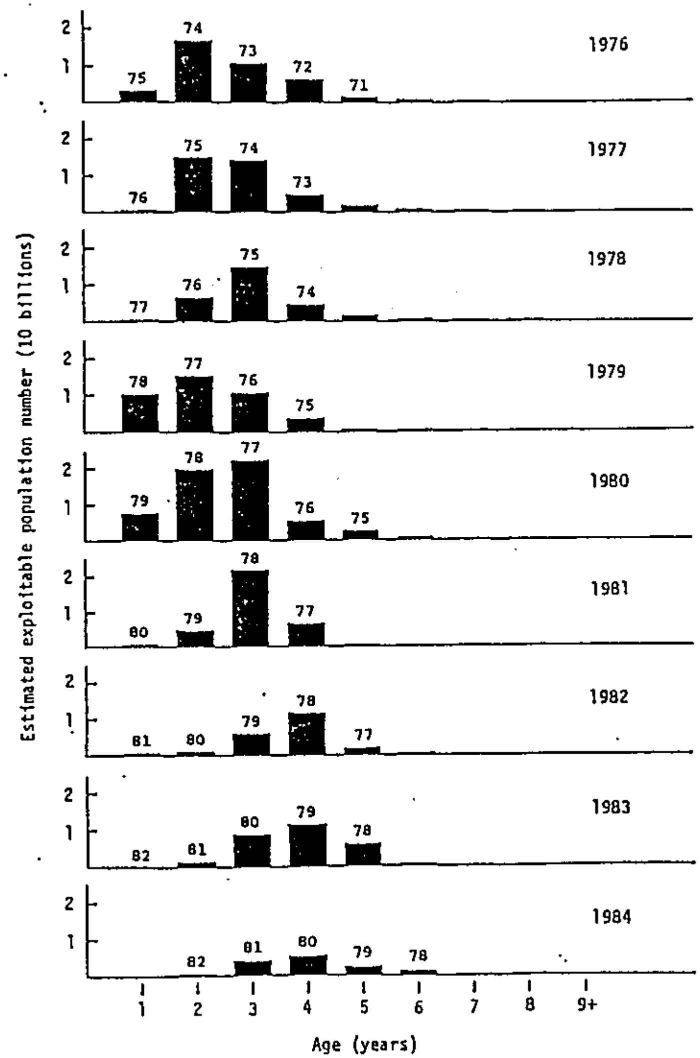

Fig.4. Estimated exploitable population number of pollock by age in the eastern Bering Sea continental shelf, obtained from Japanese multi-vessel trawl surveys in fall for the years 1976-1984. Scales were used for age determination (Sasaki 1987).

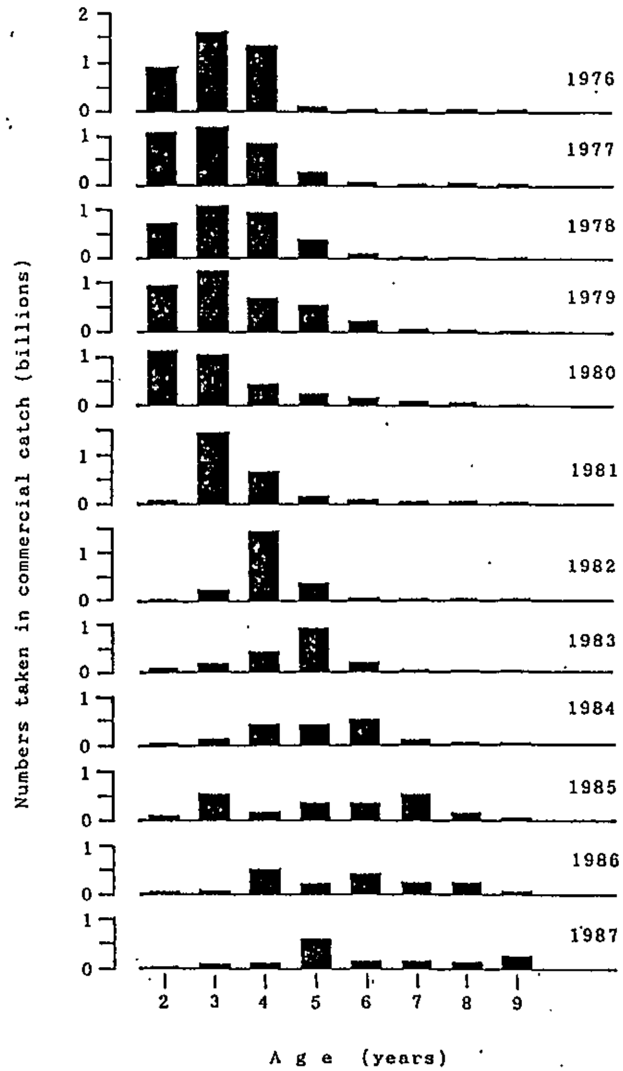

Fig.5. Age composition of pollock taken in commercial catches by all nations in the eastern Bering Sea continental shelf and slope for the years 1976-1987. Otoliths were used for age determination (Data from Wespestad and Traynor 1988).

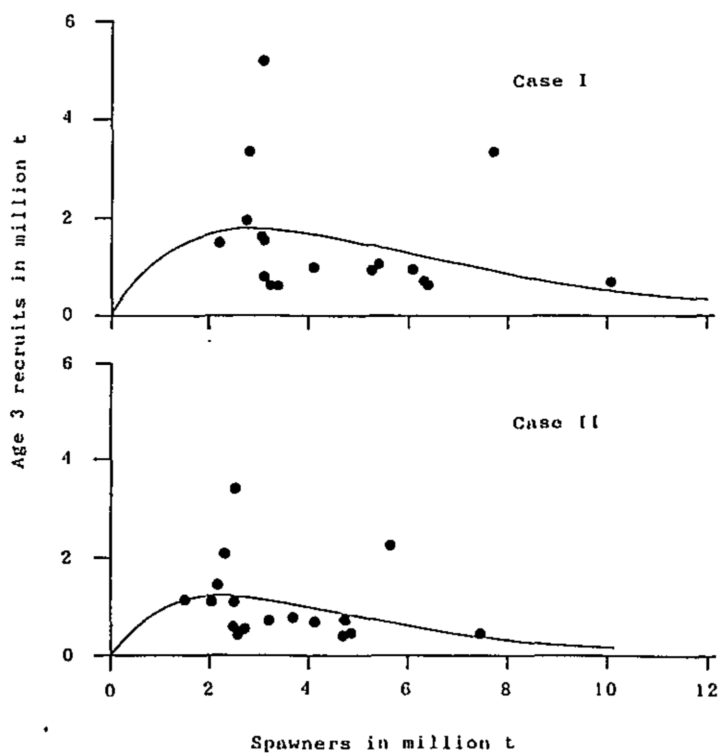

Fig.6. Spawners and age 3 recruits relationship in biomass of the eastern Bering Sea continental shelf pollock stock.

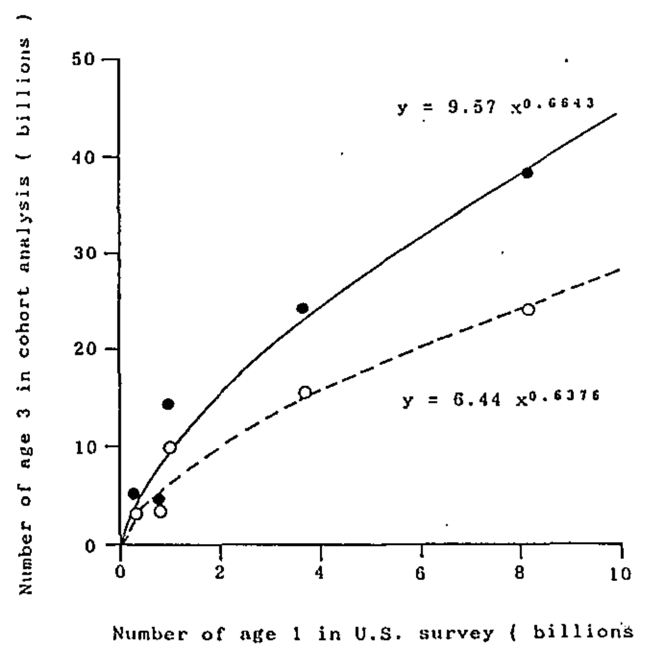

Fig.7. Relationship of U.S. survey age 1 and cohort analysis age 3 estimates of the eastern Bering Sea continental shelf pollock stock. —●—: Case I, --○--: Case II.

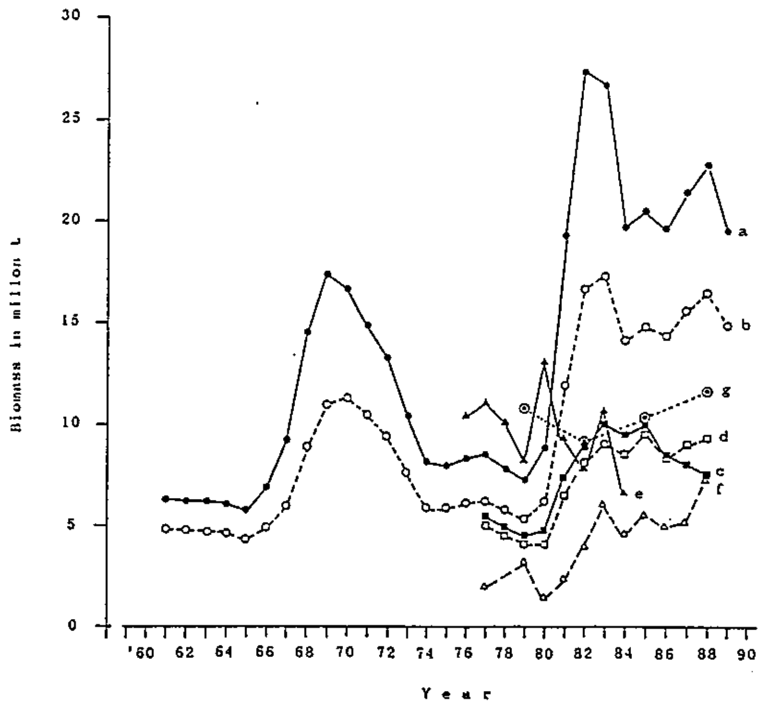

Fig.8. Biomass estimates of pollock in the eastern Bering Sea continental shelf and slope.

a : cohort analysis in this paper (Case I)
b : cohort analysis in this paper (Case II)
c : cohort analysis by US scientists (tuned to trend)
d : cohort analysis by US scientists (tuned to age)
e : Japanese multi-vessel trawl survey
f : US bottom trawl survey
g : US-Japan cooperative groundfish survey

Table I. Historical catches of walleye pollock (t) in the eastern Bering Sea and Aleutian Islands region.[a]

Year	Eastern Berng Sea Japan	U.S. Domestic	U.S. Joint ventures[b]	Others[c]	Total	Aleutian Islands region Japan	U.S. Domestic	U.S. Joint ventures[b]	Others[c]	Total	Total
1958	6,924				6,924						6,924
1959	32,793				32,793						32,793
1960	26,097				26,097						26,097
1961	24,216				24,216						24,216
1962	58,765				58,765						58,765
1963	103,353				103,353						103,353
1964	171,921				171,921						171,921
1965	229,259				229,259						229,259
1966	261,680				261,680						261,680
1967	550,131				550,131						550,131
1968	701,085			1,200	702,285						702,285
1969	830,997			32,295	863,292						863,292
1970	1,231,298			25,420	1,256,718						1,256,718
1971	1,513,995			229,840	1,743,835						1,743,835
1972	1,616,483			223,096	1,839,579						1,839,579
1973	1,471,135			283,105	1,754,240						1,754,240
1974	1,250,609			335,613	1,586,222						1,586,222
1975	1,065,038			220,005	1,285,043						1,285,043
1976	987,033			264,543	1,251,576						1,251,576
1977	774,307			109,638	883,945	5,667			1,958	7,625	891,570
1978	783,036			158,125	941,161	5,007			1,257	6,264	947,425
1979	749,935			164,652	914,587	8,038			1,457	9,495	924,082
1980	797,411		10,479	161,032	968,922	45,804			12,104	57,908	1,026,830
1981	767,596		41,938	166,280	975,814	38,763			17,536	56,299	1,032,113
1982	747,266		52,622	156,370	956,258	36,873		1,983	22,616	61,472	1,017,730
1983	669,335	912	146,467	180,045	996,759	29,645		2,547	26,994	59,186	1,055,945
1984	619,458	6,727	230,314	235,407	1,091,906	34,519	3,891	6,694	32,651	77,755	1,169,661
1985	587,788	38,084	370,257	184,935	1,181,064	34,151	583	7,283	15,236	57,253	1,238,317
1986	258,315	47,363	804,842	80,972	1,191,492	6,085	777	10,261	8,934	46,857	1,237,549
1987	2,645	218,000	1,015,000	1,000	1,237,000	0	1,000	28,000	0	30,000	1,267,000
1988	0	489,000	739,000	0	1,228,000	0	2,000	41,000	0	43,000	1,271,000

a. Japanese catch data are the combined values of the INPFC Area 1 and 2 in the Bering Sea, and the INPFC Area 5 in the Aleutian Islands region including all types of fisherey, for 1958-1976 as reported by Forrester et al.(1978) and Forrester et al.(1983), and for 1977-1986 in data file of Far Seas Fish. Res. Lab., Shimizu. The catches for 1977-1987 are taken only in the U.S. 200-mile zone.

b. Joint ventures between U.S. fishing vessels and Republic of Korean, Japanese, Polish, Federal Republic of Germany and U.S.S.R. Processors.

c. U.S.S.R., Republic of Korea, Taiwan, Poland, Federal Republic of Germany, Portugal and People's Republic of China.

Table 2. Relative indices of walleye pollock abundance obtained from Japanese commercial fisheries in the eastern Bering Sea, 1973-1986.

Year	Method A[a]	Method B[b]
1973	12.4	140
1974	10.5	104
1975	9.7	97
1976	9.8	100
1977	9.1	86
1978	9.7	93
1979	9.9	95
1980	9.3	95
1981	9.6	94
1982	10.9	94
1983	11.5	117
1984	14.6	176
1985	14.6	153
1986	18.8	203

a Ton per hour, standerdized to pair trawler (Yamaguchi and Okada 1984).
b Percent of 1976 value, INPFC ADI Workshop method (Low and Ikeda 1980).

Table 3. Biomass estimates[a] of walleye pollock obtained from trawl and hydroacoustic surveys in the eastern Bering Sea, 1975-1987.

Year	Japan		U.S.A.[d]	U.S.-Japan[e]		
	Bottom trawl[b]	Hydroacoustic[c]	Bottom trawl	Bottom trawl	Hydroacoustic	Total
1975	-	-	1,958,400	-	-	-
1976	10,398,000	-	-	-	-	-
1977	10,971,200	-	-	-	-	-
1978	10,057,000	-	-	-	-	-
1979	8,215,800	-	-	3,204,300	7,457,500	10,661,800
1980	13,118,000	-	1,485,900	-	-	-
1981	9,337,400	-	-	2,442,000	-	-
1982	7,793,000	-	-	4,039,600	4,900,500	8,940,100
1983	10,684,800	-	6,064,800	-	-	-
1984	6,553,500	4,809,900	4,633,000	-	-	-
1985	-	-	-	5,522,200	4,798,500	10,320,700
1986	-	-	4,977,900	-	-	-
1987	-	-	5,200,000	-	-	-

a All is considered to be underestimated because the coverage of survey area by each survey is defective not only horizontally but also vertically.
b Multi-vessel trawl survey in fall (Yamaguchi and Okada 1984, Teshima and Okada 1985).
c Vicinity of Pribilof Islands (Harada et al. 1985).
d Continental shelf region only (Bakkala et al. 1986, Wespestad and Traynor 1987)
e Combined continental shelf and slope regions (Bakkala et al. 1986).

Table 4. Catch at age, and fishing mortality coefficient F and estimated numbers of the eastern Bering Sea continental shelf pollock stock in millions by age as estimated by cohort analysis.

Year	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Age	Catch in number (Case I)																									
3	18.7	2.5	32.1	53.0	99.7	58.3	348.5	71.6	235.8	212.3	544.8	1,436.1	684.7	424.7	416.3	385.1	465.4	701.7	80.4	81.5	55.6	189.6	32.9	43.9	225.7	
4	12.4	24.3	8.0	204.3	57.5	250.6	402.5	284.0	399.7	406.3	120.2	126.9	421.2	221.2	263.3	156.3	141.3	236.8	453.2	137.6	143.6	44.5	150.2	34.0	136.0	
5	21.7	98.6	88.6	46.8	289.7	259.7	286.4	297.5	482.7	321.5	208.4	22.4	80.4	108.0	164.4	186.8	113.1	80.7	181.3	140.1	202.1	147.6	97.6	291.4	106.7	
6	21.8	49.0	113.4	173.0	134.7	181.0	112.7	894.7	410.2	309.0	216.8	71.1	45.4	59.8	80.5	162.3	153.7	81.7	59.3	203.4	521.6	288.9	374.1	158.6	504.1	
7	61.2	12.2	10.4	41.1	38.3	3.9	36.6	86.9	160.9	171.3	138.9	80.9	52.9	25.6	22.4	37.7	75.5	48.6	20.0	32.3	114.7	398.0	224.3	158.0	207.1	
8	27.5	11.8	11.4	12.4	45.9	20.3	18.3	57.1	81.1	149.5	111.7	59.3	54.3	36.7	15.1	16.0	51.6	41.5	22.7	13.0	36.0	107.3	205.1	111.3	99.5	
9	5.8	5.5	4.4	6.2	6.5	13.0	10.4	16.1	22.1	56.9	116.7	45.2	36.4	32.9	16.3	20.4	21.2	25.4	14.1	8.9	24.7	37.3	47.5	265.2	39.3	
10																										
Age	F (Case I)																									
3	0.003	0.001	0.005	0.006	0.006	0.005	0.038	0.008	0.037	0.057	0.133	0.239	0.121	0.072	0.108	0.081	0.050	0.023	0.005	0.007	0.014					
4	0.010	0.028	0.006	0.084	0.018	0.039	0.101	0.080	0.122	0.185	0.091	0.091	0.235	0.116	0.129	0.119	0.085	0.070	0.040	0.019	0.031	0.031				
5	0.087	0.117	0.110	0.068	0.193	0.123	0.662	0.119	0.247	0.160	0.160	0.026	0.067	0.102	0.139	0.149	0.140	0.075	0.082	0.058	0.040	0.048	0.101			
6	0.162	0.322	0.213	0.360	0.313	0.197	0.079	0.336	0.266	0.276	0.172	0.083	0.073	0.097	0.114	0.220	0.196	0.158	0.080	0.139	0.100	0.082	0.162	0.265		
7		0.155	0.126	0.135	0.153	0.016	0.063	0.098	0.112	0.206	0.231	0.108	0.099	0.065	0.058	0.087	0.183	0.108	0.063	0.069	0.131	0.125	0.103	0.132	0.840	
8			0.258	0.266	0.267	0.136	0.116	0.171	0.112	0.175	0.246	0.180	0.119	0.112	0.059	0.637	0.199	0.176	0.079	0.064	0.123	0.212	0.106	0.082	0.139	
9				0.266	0.267	0.136	0.116	0.171	0.112	0.175	0.246	0.180	0.195	0.119	0.080	0.129	0.136	0.173	0.101	0.048	0.202	0.220	0.166	0.236	0.045	
10																										
Age	Estimated numbers (Case I)																									
3	4,001	3,316	8,255	10,561	21,457	13,540	11,445	11,310	8,038	4,733	5,351	8,189	7,372	7,555	4,984	6,072	11,854	38,185	24,050	15,120	4,853					
4	1,715	1,654	1,374	3,408	4,353	8,849	5,586	4,569	4,655	3,214	1,855	1,943	2,674	2,710	2,918	1,856	2,323	4,679	15,480	9,929	6,230	1,984				
5	338	1,161	1,109	932	2,143	2,924	5,822	3,452	2,856	2,818	1,827	1,159	1,213	1,445	1,651	1,755	1,126	1,459	2,983	10,171	6,664	4,129	1,316			
6	175	212	706	680	596	1,209	1,769	3,726	2,096	1,526	1,642	1,065	772	776	892	983	1,034	670	926	1,879	6,564	4,377	2,692	813		
7		102	105	391	324	298	679	1,117	1,821	1,099	792	945	670	491	481	544	540	582	391	585	1,118	4,061	2,757	1,535	427	
8			60	63	233	190	201	434	693	1,113	612	430	580	415	315	311	341	307	357	251	373	671	2,451	1,071	920	126
9				31	33	122	114	122	250	424	639	327	245	352	254	203	199	191	176	226	161	226	371	1,508	1,072	548
10					16	17	73	69	70	153	243	342	187	138	214	160	122	119	110	109	147	90	124	215	815	701
Age	Catch in number (Case II)																									
3	12.3	2.9	38.9	61.0	114.7	68.2	400.8	82.4	271.3	244.2	826.9	1,652.3	787.8	488.6	479.0	443.0	535.5	807.4	104.0	93.8	64.0	218.1	37.9	50.5	259.6	
4	14.7	28.9	9.6	243.0	68.4	298.1	478.8	349.7	475.5	483.4	142.8	150.9	501.0	283.1	313.2	185.9	166.0	281.8	539.1	163.7	171.0	52.9	178.6	40.4	161.7	
5	24.7	112.0	100.7	53.1	329.1	285.0	325.4	337.9	548.3	365.2	236.7	25.4	68.6	122.7	186.8	212.2	128.5	91.6	205.9	499.8	229.6	167.6	110.9	331.1	121.2	
6	21.8	49.0	113.4	173.0	134.7	181.0	112.7	894.7	410.2	309.0	216.8	71.1	45.4	59.8	80.5	162.3	153.7	81.7	59.3	203.4	521.6	288.9	374.1	156.6	504.1	
7	61.2	12.2	10.4	41.1	38.3	3.9	36.6	86.9	160.9	171.3	138.9	80.9	52.9	25.6	22.4	37.7	75.5	48.6	20.0	32.3	114.7	398.0	224.3	158.0	207.1	
8	27.5	11.8	11.4	12.4	45.9	20.3	18.3	57.1	81.1	149.5	111.7	59.3	54.3	36.7	15.1	16.0	51.6	41.5	22.7	13.0	36.0	107.3	205.1	111.3	99.5	
9	5.8	5.5	4.4	6.2	6.5	13.0	10.4	16.1	22.1	56.9	116.7	45.2	36.4	32.9	16.3	20.4	21.2	25.4	14.1	8.9	24.7	37.3	47.5	265.2	39.3	
10																										
Age	F (Case II)																									
3	0.003	0.001	0.005	0.006	0.006	0.005	0.038	0.008	0.037	0.057	0.133	0.239	0.121	0.072	0.108	0.081	0.050	0.023	0.005	0.007	0.014					
4	0.010	0.028	0.006	0.084	0.018	0.039	0.101	0.080	0.122	0.185	0.091	0.091	0.235	0.116	0.129	0.119	0.085	0.070	0.040	0.019	0.031	0.031				
5	0.087	0.117	0.110	0.068	0.193	0.123	0.662	0.119	0.247	0.160	0.160	0.026	0.067	0.102	0.139	0.149	0.140	0.075	0.082	0.058	0.040	0.048	0.101			
6	0.162	0.322	0.213	0.360	0.313	0.197	0.079	0.336	0.266	0.276	0.172	0.083	0.073	0.097	0.114	0.220	0.196	0.158	0.080	0.139	0.100	0.082	0.162	0.265		
7		0.155	0.126	0.135	0.153	0.016	0.067	0.098	0.112	0.206	0.231	0.108	0.099	0.065	0.058	0.087	0.183	0.108	0.063	0.069	0.131	0.125	0.103	0.132	0.840	
8			0.258	0.266	0.267	0.136	0.116	0.171	0.112	0.175	0.246	0.180	0.119	0.112	0.059	0.637	0.199	0.176	0.079	0.064	0.123	0.212	0.106	0.082	0.139	
9				0.266	0.267	0.136	0.116	0.171	0.112	0.175	0.246	0.180	0.195	0.119	0.080	0.129	0.136	0.173	0.101	0.048	0.202	0.220	0.166	0.236	0.045	
10																										
Age	Estimated numbers (Case II)																									
3	4,001	3,316	8,255	10,561	21,457	13,540	11,445	11,310	8,038	4,733	5,351	8,189	7,372	7,555	4,984	6,072	11,854	38,185	24,050	15,120	4,853					
4	1,715	1,654	1,374	3,408	4,353	8,849	5,586	4,569	4,655	3,214	1,855	1,943	2,674	2,710	2,918	1,856	2,323	4,679	15,480	9,929	6,230	1,984				
5	338	1,161	1,109	932	2,143	2,924	5,822	3,452	2,856	2,818	1,827	1,159	1,213	1,445	1,651	1,755	1,126	1,459	2,983	10,131	6,664	4,129	1,316			
6	175	212	706	680	596	1,209	1,769	3,726	2,096	1,526	1,642	1,065	772	776	892	983	1,034	670	926	1,879	6,564	4,377	2,692	813		
7		102	105	391	324	298	679	1,117	1,821	1,099	792	945	670	491	481	544	540	582	391	585	1,118	4,061	2,757	1,535	427	
8			60	63	233	190	201	434	693	1,113	612	430	580	415	315	311	341	307	357	251	373	671	2,451	1,071	920	126
9				31	33	122	114	122	250	424	639	327	245	352	254	203	199	191	176	226	161	226	371	1,508	1,072	548
10					16	17	73	69	70	153	243	342	187	138	214	160	122	119	110	109	147	90	174	215	815	701

Table 5. Estimated numbers of ideal pollock stocks of the eastern Bering Sea continental shelf and Aleutian Basin in millions.

Age \ Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Eastern shelf stock (Case I)																														
3	3,964	3,964	3,964	3,964	3,297	6,092	10,463	21,296	13,314	11,267	11,060	3,092	4,742	5,431	8,384	7,420	1,514	5,062	8,899	11,834	38,061	23,055	14,716	4,647	24,177	4,946	24,040	16,160	4,300	9,570
4	1,644	1,644	1,644	1,644	1,644	1,358	3,356	4,310	8,033	5,522	4,673	4,596	2,874	1,675	1,090	2,936	2,616	2,820	1,853	2,250	4,437	15,767	9,926	5,097	1,927	10,020	2,049	9,971	8,703	1,704
5	1,124	1,120	1,112	1,103	1,088	1,074	863	2,160	2,726	5,670	3,444	2,767	2,748	1,438	858	1,144	1,341	1,661	1,728	1,127	1,391	2,675	18,311	6,508	3,809	1,208	6,439	1,283	6,384	4,274
6	763	766	757	746	730	711	694	553	1,319	1,752	3,545	2,042	1,662	1,611	958	565	658	1,106	1,014	1,051	697	839	1,747	6,754	4,205	2,388	736	4,045	874	4,078
7	526	524	518	508	494	477	459	434	347	818	1,094	2,099	1,226	970	920	564	335	409	615	617	650	430	540	1,145	4,363	2,636	1,533	487	2,549	525
8	360	358	354	348	336	322	308	287	273	223	529	640	1,261	116	554	542	335	288	250	411	381	392	274	359	739	2,335	1,692	963	312	1,651
9	246	245	242	238	230	220	208	193	188	175	138	313	389	736	409	326	322	208	123	152	254	230	256	180	232	463	1,756	1,063	617	159
10	168	168	166	163	157	150	142	130	121	116	109	82	160	223	470	241	194	200	123	77	94	153	158	160	116	145	790	1,103	681	393
11	115	115	113	111	108	103	97	89	82	78	72	65	58	118	130	247	143	120	122	77	48	57	188	98	108	73	93	167	786	434
12	79	78	77	76	74	70	66	61	56	53	49	43	39	29	63	76	147	89	74	74	48	79	37	66	64	80	47	59	124	450
13	54	54	53	52	50	48	45	41	38	36	33	79	26	23	17	37	45	91	54	45	46	39	19	24	42	40	44	29	38	76
14	37	37	36	36	34	33	31	28	26	25	22	19	17	15	13	10	22	78	56	33	28	28	13	12	16	27	26	27	19	74
15	25	25	25	24	24	22	21	19	18	17	15	13	12	10	9	8	6	16	17	34	20	17	14	12	8	10	17	16	10	12
16	17	17	17	17	16	15	15	13	12	11	10	9	8	7	6	5	5	4	8	10	21	12	11	12	8	5	6	11	10	11
17	12	12	12	11	11	11	10	9	8	8	7	6	5	5	4	3	3	3	2	5	6	13	8	7	8	5	3	4	7	7
Eastern shelf stock (Case II)																														
3	2,341	2,341	2,341	2,341	1,814	5,023	5,916	13,164	8,075	8,133	7,491	5,530	3,032	3,762	6,463	5,458	5,325	3,577	4,081	7,865	23,724	14,128	9,479	3,474	15,301	3,162	15,590	10,650	2,938	6,440
4	1,062	1,062	1,062	1,062	1,062	823	2,268	2,686	5,974	4,028	3,687	3,403	2,510	1,187	1,329	2,463	2,015	2,116	1,392	1,577	3,002	10,767	6,412	4,484	1,577	6,944	1,435	7,075	4,033	1,357
5	795	791	784	776	762	750	573	1,508	1,765	4,053	2,633	2,361	2,036	1,510	644	418	1,521	1,340	1,357	885	1,019	1,924	7,489	4,487	3,097	1,958	4,768	964	4,043	3,296
6	595	592	584	573	557	538	522	379	991	1,197	2,650	1,615	1,352	1,225	639	393	508	897	859	865	573	636	1,338	5,241	3,099	2,078	726	3,202	660	3,302
7	445	443	437	426	411	393	374	345	249	672	703	1,625	358	814	713	536	247	326	638	547	558	358	442	337	3,620	2,440	1,427	488	2,192	450
8	333	331	327	319	306	290	274	246	227	169	440	460	372	581	474	435	331	159	218	407	354	349	249	310	647	2,429	1,428	958	334	1,495
9	249	248	245	239	229	216	202	181	163	154	118	270	287	545	338	289	268	217	182	134	263	221	243	174	214	434	1,666	959	656	278
10	186	186	183	179	171	162	150	134	119	110	101	68	161	173	348	206	136	176	139	65	85	164	154	170	120	143	298	1,120	656	447
11	140	139	137	134	128	121	112	99	88	81	72	62	48	97	101	208	127	117	143	88	42	54	114	107	117	81	98	208	767	418
12	104	104	102	100	95	88	84	74	65	60	53	44	37	24	56	61	128	83	75	72	57	26	38	88	74	79	55	66	137	573
13	78	78	77	75	72	66	63	56	49	44	39	32	26	22	18	39	38	84	54	44	46	36	18	26	55	50	54	37	45	93
14	58	58	57	56	54	51	47	42	37	33	29	24	19	16	15	9	21	25	54	34	31	29	25	13	18	37	34	36	25	31
15	44	44	43	42	40	38	35	31	27	25	22	18	14	12	9	8	5	14	16	34	22	18	28	17	9	12	25	23	25	17
16	33	33	32	31	30	28	26	23	20	19	16	13	11	9	7	6	5	3	9	10	22	14	13	14	12	4	8	17	16	17
17	24	24	24	23	22	21	20	17	15	14	12	10	8	6	5	4	3	3	2	8	7	14	10	9	10	8	4	6	12	11
Basin stock (Case I)																														
3	7,103	7,103	7,103	7,103	5,998	14,561	18,250	38,162	23,859	28,110	19,855	14,142	8,498	9,732	15,024	13,297	13,465	8,664	10,929	21,207	68,205	42,927	25,475	8,327	43,325	8,852	43,080	28,959	7,706	17,149
4	4,858	4,858	4,858	4,858	4,858	4,848	9,517	12,022	26,898	16,316	13,007	13,578	8,452	4,862	5,554	8,852	7,805	8,357	5,475	6,649	13,189	46,443	29,356	17,421	5,695	29,520	6,054	29,461	19,804	5,270
5	3,322	3,309	3,288	3,260	3,214	3,133	2,610	6,284	8,854	14,774	10,187	8,176	8,154	4,958	2,831	3,272	5,263	4,986	5,104	3,331	4,110	9,904	30,463	19,231	11,254	3,530	18,025	3,803	18,860	12,627
6	2,272	2,261	2,250	2,226	2,193	2,146	2,109	1,787	4,866	5,348	10,861	6,483	5,239	5,152	3,858	1,787	2,066	3,429	3,171	3,292	2,164	2,639	5,282	20,349	12,731	7,317	2,383	12,040	2,419	11,960
7	1,554	1,554	1,551	1,538	1,522	1,499	1,469	1,442	1,167	2,781	3,652	7,496	4,433	3,583	3,524	2,114	1,228	1,427	2,345	2,188	2,249	1,480	1,405	3,558	11,005	4,565	4,781	1,468	7,606	1,525
8	1,082	1,062	1,062	1,060	1,052	1,011	1,025	1,005	986	798	1,182	2,497	5,128	3,032	2,450	2,410	1,449	841	976	1,603	1,401	1,538	1,012	1,229	2,441	8,309	5,562	3,023	928	4,738
9	727	727	727	727	725	720	712	701	667	874	546	1,308	1,768	3,586	2,073	1,676	1,648	991	575	667	1,085	1,013	1,452	689	834	1,648	6,032	3,547	1,910	585
10	497	497	483	497	497	486	492	487	466	470	461	373	669	1,168	2,397	1,418	1,146	1,127	676	393	456	749	693	716	460	562	1,066	3,016	7,241	1,205
11	340	340	340	340	340	340	339	337	333	328	321	315	255	606	789	1,639	970	784	771	463	268	312	512	472	486	315	364	680	2,430	1,413
12	232	232	232	232	232	232	232	232	230	220	224	220	216	175	416	546	1,121	663	536	527	311	181	213	349	320	328	204	232	430	1,533
13	159	159	159	158	159	158	158	159	158	157	156	153	150	148	119	284	374	767	453	368	368	216	126	145	237	216	212	136	147	271
14	109	109	109	109	109	108	108	109	109	108	104	106	105	103	101	82	195	255	524	318	250	246	148	86	99	160	140	135	82	93
15	74	74	74	74	74	74	74	74	74	74	74	74	73	72	70	69	56	133	175	358	212	171	168	181	58	66	183	89	86	57
16	51	51	51	51	51	51	51	51	51	51	51	51	50	50	49	48	47	38	91	119	245	145	117	115	68	39	43	66	56	54
17	35	35	35	35	35	35	35	35	35	35	35	35	35	34	34	34	33	37	78	82	62	168	99	80	78	46	25	27	42	36
18	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	23	23	22	22	18	42	56	115	83	54	52	30	16	17	26
Basin stock (Case II)																														
3	3,245	3,245	3,245	3,245	2,514	6,962	8,202	10,245	12,381	11,256	10,394	7,665	4,202	5,216	9,235	7,568	7,380	4,958	5,656	10,981	32,801	19,581	13,892	4,815	21,207	4,383	21,608	14,761	4,144	8,976
4	2,428	2,428	2,428	2,428	2,428	1,881	5,209	6,136	13,652	9,204	8,424	7,777	5,735	2,529	3,036	5,629	4,673	4,835	3,100	3,603	7,012	24,604	14,652	10,245	3,603	15,869	3,239	16,168	11,045	3,101
5	1,817	1,808	1,791	1,774	1,742	1,714	1,309	3,447	4,833	9,262	6,017	5,166	4,652	3,451	1,472	1,851	3,476	3,061	3,101	2,026	2,327	4,397	17,114	10,253	7,077	2,417	10,895	2,203	11,068	7,531
6	1,359	1,358	1,343	1,324	1,300	1,266	1,233	921	2,417	2,873	6,178	4,076	3,456	3,121	2,238	994	1,258	2,434	2,121	2,141	1,408	1,591	3,172	12,353	7,321	4,962	1,671	7,366	1,495	7,479
7	1,017	1,017	1,015	1,005	991	972	947	925	689	1,808	2,150	4,847	3,450	2,586	2,335	1,704	744	941	1,821	1,587	1,601	1,053	1,190	2,362	9,133	5,369	3,452	1,137	4,957	1,081
8	761	761	761	759	752	742	770	709	692	518	1,353	1,609	3,627	2,287	1,935	1,740	1,275	557	704	1,363	1,186	1,198	788	868	1,746	6,692	3,734	2,349	765	3,320
9	569	569	569	569	568	563	555	548	530	510	388	1,013	1,204	2,714	1,708	1,448	1,308	854	417	527	1,019	880	816	587	655	1,279	4,655	2,541	1,581	512
10	426	426	426	426	426	425	421	415	407	397	388	269	758	901	2,031	1,278	1,083	978	714	312	394	762	664	667	434	480	890	3,167	1,710	1,058
11	319	319	319	319	319	319	318	315	311	305	297	290	216	567	674	1,520	950	811	732	534	233	295	570	495	493	318	334	606	2,132	1,145
12	239	239	239	239	239	239	239	238	236	232	228	222	217	162	424	504	1,137	715	607	548	359	174	221	425	366	361	221	227	498	1,421
13	179	179	179	179	179	178	179	179	178	176	174	171	166	162	121	317	377	851	535	454	410	299	130	164	314	268	251	150	153	273
14	134	134	134	134	134	134	134	134	134	133	132	130	128	124	122	90	236	282	637	401	339	306	224	97	121	230	186	171	101	102
15	100	100	100	100	100	100	100	100	100	100	100	99	97	96	93	91	68	178	211	476	299	254	229	166	72	89	160	127	115	68
16	75	75	75	75	75	75	75	75	75	75	75	75	74	73	72	70	68	51	133	158	356	224	190	171	123	53	62	109	85	77
17	56	56	56	56	56	56	56	56	56	56	56	56	56	55	55	54	52	51	38	168	118	266	160	141	126	98	37	42	73	57
18	42	42	42	42	42	42	42	42	42	42	42	42	42	42	41	41	40	39	38	28	74	88	199	125	105	92	63	25	26	49

Assessment of Walleye Pollock Biomass in the Aleutian Basin Based on Cohort Analysis and Polish Fisheries Data

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ABSTRACT

Cohort analysis was used to estimate the biomass of walleye pollock in the Aleutian Basin of the Bering Sea in the period of 1985-89. Catch-at-age and catch-per-unit effort data from the Polish fishing fleet operating in international waters of the Aleutian Basin were used in the analysis. Results showed that biomass of the exploitable population (ages 5 to 21 years) varied in this period between 21 and 15 million metric tons (t).

The selectivity curves estimated from separable virtual population analysis suggested that pollock exploited in international waters of the Aleutian Basin belonged to a larger population which ranged beyond the area of exploitation. The present fishing mortality coefficient was estimated at 0.24 which is lower than the $F_{0.1}$ fishing rate of 0.6 derived from the Ricker exponential yield model. Based on the estimated biomass of 15.3 million t and on assumed catch of 1.5 million t, the exploitation rate of pollock in the international zone was 10 % which is much lower than the rate in the eastern Bering Sea.

INTRODUCTION

Walleye pollock (Theragra chalcogramma) is the principal commercial species in the Bering Sea. It is abundant along the outer continental shelf and slope between 100 and 500 m with main concentrations on the outer shelf at depths which vary with environmental conditions (Bakkala et al. 1986). In recent years pollock have also been found to occupy pelagic waters of the Aleutian Basin (Fig. 1), at times in high density, especially in international waters of the Basin (Okada 1986, Jackowski and Trociński 1989).

Following this discovery, commercial fisheries began to develop in the international zone of the Aleutian Basin. Catches of pollock in these waters by Japanese and Republic of Korea fisheries were only 4,200 metric tons (t) in 1982, but by 1983 had reached 70,700 t. Fisheries by Poland and the People's Republic of China also began operations in this area in 1985 and catches increased rapidly to 1.0 million t in 1986 and 1.3 million t in 1987. By 1987 the catch of pollock in international waters reached a level equalling those in the entire U.S. Exclusive Economic Zone (EEZ) of the Bering Sea (Table 1).

Because of the high level of these recent catches, an assessment of the condition of the exploitable population in international waters of the Aleutian Basin have become important. In this paper we estimate the biomass of Aleutian Basin pollock from a cohort analysis using data from the Polish fishery in the international zone and examine the trends in these estimates over the period from 1985-1989.

STOCK STRUCTURE OF BERING SEA POLLOCK

Although the stock structure of pollock in the Bering Sea has not been defined, three stocks are assumend for management purposes by the United States (Resource Assessment Document 1987). Two of these are in the U.S. EEZ, the eastern Bering Sea and Aleutian Islands region stocks and the third in the U.S.S.R. EEZ. The relationship between pollock in U.S. and U.S.S.R. waters and those in the international zone and other waters of the Aleutian Basin is unknown, but is the subject of current studies. Differences in age composition and growth and in meristic, morphometric, and reproductive characteristics between pollock of the Aleutian Basin and the surrounding areas of the Bering Sea have been documented by Traynor and Nelson (1985), Okada and Yamaguchi (1985), Lynde et al. (1986), Hinckley (1987), and Janusz et al. (1989). Studies have also shown that a large population of pollock spawns in the Aleutian Basin and that pollock eggs are abundant in these waters, particularly in the southeastern part of the Basin (Okada 1986, Hinckley 1987).

There are many working hypothesis concerning the origin of pollock in international waters of the Aleutian Basin. An American scientist (Dawson 1989) presented 5 working hypothesis ranging from a separate stock in international waters of the Basin to a single stock for the entire Bering Sea. A U.S.S.R. scientist (Stepanenko 1989) assumed the existence of only two stock in the Bering Sea, one in U.S. waters and the second in U.S.S.R. waters, of which both contribute to the population in the Aleutian Basin during feeding migrations.

In our assessment, we have assumed as a working hypothesis that pollock in the Aleutian Basin are an independent stock and that the population exploited in the international zone is a part of this Aleutian Basin stock.

MATERIALS AND METHODS

In estimating biomass from cohort analysis, the following data are required: catch- and weight-at-age, an estimate of natural mortality (M), and estimates of fishing mortality (F) by age in the terminal year and for the oldest age in all previous years. Unfortunately, we only had catch- and weight-at-age data from the Polish fishery which had to be used to apportion all-nation catches in the international zone into age components (Table 2). In addition, catches by some nations were not available for 1988 and 1989 so it was necessary to assume that total catch was 1.5 million t in each of these two years.

Natural mortality was estimated from a catch curve based on 1985 catch-at-age data when the exploitation rate was low. The slope of the curve was -0.37 which provides a rough estimate of total mortality in 1985 (Fig. 2A). This suggests that natural mortality may range from 0.2 to 0.3. Because 0.3 has been used as the estimate of natural mortality for eastern Bering Sea shelf pollock (Wespestad 1989), we assumed natural mortality was about 0.2 in the Aleutian Basin where cannibalism is lower.

To derive estimates of fishing mortality (F), catch curves over the years 1986-1989 were first averaged (Fig. 2C). Catches increased substantially over this period. Thus, by subtracting the M value from the estimate of total mortality (Z=0.42) derived from the average-catch curve, a first estimate of terminal fishing mortality was provided.

The fishing mortalities resulting from cohort analysis were tuned iterratively to the effort data (Table 3). Unfortunately, the time-series of effort data, as well as the catch-at-age data was short, spawning only 5 years. The effort data were obtained by dividing the total all-nation catch in the international zone by the CPUE (in units of catch per fishing day) from the Polish fishing fleet.

In the tuning procedure the Laurec-Shepherd (Pope and Shephard 1985) method was used. This method is expected to be the best among the ad hoc tuning methods (Anon., 1988; Anon., 1990). It performs well if catchability coefficients do not show any trend with time. So, during simulations for each age group t statistics were calculated to test the regression coefficients of log catchability against time. As all the coefficients were not significant the Laurec - Shepherd method was applicable and it is believed to give reliable estimates of stock size and mortality.

RESULTS

Estimates of biomass from the above procedures for the exploitable population of pollock (ages 5 to 21) ranged from 21.7 to 15.3 million t during the period of 1985 to 1989 (Table 4).

There was good agreement in the estimates of total mortality (Z) from cohort analysis and the catch curves. The mean Z for 1985-1989 was 0.40 and 0.41 from cohort analysis and catch curve, respectively. In 1985, the estimate of Z was about 0.1 higher than from cohort analysis (Fig. 2A). The correlation coefficients of F-at-age estimates with fishing effort over the 5 years varied from 0.76 to 0.99 for age 5-19, and were higher than 0.90 for most ages. The mean (age 9-19) F values increased from 0.05 in 1985 to 0.24 in 1989.

These rates of exploatation can be compared with the commonly referenced rates of exploatation $F_{0.1}$ and F_{max}.

However, usually applied Beverton and Holt (1957) model can not be used in this case as fishing mortality coefficients indicate that selection curves are domed shaped. So, first separable VPA (Pope and Shepherd, 1982) was run to estimate selection curve (Fig. 3). Next, Ricker (1975) exponential yield per recruit model was employed.

The $F_{0.1}$ value was determined to be about 0.6 but F_{max} was not reached on the curve with the range of F values used (Fig. 4). This comparison suggests that the present level of fishing mortality (F=0.24) is not too high and that catches at the 1989 level can be continued without danger of the stock collapsing.

DISCUSSION

This paper presents the first biomass estimates for pollock of the Aleutian Basin based on analytical methods using cohort analysis. Summer hydrocoustic surveys carried out by the Japanese in the portion of the Aleutian Basin east of the U.S.-U.S.S.R. convention line produced biomass estimates of 5.4 million t in 1978 and 1.3 million t in 1979 (Okada 1979, Okada and Yamaquchi 1985). However, a more recent hydroacoustic survey conducted by the Japan Marine Resource Research Center in August to September 1987 indicated that the biomass in the international zone alone was 9.1 million t (Sasaki 1989). Wespestad (1989) suggested that based on available data, the biomass of pollock in the Aleutian Basin may be relatively large.

The catch-at-age data indicated that recruitment of pollock to the exploitable stock in the international zone starts at age 5 (very rarely at age 4) and increases at older ages. Polish fishing vessels use trawls with 100 mm mesh in the codend which should ensure full retention of age 5 pollock, but selectivity curve based on separable VPA indicates that selectivity is low for this age group. This suggests that recruitment of age groups into the international zone is gradual. Because of this gradual recruitment, the population in international waters is very resistent to overfishing.

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Table 1. Catches of walleye pollock in the Bering Sea (thousands of metric tons),1980-89.

Year	International waters						U.S. EEZ	U.S.S.R.
	China[a]	Japan	Korea[b]	Poland	U.S.S.R.	Total	All nations	EEZ
1980	-	2.4	12.5	-	-	14.9	958.3	-
1981	-	.2	-	-	-	.2	973.5	-
1982	-	1.3	2.9	-	-	4.2	956.0	-
1983	-	4.1	66.6	-	-	70.7	982.4	-
1984	-	100.9	80.3	-	-	181.2	1098.8	-
1985	1.6	136.6	82.4	115.9	-	336.4	1178.8	-
1986	3.2	698.0	155.8	163.2	-	1020.2	1189.4	-
1987	4.1	802.6	241.9	230.3	-	1279.0	1253.5	700-800
1988	17.4	755.0	268.6	298.7	(c)	1500.0[d]	1228.0	(c)
1989	(c)	638.1	(c)	268.6	(c)	1500.0[d]	(c)	(c)

a/ Peoples Republic of China
b/ Republic of Korea
c/ No data
d/ Assumed

Table 2. Walleye pollock catches-at-age in numbers (millions) in international waters of the Bering Sea, 1985-89.

Age	Year				
	1985	1986	1987	1988	1989
5	5.1	1.8	4.8	2.7	4.1
6	13.5	8.9	25.7	19.8	44.0
7	50.9	57.1	34.8	106.2	53.0
8	122.0	295.4	147.7	104.5	157.1
9	85.2	352.4	423.7	183.6	117.1
10	26.8	180.1	444.4	312.0	163.8
11	21.9	81.9	157.7	403.3	352.1
12	46.8	82.8	111.5	142.4	450.1
13	55.4	183.5	140.8	101.6	172.5
14	26.4	156.8	240.8	102.9	64.9
15	3.4	41.7	121.4	176.4	45.3
16	3.1	11.5	15.9	107.6	131.2
17	2.6	2.1	11.3	18.8	78.3
18	4.5	9.7	4.7	9.6	15.1
19	3.3	6.3	3.9	3.0	3.0
20	1.5	12.5	5.5	5.9	1.0
21	0.5	0.9	1.9	2.1	2.5

Table 3. Catch-per-unit effort (tons/day) of walleye pollock from Polish stern trawlers fishing in international waters of the Bering Sea and an index of fishing effort (thousand days) for all fisheries operating in these waters.

Year	1985	1986	1987	1988	1989
CPUE	54.5	47.7	47.0	43.8	42.9
Effort index	6.2	21.4	27.2	34.2	35.0

Table 4. Estimated stock size in numbers (millions) and biomass (thousands of metric tons) of walleye pollock in the Aleutian Basin based on cohort analysis.

Stock in numbers			Year		
Age	1985	1986	1987	1988	1989
5	2694.4	4077.7	2522.7	5087.7	2287.7
6	3932.8	2201.4	3336.9	2061.1	4163.0
7	8119.8	3207.7	1794.3	2708.8	1669.6
8	8756.5	6601.9	2574.6	1437.5	2121.7
9	2650.1	7058.8	5137.9	1974.4	1082.4
10	1043.8	2092.6	5460.4	3823.2	1450.3
11	1034.5	834.4	1550.4	4068.5	2847.8
12	2279.9	827.2	609.1	1126.7	2966.1
13	1601.4	1324.3	602.3	397.8	793.6
14	266.0	1261.0	1327.6	365.7	233.7
15	90.6	193.9	890.7	869.0	206.3
16	34.5	71.1	121.0	619.4	551.9
17	93.5	25.5	47.8	84.7	409.7
18	66.8	74.2	19.0	28.9	52.3
19	53.3	50.6	52.0	11.4	15.0
20	261.2	40.7	35.8	39.0	6.6
21	27.9	212.5	22.0	24.3	26.5
Total	33012.1	30655.6	26104.3	24728.0	20884.3
Stock Biomass					
Age					
5	1444.2	1985.8	1031.8	3240.9	1242.2
6	2241.7	1111.7	1631.7	1403.6	2597.7
7	5074.9	1847.7	999.4	1985.5	1168.7
8	5709.2	4113.0	1570.5	1129.9	1601.9
9	1855.1	4630.6	3272.8	1587.4	859.4
10	776.1	1429.3	3598.4	3135.0	1155.9
11	784.2	594.1	1046.5	3401.3	2298.2
12	1753.3	598.0	429.4	952.0	2423.3
13	1286.0	1337.2	439.1	340.5	659.5
14	213.9	926.9	978.4	311.6	195.9
15	81.6	144.6	664.4	763.0	175.6
16	31.3	54.4	95.8	542.6	476.3
17	78.8	22.4	40.3	77.1	354.8
18	56.6	58.9	16.2	25.6	47.6
19	45.3	43.1	45.7	10.1	14.4
20	249.7	30.6	30.5	35.5	5.5
21	27.1	168.7	16.2	21.8	23.3
Total	21708.9	19097.0	15907.3	18963.4	15300.3

Table 5. Estimated fishing mortality coefficients of walleye pollock in international waters of the Bering Sea from cohort analysis.

Age		Year				
		1985	1986	1987	1988	1989
5		0.002	0.000	0.002	0.001	0.002
6		0.004	0.004	0.009	0.011	0.012
7		0.007	0.020	0.022	0.044	0.036
8		0.016	0.051	0.065	0.084	0.085
9		0.036	0.057	0.096	0.108	0.127
10		0.029	0.100	0.094	0.095	0.133
11		0.024	0.115	0.119	0.116	0.146
12		0.023	0.117	0.226	0.150	0.183
13		0.039	0.118	0.299	0.332	0.273
14		0.116	0.148	0.224	0.372	0.363
15		0.042	0.271	0.163	0.254	0.276
16		0.104	0.197	0.157	0.213	0.302
17		0.031	0.096	0.303	0.281	0.236
18		0.077	0.156	0.312	0.457	0.380
19		0.071	0.143	0.087	0.345	0.248
20		0.006	0.415	0.186	0.186	0.183
21		0.020	0.050	0.100	0.100	0.105
FU	(9-19)	0.054	0.138	0.189	0.248	0.242
FW	(9-19)	0.034	0.090	0.126	0.141	0.182

FU - Mean F values unweighted by catch.

FW - Mean F values weighted by the size of catches.

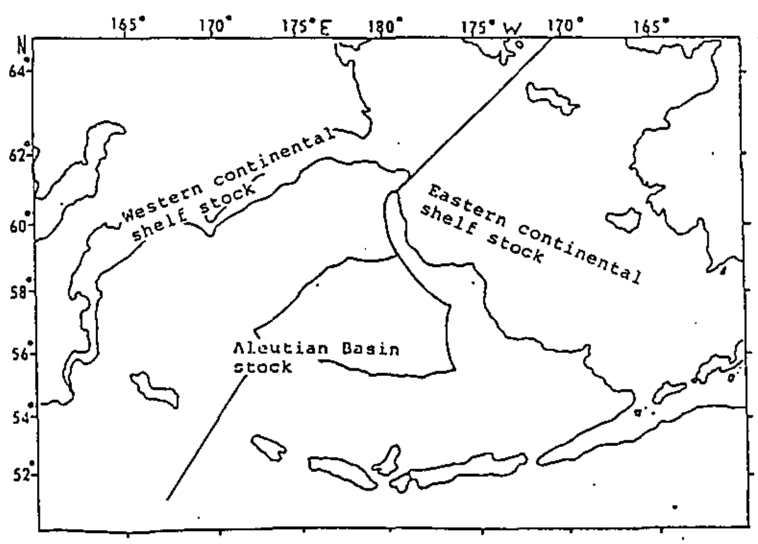

Figure 1. Assumed three stocks of pollock in the Bering Sea.

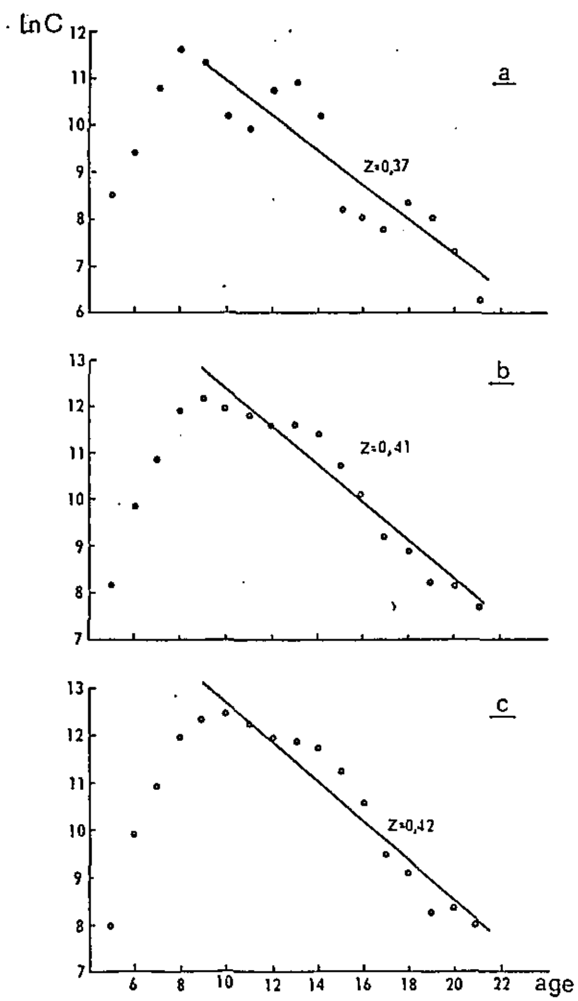

Figure 2. Catch curves for walleye pollock taken in international waters of the Bering Sea:

a is the catch curve for 1985,
b is the mean catch curve for 1985-1989, and
c is the mean catch curve for 1986-1989.

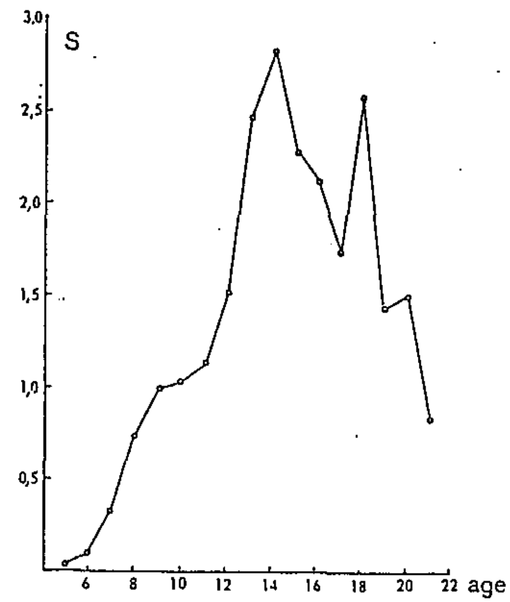

Figure 3. Selectivity curve determined from separable VPA.

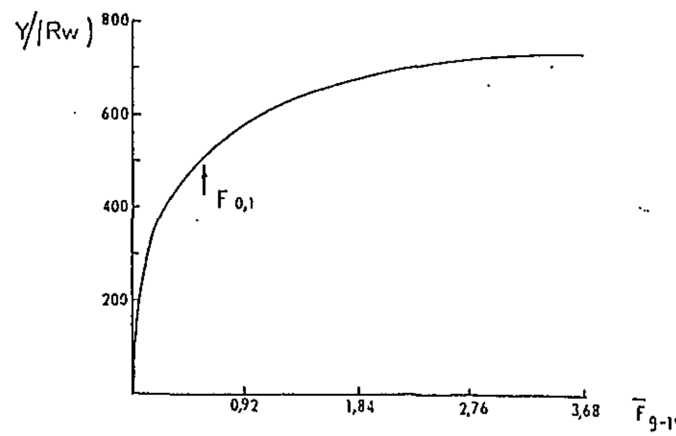

Figure 4. Yield per recruit biomass for walleye pollock in international waters of the Bering Sea based on the exponential model of Ricker (1975).

The Walleye Pollock Migrations in the Bering Sea

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The walleye pollock inhabits practically the whole Bering Sea aquatory. On the background of intermittent distribution it forms concentrations with different density not only at the shelf but over deep-water basins as well. They may be seasonal or constant, and they differ in size-age composition and physiological state of the aggregated individuals. As a result of recentnumerous ichthyoplankton and trawl surveys, the spawning places, juveniles' (recruitment) and mature individuals' habitation areas were determined. Spatial and seasonal comparison of that data, as well as the observations of the commercial fleet dislocation changes demonstrate not only the migrations pattern but the origination of some concentrations as well. All those questions become especially important in connection to the increased commercial pressure and starting of large-volume international fishing outside the U.S. and U.S.S.R. economic zones over the Aleutian Basin.

The maturing walleye pollock eggs is spread practically all over the shelf from Unimak Island at the south-east through Ozyorny Gulf at the south-west, and sometimes even projecting out of the shelf area. But the main part of eggs is concentrated at the Unimak-Pribyloff shelf in the south-eastern Aleutian Basin (Unalashka and Bogoslof Islands aquatorp) and in Olyutorsky Gulf. According to multi-annual averaged data (1983 - 1986, 1988), in the said areas there are distributed about 41, 49 and 6% of the sea's total abundance correspondingly (roughly). At extensive aquatories of the northern shelf from 174°E to 174°W there are distributed about 6%, and in the central part of the sea outside 3 km isobath - not more than 1% of the whole abundance.

Approximately this way, the larvae were distributed excluding the Bogoslof Island area, where they were few, nearing 0.3%. The densest larvae concentrations were situated in the south-eastern part of the sea. At the relatively small aquatory of the Pribyloff-Unimak shelf more than 80% of all registered larvae are distributed, in Olyutorsky and Karaginsky Gulfs - 2.5%, in the northern areas - 2.9%, and over deep waters outside 3 km isobath - as little as 0.8%.

In the Asian waters about 70% of eggs and larvae are concentrated in Olyutorsky and Karaginsky Gulfs, and in American waters - more than 90% of eggs are distributed in the south-esatern part and more than 80% of larvae - at the Unimak-Pribyloff shelf. The eggs laid off Bogoslof Island over the depths 1 - 3 km is carried by dominant currents towards the shelf at the east and north-east as it matures. Such a drift existence is proven by the surveys carried out in 1984 and 1989.

The overall distribution of fingerlings and yearlings was studied in 1987 and 1988. The fingerlings born in 1987 are distributed all over the shelf in American waters, but about 75% of their total abundance concentrated at the south-esatern shelf (Unimak-Pribyloff Islands). In the area adjacent to St. Matthew Island 22% were distributed and in the waters adjacent to the USSR zone - only 3% of the registered abundance. The fingerlings of the same year-class were distributed primarily in the north of the U.S. zone - only 3% of the registered abundance. The fingerlings of the same year-class were distributed primarily in the north of the U.S. zone in spring 1988. At the St.Matthew shelf more than 60% of the total abundance were registered, but at the main spawning places to the south of Pribyloff Islands - only 31 %. The distribution of yearlings' (1+) and two-year-olds' (2) of the 1986 year-class is even more demonstrative. More than 83% of individuals aged 1+ were concentrated in 1987 at the sea's northern shelf, at the aquatory between St.Matthew Island and Navarin Cape, and only 17% - in the Pribyloff-Unimak area. In spring 1988 more than 90% of two-year-olds of the same year-class were distributed at the northern shelf in the U.S.-U.S.S.R. adjacent waters, and only about 1% - to the south of Pribyloff Islands. Thus, in the process of development and growth from eggs to two-year-olds there takes place active and passive migration of walleye pollock to the north-west from American spawning places along the outer shelf towards Navarin Cape with the following exit into the U.S.S.R. zone.

In the Asian waters such migration of the juveniles can not be traced. As the eggs develops, it is partially carried from Olyutorsky Gulf to the south-west. The larvae are concentrated primarily in Korf Gulf and Litke Strait (64% of the overall abundance). Here the majority of fingerlings is distributed as well (79%), but the yearlings return back to Olyutorsky Gulf. At the same time, there is the eggs and larvae drift from the Olyutorsky-Navarin shelf area (170 - 176°E) to the south-west. The abundance of two first age groups (0+, 1+) in the said area decreases to o.1 - 0.6%, but the eggs and larvae here comprise 15 - 17% of the overall abundance at the Asian shelf.

The senior walleye pollock after spawning in summer and fall is distributed all over the sea, forming several concentrations of different density. For example, in September - October 1987 there were two large concentrations discovered: one at the outer shelf and partially at the slope of the northern sea area, in the U.S. - U.S.S.R. adjacent waters, and the second one - over the Komandor Basin and the Shirshov Ridge southern part. Several smaller concentrations were situated at the North-Western Bering Sea shelf to the west of 176°E. The first of the large concentrations consisted of immature individuals sized 18 - 36 cm (75 - 87% of the overall abundance), the second one - of fish sized 44 - 52 cm (82 - 88 %) which had spawned many times. The spatial size-age structure of feeding walleye pollock is very well illustrated by the data on the relative abundance distribution of size groups (see Table 1).

Over the deep-water basins there concentrate more than 93% of the overall abundance of the mature walleye pollock of 44 - 52 cm size group, and at the shelf of the sea's northern part - more than 95% of 2 - 4 -year-olds (18 - 36 cm). The same approximate correlation is preserved for biomass characteristics. So it is necessary to underline that the Bogoslof Island spawning concentration exclusively consists of large individuals sized 44 - 52 cm, which are also dominant in all pelagic concentrations over Komandor and Aleutian Basins. At the shelf spawning places off Pribyloff and Unimak Islands the 36 - 42 cm size

Table 1. Relative abundance of walleye pollock in the Bering Sea (1987 surveys, %)

Size groups, cm / Areas	18-36	36-44	44-52	52-60	> 60
SHELF & SLOPE					
1.Olyutorsky & Karaginsky	0.6	5.0	0.9	1.1	-
2.Olyutorsky-Navarin (170 - 176°E)	1.6	7.8	1.2	1.1	2.4
3.Navarin	16.2	20.1	2.4	28.5	65.9
4.St.Matthew	79.1	49.5	2.0	12.1	14.6
5.Pribyloff-Unimak	2.5	1.6	0.1	5.8	17.1
DEPTHS MORE THAN 1000M					
6.Komandor Basin	0.1	9.2	62.7	37.2	-
7.Aleutian Basin	0.1	6.8	30.7	14.2	-
Including neutral waters	0.1	2.9	16.2	5.3	-
TOTAL, %	100.0	100.0	100.0	100.0	100.0

groups are dominant, the majority of which takes part in spawning for the first time. In the areas to the north of Pribyloff Islands extending into the U.S.S.R. zone. The concentrations consist of immature individuals with dominant sizes up to 39 cm, which agrees with the absence of spawning here.

The revealed peculiarities of the size-age structure in the spawning period together with the seasonal variation of distribution provide a reliable basis for the migrating walleye pollock differentiation by reproduction areas.

The repeated surveys in 1987 revealed the shift in the large walleye pollock aggregation over the Komandor Basin towards the east. In September it was situated in the south-eastern basin, at the south-western slopes of Shirshov Ridge (its axis being at 170°E). In October the aggregation shifted to the ridge's eastern slopes with distribution over the neutral waters aquatory. The pelagic walleye pollock's eastward migration is proven by the consecutive dislocation shifting of the Soviet commercial fishing fleet in 1988 - 1989. In September the highest catches were observed over the southern Shirshov Ridge, and then the fishing squares consecutively shifted to the west across the Aleutian Basin. In December and January the maximum concentrations were located at first in the western part of neutral waters, and then - in the south-eastern part. At the same time, some part of walleye pollock shifted to the west towards Ozyorny Gulf, and to the north along the eastern slopes of Shirshov Ridge and then to the east along the outer shelf and continental slope. Those details of the distribution consecutive variation were distinctly traced by the commercial fishing fleet dislocation in fall and winter 1986 - 1989. The mature walleye pollock concentration (44 - 52 cm) in February right before the spawning in the south-eastern part of neutral waters was confirmed by R/V "Kayo-Maru" survey in 1990 in which the author took part. In the same area the joint commercial fleet (42 vessels of Japan, South Korea, Taiwan) also operated.

We were also able to trace the exit of walleye pollock out of the U.S. zone into the south-eastern part of neutral waters in April 1989 and its further migration to the north-west along the slope. In June the Soviet fishing fleet operated in the northern part of neutral triangle and after that - in the U.S.S.R. zone.

The walleye pollock that left the U.S. zone in April, consisted of the individuals sized more than 40 cm, the size group 45 - 50 cm dominating, which was characteristic of the Bogoslof spawning place walleye pollock. The walleye pollock migrating to the north along the neutral waters eastern border was smaller. Its size composition is characteristic of the walleye pollock spawning at the Pribyloff-Unimak spawning places, the dominant sizes practically identical (36 - 41 cm).

On the basis of the size-age structure spatial-temporal variance analysis, the chart of the Bering Sea walleye pollock migrations is drawn (which is shown at Fig.1 in the generalized form). The locations of the largest spawning places, migrations' routes in the first years, the juveniles' habitation areas, pre-spawning and after-spawning migrations of mature individuals and areas of their concentrations are shown. The walleye pollock spawning off Bogoslof Island migrates to the north-west and becomes widely distributed over the aquatories of Aleutian and Komandor Basins. The Pribyloff-Unimak walleye pollock migrates to the north along the outer shelf and slope, gradually comes out of the shelf area and is distributed over the basin itself. The walleye pollock of ultimate size groups (52 - 60 cm and more) does not go out of the shelf area. After spawning, it migrates to the north and to the upper shelf simultaneously, the largest individuals coming to the minimal depth,

The fingerlings and yearlings of American origin in the process of growth migrate to the north and inhabit the Navarin - Matthew shelf until reaching the sexual maturity, in winter seasonally migrating to the upper slope and at the same time to the south towards Pribyloff Islands and vice versa. The individuals reaching maturity for the first time (36 - 46 cm) spawn at the Pribyloff-Unimak shelf, and the fish spawning repeatedly (44 - 52 cm) are concentrated over big depths off Bogoslof Island during the spawning. The spawning of those two large size-spawning groups takes place with approximately 1-month interval. The spawning peak off Bogoslof Island is in late February - early March, at the Unimak-Pribyloff shelf - in the first decade of April.

The walleye pollock yearlings, two-year-olds and the fish spawning for the first time (of the Asian spawning) do not do any northward migrations along the shelf, they concentrate nearby their spawning places, primarily in Karaginsky and Olyutorsky Gulfs. The seasonal character of their distribution varies according to the "shelf - continental slope" pattern. The large-sized walleye pollock of multi-spawning dominant 44 - 52 cm size group feeds over Komandor Basin, where it mixes with the walleye pollock of American origin. It goes out into the open waters primarily along the Shirshov Ridge.

The concentration of pre-spawning pelagic walleye pollock in the open waters starts in late August - September over the south-eastern Komandor Basin at first, and then - at the adjacent aquatory of Aleutian Basin, including neutral zone. In October - February the American walleye pollock gradually migrates to the east, as its sex products mature, and in February - March it concentrates at the spawning places off Bogoslof Island. The smaller-sized walleye pollock migrates to the east along the continental slope of the sea's northern part, and in April - May it forms pre-spawning and spawning concentrations at the Pribyloff-Unimak shelf. The Asian walleye pollock in its pre-spawning period (December -

March) concentrates over the continental slope of Ozyorny and Karaginsky Gulfs and migrates for spawning to Olyutorsky Gulf.

The distribution of the walleye pollock size-age groups in winter - spring period (pre-spawning and spawning) which are differentiated by sexual maturity (the size of fish maturing for the first time is 36 cm, 44 cm is the length when 50% matures), is highly informative for the populational composition studies. As it is shown above, at the Bogoslof Island spawning place there are no immature individuals (smaller than 36 cm), no fish of ultimate age, size exceeding 58 cm (or in small quantities). In Pribyloff -Unimak area also there is almost no walleye pollock sized less than 36 cm, and there is a distinct deficit of fish sized 44 - 52 cm which are dominant at the Bogoslof Island spawning place. The individuals sized 38 - 44 cm are prevailing here, and the senior individuals (more than 58 cm) are in normal correlation. At the aquatory to the south-west from Pribyloff Islands and at the adjacent Navarin shelf the walleye pollock sized 38 - 40 cm, immature walleye pollock or the fish reached maturity for the first time are represented most completely. The yearlings and two-year-olds practically absent at the spawning places are concentrated here. Thus, all groups cited above, which are inter-annually stable are the parts of the united Eastern Bering Sea population. In the feeding period the fish widens its areal covering the whole Aleutian Basin and partly - Komandor Basin. In connection to this kind of distribution it is necessary for the correct stocks assessment to search for the methods of abundance (biomass) estimation of all size-age groups and to determine the overall age composition which would take into consideration their correlation.

In the Asian waters to the east of 176°E, the areas of eggs, larvae, juveniles and producers distribution are practically similar. Consequently, another population, independent of the Eastern Bering Sea one, is distributed here. This one is less-migrating and more attached to the places of reproduction. This peculiarity seems to be determined by considerably lower abundance and better food provision.

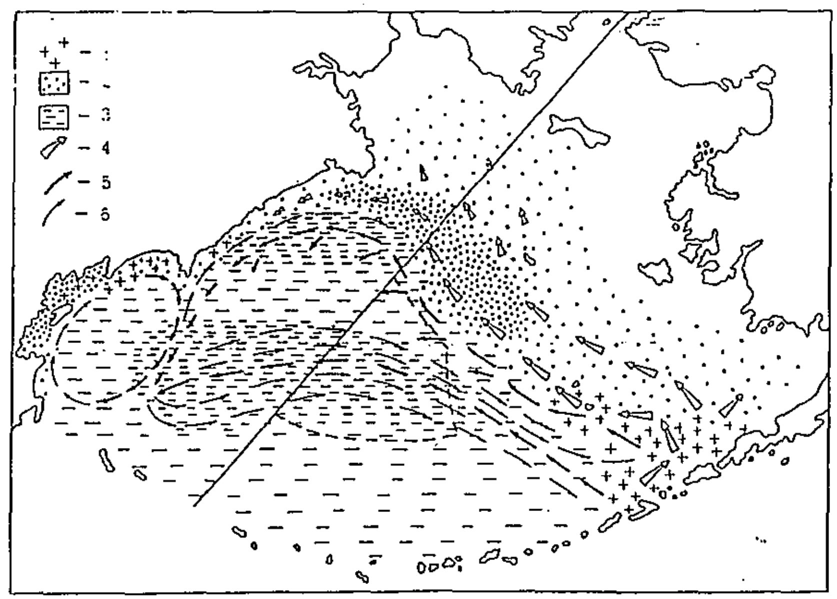

Fig. 1. Principal chart of the walleye pollock migrations in the Bering Sea.

1.spawning places; 2.juveniles' distribution (1-4 years old); 3. feeding walleye pollock distribution (more than 5 years old); 4. larvae drift, yearlings and two-year-olds migrations; 5,6.after-spawning and pre-spawning migrations of mature walleye pollock. The density of colouring corresponds to the quantitative distribution.

The Monitoring of the Humpy Shrimp (Pandalus goniurus) stock in the Bering Sea

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The humpy shrimp (*Pandalus goniurus*) are the most abundant shrimp species on the shelf of the western Bering Sea. The catches of the species reach up to dozen tons per half hour. But their abundance fluctuatesv very much, from about 1 million tons to few thousand tons. The flucyuations make a task of the shrimp stock monitoring very important. To get the fish industry ready for shrimp harvesting in advance we should know about the first evidences of the shrimp stock improvement. Hence, the stock monitoring is to be conducted continiuosly, not only during periods of high abundance, but in poor years too.

In 1988 at the similar symposium in Sitka, Alaska, we tried to draw the attention of fishery biologists to "Spline Survey Designer Software System" (SSDSS) developed in VNIRO (Stolyarenko, 1987) for mapping the distribution, computing the stock and designing the surveys. The software system is more advanced compared with the conventional random stratified method or, even more so, with widely used method of evenly distributed trawl stations in fish surveys. SSDSS is more advantageous compared with the methods both in relation to stock computing and survey design. The SSDSS design consists of two stages: (1) frame design (about 70% of all stations) and (2) adaptive design (about 30% of the trawl stations). The trawl stations which are reserved for the adaptive design are used during the survey to make corrections into exploration taking into account real survey situation. In 1988 only application of the SSDSS for full scale specific survey was described.

But in poor years the full scale shrimp surveys are unlikely because they are too costly. Fishery managers do not agree usually to pay their money for studying the shrimps in poor years. Taking into consideration that the monitoring of shrimp stock is desirable even in poor years, only limited number of trawl stations can be made for the monitoring. Approximately 10-20 stations seem to be realistic in such reduced surveys which are, as a rule, a part of multispecies explorations. Naturally the random distribution of few trawl stations in the reduced surveys is not reasonable. It is much more wisely to concentrate research efforts in the most informative and promising areas.

To define these areas maps of average catch distribution based on long term series observations were computed by means of the SSDSS. The maps were made for three areas in the western Bering Sea (the Anadyr Bay, Cape Navarin area and area off South Koryak coast) and for two seasons (spring - early summer and late summer - autumn) (Figs.1-6). The maps of average catches reflect the results of observations made in 1967-1985. But for survey design of future expeditions distributional maps of the survey importance function are of great value. The maps (Figs.7-12) lead fishery biologists (experts) to explore both areas with high values of average annual catches and areas with high variability of the catches (Stolyarenko, 1987; Stolyarenko, Ivanov, 1987, 1988). The SSDSS can provide the expert biologists with survey design dealing with any possible number of trawl stations ([illegible] 10-20 in poor years instead of [illegible] 100 in rich years). The design is based on two principles: (1) the density of trawl station distribution is proportional to the survey importance function, i.e. maximum number of trawls will be input in areas with high catces and in areas with highly variable catches; and (2) the stations will be distributed randomly.

The combination of random distribution and using of our knowledge on shrimp distribution in the preceding years (i.e. concentration of efforts in the most prospecting areas) is an advantageous feature of the SSDSS. Thus, the method of spline approximation of stock density can be used both for full scale surveys (e.g. in rich years, with trawl station number ca. > 100) and for reduced surveys (for monitoring of stockin poor years; with number of stations ca. 10-20).

Of course, the method can be applied not only to shrimp surveys. It has been already sussessfully used in surveys of wide range of biological species, including such fishes as cod and ocean perch in the North West Atlantic. Seemingly, the method can be applied to Alaska pollock stock surveys in the Bering Sea. Conventional survey design used widely up to date in the pollock stock studies is based on evenly distributed trawl stations. The design seems to be too wasteable and does not adequate to thecomputer level.

(Complete report will be published in the Proceedings of the Symposium)

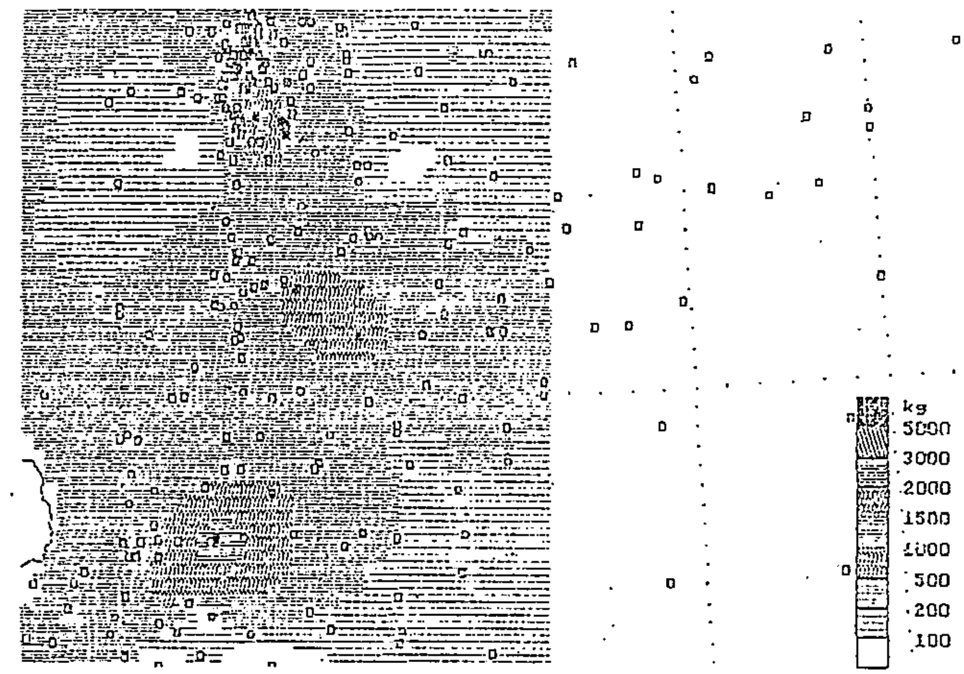

Рис.I. Анадырский залив. Средние многолетние уловы в весене-летний сезон.
Fig.1. The Anadyr Bay. The average catches estimated on long term series observations. for spring-early summer season.

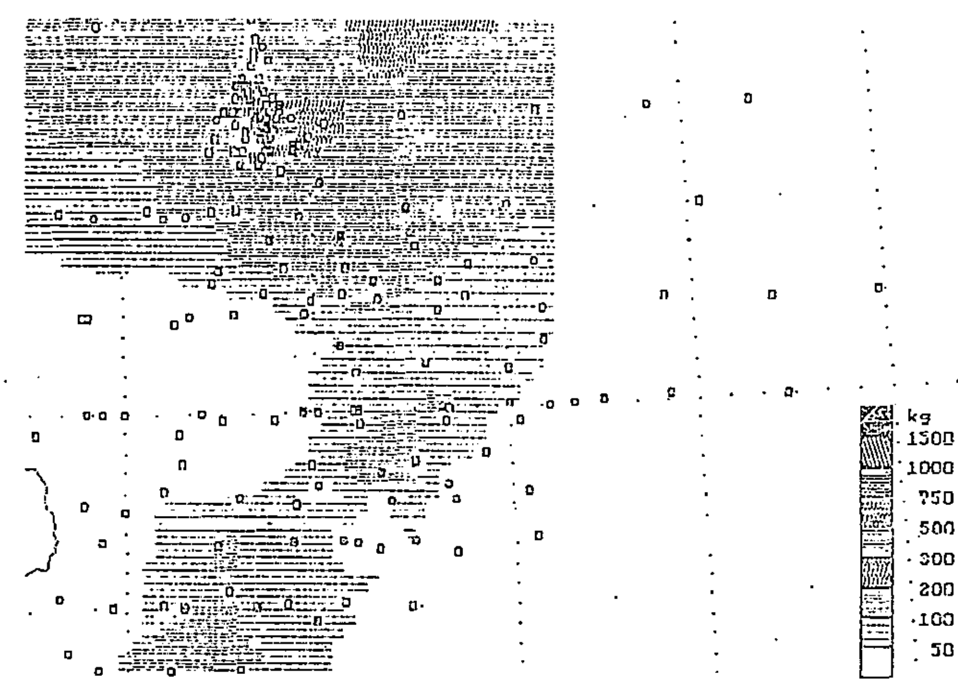

Рис.2. Анадырский залив. Средние многолетние уловы в летне-осенний период.
Fig.2. The Anadyr Bay. The average catches estimated on long term observations for summer-autumn season.

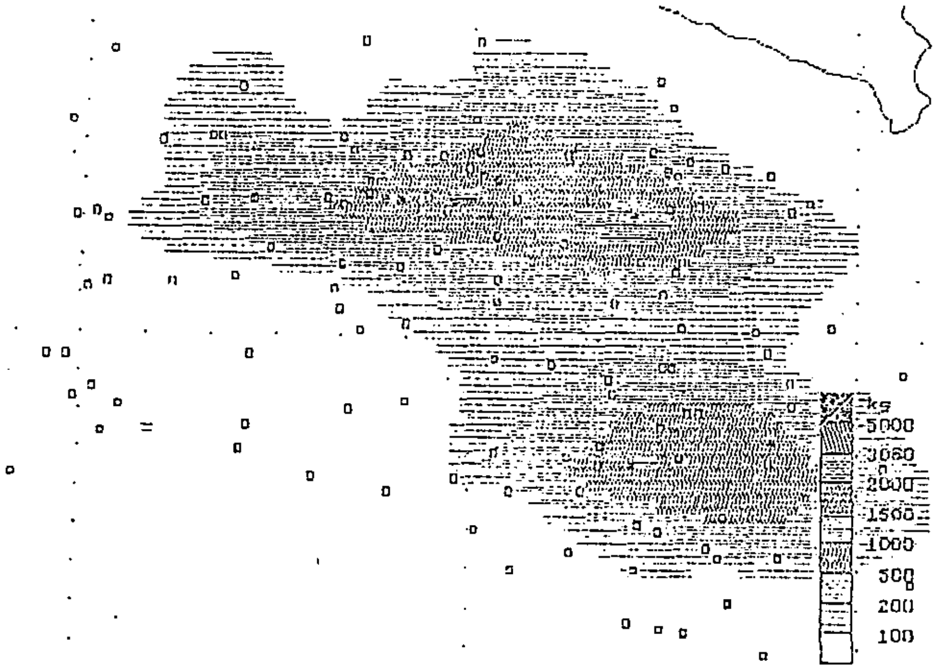

Рис.3. Наваринский район. Распределение средних многолетних уловов в весенне-летний период.
Fig.3. The area off Cape Navarin. The average catches estimated on long term series observations for spring-early summer season.

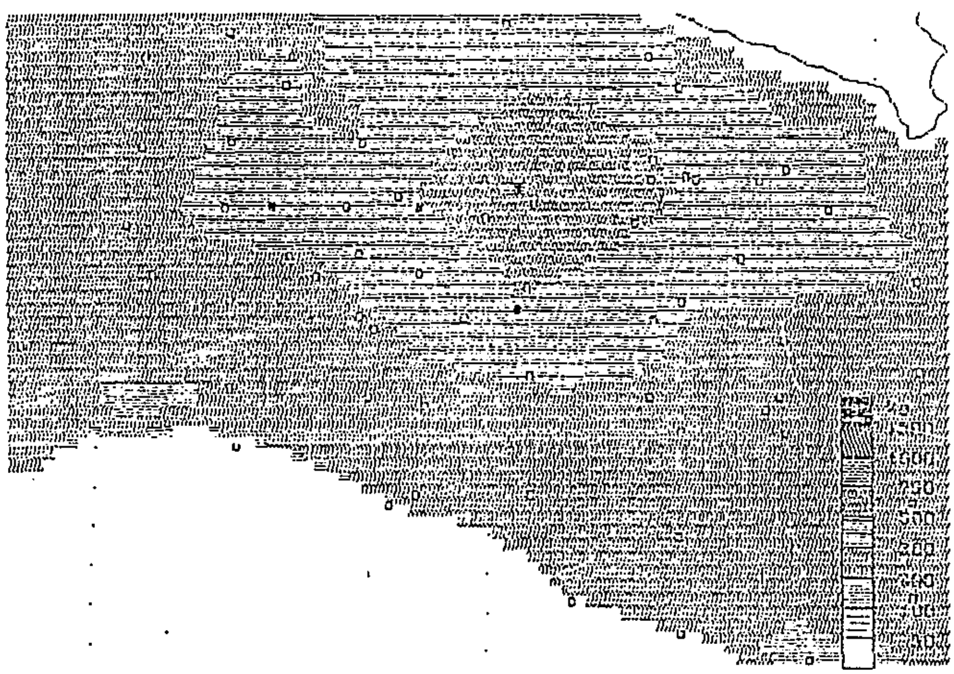

Рис.4. Наваринский район. Распределение средних многолетних уловов в летне-осенний период
Fig.4. The area off Cape Navarin. The average catches estimated on long term series observations for late summer-autumn season.

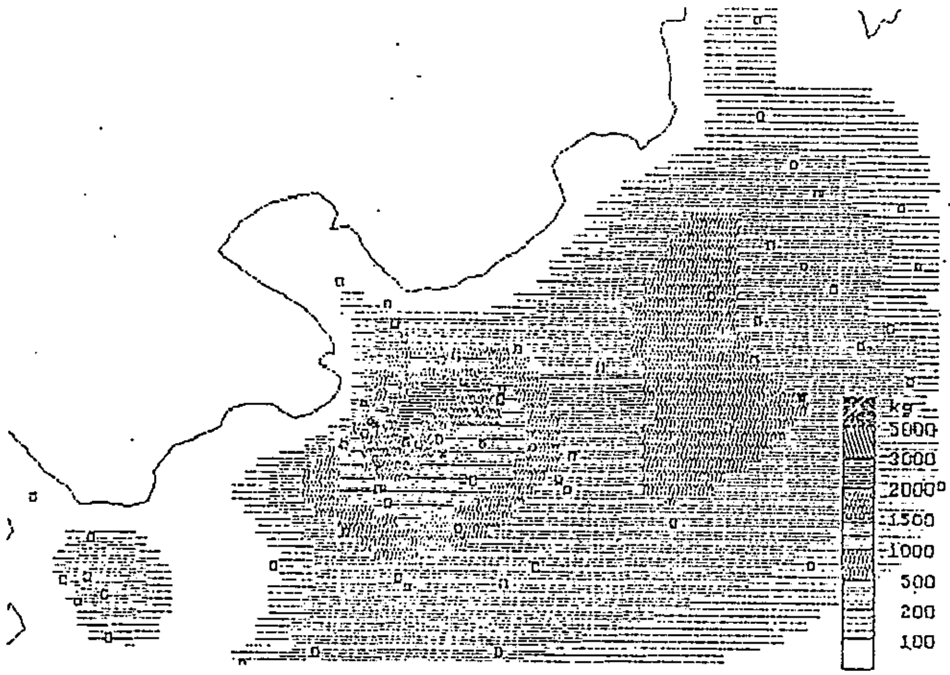

Рис.5. Южно-Корякский район7 Распре деление средних многолетних уловов в весенне-летний период.
Fig.5. The area off South Koryak Coast. The average catches estimated on long term series observations for spring-early summer season.

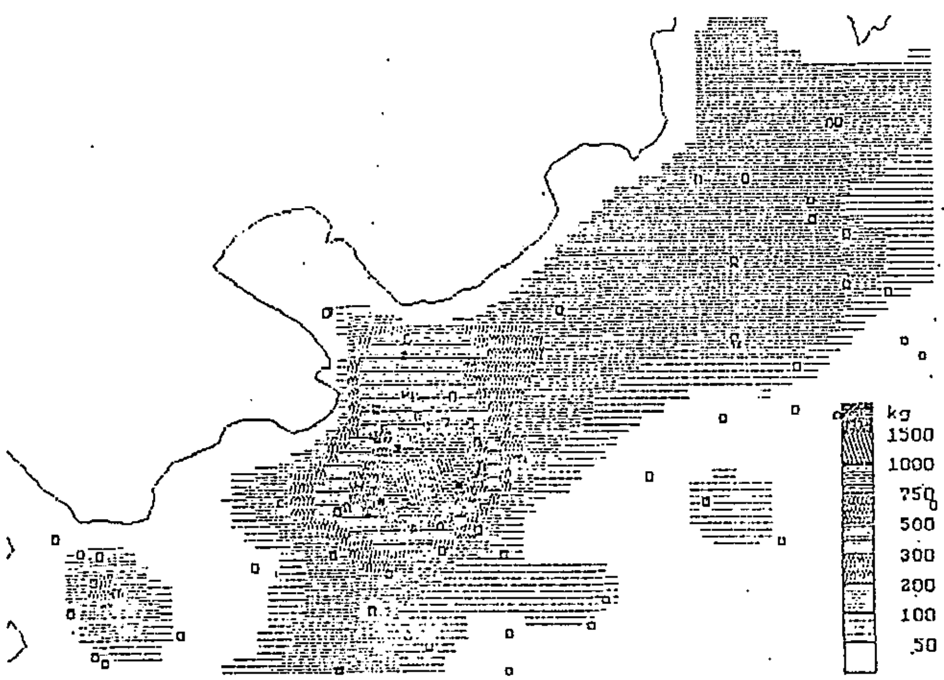

Рис.6. Распределение средних многолетних уловов в Южно-Корякском районе в весенне-летний период.
Fig.6. The area off South Koryak coast. The average catches estimated on long term series observations for summer-early autumn season.

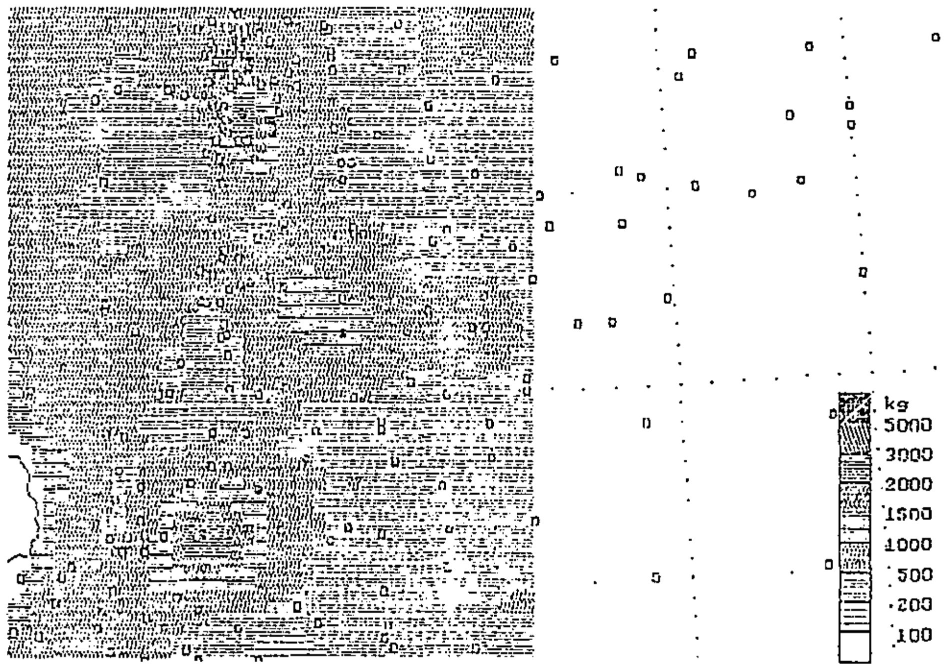

Рис.7. Анадырский залив. Распределение функции важности в весенне-летний период.
Fig.7. The Anadyr Bay. The distribution of function of survey importance for spring-early summer season.

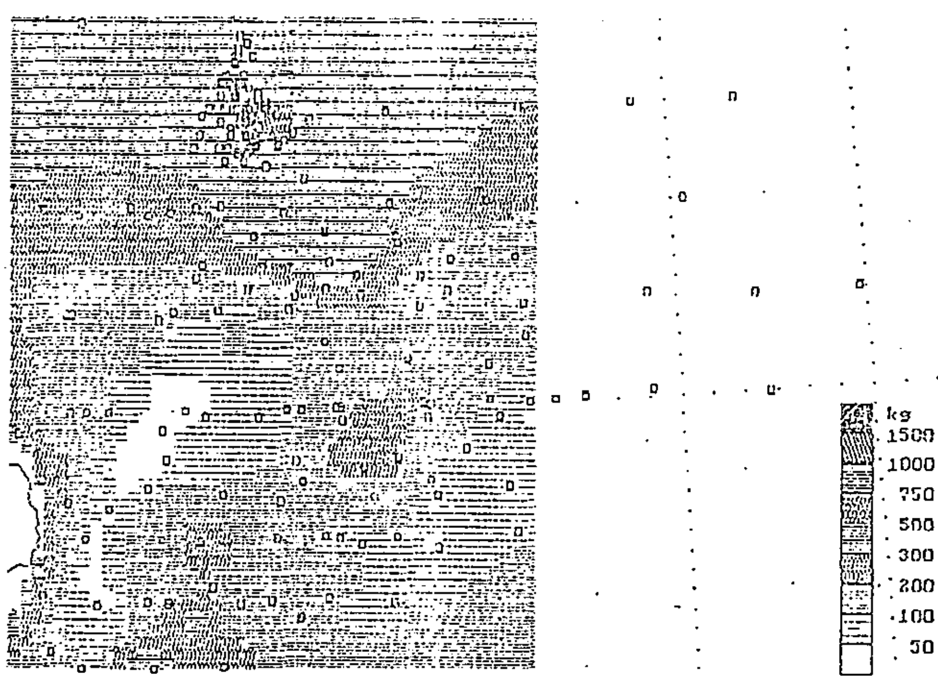

Рис.8. Анадырский залив. Распределение функции важности в летне-осенний период
Fig.8. The Anadyr Bay. The distribution of survey importance function for summer-early autumn season .

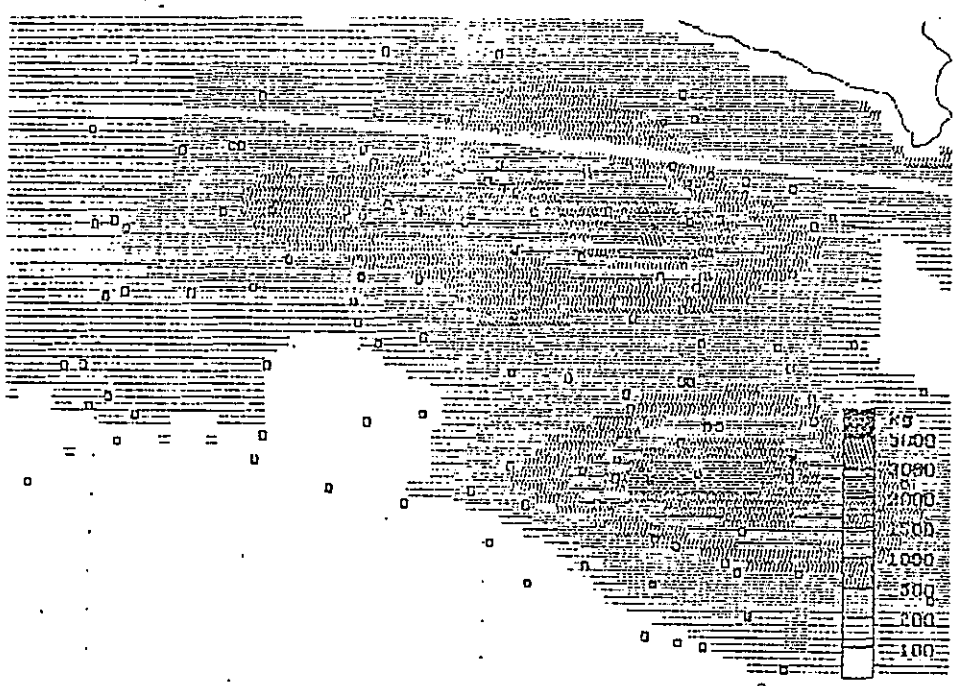

Рис.9. Наваринский район. Распределение функции важности в весенне-летний период.
Fig.9. The area off Cape Navarin. The distribution of survey importance function for spring-early summer season.

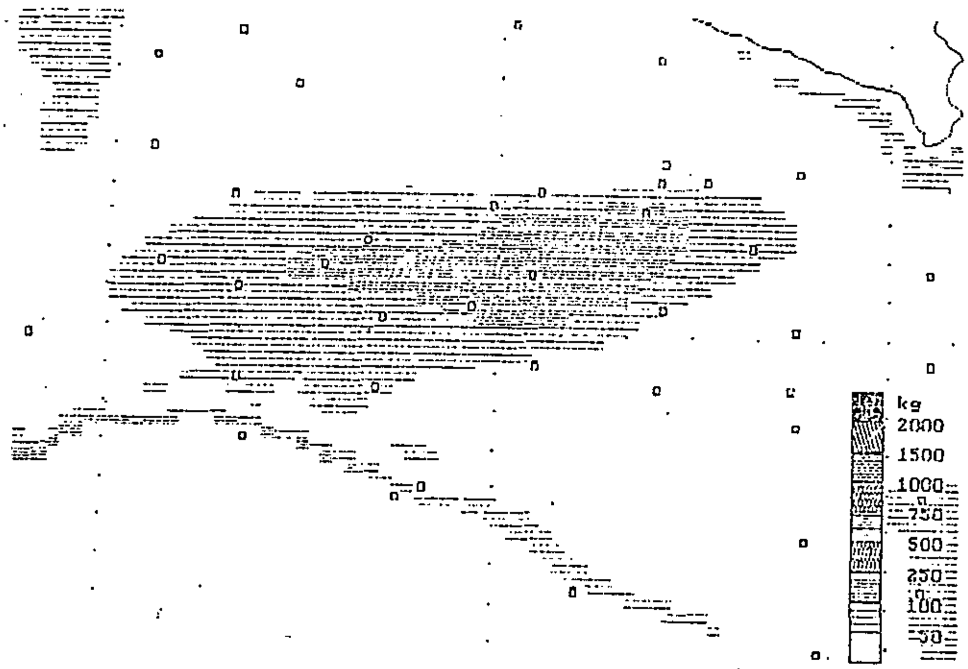

Рис.10. Наваринский район. Распределение функции важности в осенне-летний период.
Fig. 10. The area off Cape Navarin. The distribution of survey importance function for summer-early autumn season.

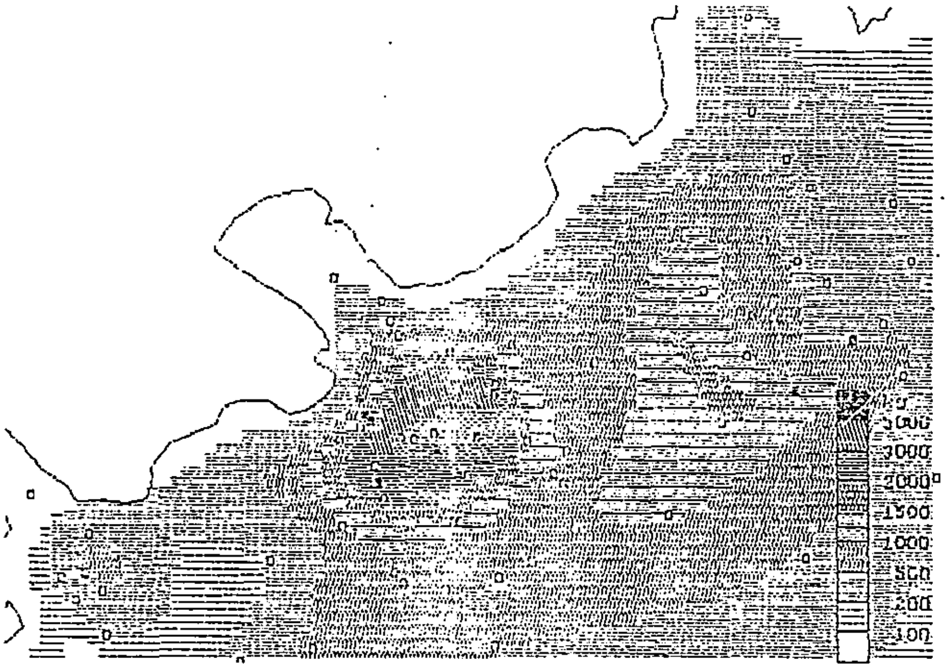

Рис.II. Южно-Корякский район. Распределение функции важности в весенне-летний период.

Fig.11. The area off South Koryak coast. The distribution of survey importance function for spring-early summer season.

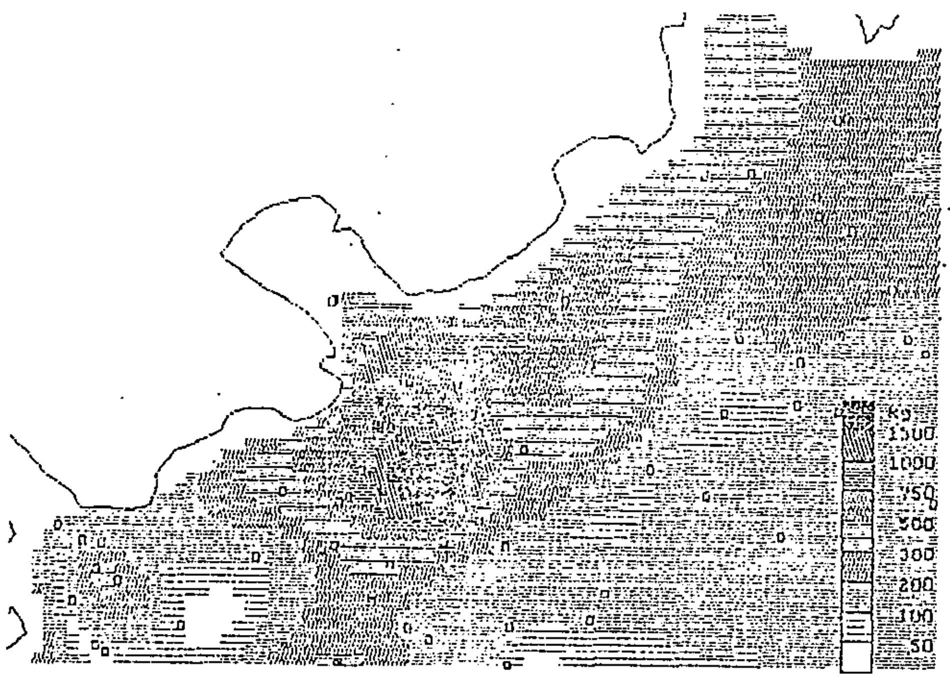

Рис.I2. Южно-Корякский район. Распределение функции важности в летне-осенний период.

Fig.12. The area off South Koryak coast. The distribution of survey importance function for summer-early autumn season.

Structure and Functioning of Ichthyocoenosis of Epipelagial of the Bering Sea

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The surveys of the last years revealed the leading role of pelagial of open waters in forming the Bering sea fish productivity. In fall considerable aggregations of feeding mature pollock were found in waters of the deep-water Basins forming in the process of large-scale migrations from the spawning areas and back. The share of pollock in epipelagic ichthyomass of the western Bering sea is 90-95%, which was estimated to be 6,6-7,6 mln.t in 1986-1987.

Ichthyocoenosis of epipelagial of the Bering sea was characterized by stability of qualitative and quantitative composition in 1986-1987. The share of some fish species in total ichthyomass did not vary much when conducting estimate surveys in the summer-fall period 1986-1988. Seasonal dynamics is more clear. The densest aggregations of pollock are located within the limits of low part of the shelf and continental slope in spring-early summer that determines decrease of ichthyomass in open waters. The biomass of herring, all kinds of salmon, feeding primarily beyond the limits of the survey area, is characterized by less values. The share of lumpsucker is increased migrating to the open part of the sea from spawning areas in littaral zone. Redistribution of ichthyomass within the system of -shelf-continental slope--open waters- takes place primarily due to feeding migration of mature pollock to the Kommander and Aleutian Basins.

Wide food spectrum of pollock allows it to develop food resources of epipelagial quite intensively. Eating away non-predator zooplankton by predatory plankton and nekton often exceeds its production 2-3 times and more in the area of the continental slope and open part of the sea in late fall. This imbalance is increased in the winter season. Due to this fact intense food relations are observed in epipelagial of the Korfo-Karaginskiy area.

Total zooplankton biomass in 0-200m layer is estimated to be 87-95 mln.t in the fall period. Its basis is represented by plankters-euryphages. Distribution of plankton biomass is less homogeneous than that of ichthyomass (from 4 up to 372 gr/m^2 in different sea areas). It is subjected to seasonal dynamics. The highest zooplankton production was observed in the Navarinskiy, Anadyrskiy, Korfo-Karaginskiy areas in August-September 1987 and only in the Navarinskiy area - in September-October, 1986. The zooplankton production had negative meanings over the entire area of the western part of the sea in November-December, 1986. The share of predatory zooplankton, having an important role in eating away euryphages, can be estimated to be 35-40% of plankton biomass in epipelagial of the open part of the sea.

At present the biomass of organisms of highest trophic level (Pinnipedia, Cetacean) is estimated to be 240-270 and 520-720 thousand tons respectively. It is significantly less than that it was prior to large-scale fisheries in the Bering sea waters (330-370 and 1120-1600 thnd t) Eating away food objects by such animals is estimated to be 8250-9870 thnd t, including 1750-2200 thnd t of fish.

Harvest Levels for Bering Sea Pollock

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ABSTRACT

Concerns over the impacts of walleye pollock (Theragra chalcogramma) fisheries in the central Bering Sea on U.S. and U.S.S.R. stocks have prompted the U.S. and U.S.S.R. to initiate discussions to develop a scientific basis for their regulation. At a November 1989 bilateral meeting of fisheries scientists from the two countries and a follow-up meeting of the U.S.-U.S.S.R. Bering Sea Fisheries Advisory Body, the scientists concluded that the pollock stocks in the Bering Sea have been very intensively harvested and suggested an appropriate harvest level for the resource. They concluded that an appropriate exploitation rate for pollock is 25% and that the allowable harvest level for the Bering Sea pollock resource should not exceed 2.63 million t for 1990. The purpose of this paper is to discuss the data and other technical basis that led to these conclusions.

Harvest Levels for Bering Sea Pollock

by

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INTRODUCTION

Pollock (Theragra chalcogramma) is the most abundant species harvested in the Bering Sea. Since the early 1960s, significant fisheries for pollock have taken place in the eastern and western Bering Sea, and the Aleutian Islands region. These areas have supported the traditional fisheries within the exclusive economic zones (EEZs) of the United States (U.S.) and the Union of Soviet Socialist Republics (U.S.S.R.). In the early 1980s, a new fishery has developed in the central Bering Sea. This area which lies outside the U.S. and U.S.S.R. EEZs is commonly known as the "donut hole" area.

The pollock fisheries in the donut hole area have been of great concern to the U.S. and U.S.S.R. because they intercept pollock stocks migrating through the area from the neighboring EEZs. The donut hole catches are now very large and the fisheries are unregulated. Concerns over the impacts of these fisheries on U.S. and U.S.S.R. stocks have prompted the U.S. and U.S.S.R. to initiate discussions to develop a scientific basis for their regulation. At a November 1989 bilateral meeting of fisheries scientists from the two countries and a follow-up meeting of the U.S.-U.S.S.R. Bering Sea Fisheries Advisory Body (BSFAB), the scientists concluded that the pollock stocks in the Bering Sea have been very intensively harvested and suggested an appropriate harvest level for the resources. The purpose of this paper is to discuss the data and other technical basis that led to these conclusions.

THE AREA AND FISHERIES

The donut hole area is bounded by the outer limits of the U.S. and U.S.S.R. 200-mile EEZs (Fig. 1). It is located in the deep Aleutian Basin, an area of the Bering Sea having depths exceeding 1,000 m. The Basin has an area of approximately 292,000 nm^2 and is bisected by the U.S-Russia Convention Line established in 1867. Approximately 43% (126,000 nm^2) of the

Aleutian Basin lies in the U.S. EEZ and 38% (111,000 nm^2) in the U.S.S.R. EEZ. The donut hole makes up the remaining 19% (55,000 nm^2) of the Basin.

Figure 2 shows the major areas of pollock fisheries in the Bering Sea. In the U.S. EEZ, fisheries have operated mainly on the eastern Bering Sea (EBS) continental shelf and slope, in the Bogoslof Island area, and in the Aleutian region. The fisheries in the U.S.S.R. EEZ have operated mainly on the western Bering Sea continental shelf and slope. The new fisheries in the donut hole area have principally fished the southern portion of the area.

Five countries conduct pollock fisheries in the donut hole area -- Japan, Republic of Korea, Poland, People's Republic of China, and the U.S.S.R. Catches (in thousands of t) from the donut hole are compared with those from the U.S. and U.S.S.R. EEZs:

Year	Donut Hole	U.S.S.R. EEZ	U.S EEZ	Total
1980	15	-	958	973
1981	-	-	974	974
1982	4	-	956	960
1983	71	-	982	1,053
1984	181	756	1,099	2,036
1985	336	662	1,179	2,177
1986	1,061	838	1,189	3,088
1987	1,437	688	1,254	3,379
1988	1,469	1,253	1,228	3,950

The pollock harvest from the donut hole area amounted to 1.47 million metric tons (t) in 1988. This exceeds those taken in the traditional fishing areas of the U.S. EEZ (1.23 million t) and the U.S.S.R. EEZ (1.25 million t).

BERING SEA ADVISORY BODY FINDINGS

A scientific advisory body, known as the Bering Sea Fisheries Advisory Body (BSFAB) was formed by the U.S.-U.S.S.R. Intergovernmental Consultative Fisheries Committee to review the technical basis for regulations, including an appropriate harvest level (AHL) for pollock fisheries in the Bering Sea. The BSFAB met in November 1989 and determined the following points with regards to establishing an AHL for the fisheries:

a. BSFAB found that a 25% exploitation rate is appropriate for the pollock resource in the Bering Sea.

b. BSFAB projected that the 1990 biomass of pollock for the entire Bering Sea to be 10,530,000 t and its corresponding AHL to be 2,632,500 t.

APPROPRIATE RATE OF EXPLOITATION

The appropriate level of exploitation depends upon the population characteristics of the species and the status of the stocks. The Bering Sea groundfish Plan Team of the North Pacific Fishery Management Council (NPFMC) has adopted general guidelines for the exploitation of Bering Sea pollock stocks as follows (NPFMC 1989):

1. When the condition of the stock is excellent (e.g., when the biomass is far above B_{msy}), an exploitation rate corresponding to F_{max} is used.

2. When the condition of the stock is good (e.g, when the biomass is near B_{msy} and stable or increasing), an exploitation rate corresponding to F_{msy} is used.

3. When the condition of the stock is fair (e.g, when the biomass is near B_{msy} and decreasing), an exploitation rate corresponding to the minimum of F_{msy} and $F_{0.1}$ is used.

4. When the condition of the stock is poor (e.g, when the biomass is far below B_{msy}), an exploitation rate sufficient to allow only for bycatch is used.

The most optimistic instantaneous rate of fishing mortality, F_{max}, is not applicable to pollock stocks in the EBS because the stock has not been in excellent condition. Therefore F_{max} has not been rigorously calculated. Moreover, this high exploitation rate is generally known to be non-sustainable for exploited fish populations.

The value of F_{msy} is dependent upon the spawner-recruit relationship. For the EBS pollock stock, Wespestad (1989) calculated F_{msy} by using a Ricker spawner-recruit model and two age-selectivity curves for pollock. Using a dome-shaped selectivity curve $F_{msy} = 0.77$ ($E = (F/(F+M)(1 - e^{-(F+M)})) = 0.44$). A lower value ($F_{msy} = 0.55$, $E = 0.37$) was calculated using an asymptotic selectivity curve.

Wespestad's (1989) estimates were later refined by Quinn et. al (1989), using essentially the same data. Quinn et. al determined that $F_{msy} = 0.31$ ($E = 0.25$). They also explored the threshold concept of exploiting pollock stocks and simulated varies fishing rates and harvesting strategies for the pollock stock. They concluded that the optimal threshold level for the pollock population ranged from 20 to 30 %, with a median of 25%.

They further simulated a unique combination of threshold level and fishing mortality and found that a fishing mortality slightly above F_{msy} would keep the population above the threshold level. Therefore an exploitation rate of 25% should be a sustainable long-tern goal.

The value of $F_{0.1}$ can be calculated to be either independent or dependent upon a spawner-recruit relationship. In the traditional Gulland and Boerema (1973) model, $F_{0.1}$ is calculated by the yield per recruit concept, and therefore, independent of the spawner-recruit relationship. This concept is also preferred by the NPFMC since a spawner-recruit relationship for pollock has not been clearly defined.

Using the yield per recruit concept, Wespestad (1989) calculated that $F_{0.1} = 0.31$ ($E = 0.25$) for the EBS pollock stock. This rate is similar to the long-term exploitation rate estimated by Quinn et al (1989). Considering that the EBS pollock stock is generally in good condition with current biomass near B_{msy}, but declining (Wespestad 1989), it is most appropriate to exploit this stock at a minimum of the F_{msy} and $F_{0.1}$ rate. Therefore, the most appropriate exploitation rate (F_{app}) for EBS pollock is 0.31 ($E_{app} = 0.25$).

However, based upon the reasoning advanced by Thompson (1989), there is a question whether the 25% exploitation rate is sustainable for pollock stocks. He considered the many uncertainties in parameter estimates that enter into the calculation of exploitation rates and examined these uncertainties in the context of Bayesian decision theory, and found that a sustainable exploitation rate lower than F_{msy} may have to be considered for all stocks in general.

STOCK STRUCTURE

While quantitative interactions between stocks in the entire Bering Sea may be somewhat uncertain, the broader picture of stock dominance and their interactions have been hypothesed. This topic was addressed at the International Symposium on the Biology and Management of walleye pollock held during November 14-16, 1988 and at a follow-up technical session on "stock structure and assessment workshop" moderated by Low (1989). Pertinent extracts of the summary are paraphrased as follows"

> "Dr. Stepanenko described the knowledge of the stocks in Soviet waters......The two largest populations in the northern Pacific Ocean are in the Okhotsk Sea and the Bering Sea....In the eastern part of the Soviet Union, south of Cape Navarin and the Olyutorskiy coast, there is only one stock......
>
> Dr. Maeda discussed a paper on the pollock stock structure at the western side of Hokkaido.....Japanese scientists conclude that the spawning stock is divided into three groups around Hokkaido: north, west, and southeast.....
>
> Dr. Low discussed stock structure for the eastern Bering Sea, where the northwest and southeast slope stocks are distinct.....The Aleutian stock may be separate, and possibly part of the Kommander Island stock referred by Dr. Stepanenko. The donut area of the Bering Sea may be a separate stock, or it may be part of all the other units.....It may be reasonable to assume there is one major stock in the eastern Bering Sea area, from a management point of view. In the western Bering Sea, the Olyutorskiy-Navarin area could be considered another major stock, and the Kommander Island area could be a third major stock. Pollock are spawning and appear to be migrating during the spawning season from the donut area into the U.S. Exclusive Economic Zone in an easterly and southeasterly direction. The Bogoslof area fish might represent part of this stock..."

At the November 1989 bilateral meeting between the U.S and the U.S.S.R. (BSFAB 1989), the

> "Soviet side believes that there are 2 pollock stocks in the Bering Sea, an Asian or western Bering Sea stock and an eastern Bering Sea stock. The pollock found in the central Bering Sea (referred to as the 'donut hole' by the U.S. side) are believed to be members of the western and eastern Bering Sea stocks that migrate through that area either to feed or to return to spawning grounds within an EEZ. The eastern Bering Sea stock consists chiefly of pollock that spawn in the regions of Bogoslof Island, Unimak Pass and the Pribilof Islands while the western Bering Sea stock is made up for the most part of pollock that spawn from Olyutorskiy Bay to Cape Navarin (Figure 3).
>
> The Soviet side stated that the pollock found in the deep water area of the central Bering Sea are a mixture of pollock from the western Bering Sea shelf and from the eastern Bering Sea (Figure 4). It is the migration of these fish back and forth to the spawning grounds in the U.S. EEZ that results in the apparent movement of pollock from west to east across the central Bering Sea during the fall and winter period. No spawning has been observed in the deep water portion of the western Bering Sea."

While the quantitative stock relationship between the Aleutian basin (in general) and that of the donut hole pollock (in particular) with that of the EBS may not be clear, the near absence of age 0 to 4 pollock in both research and commercial catches from the donut hole and the Basin suggested to Dawson (1989) that the Basin population is not a closed self-sustaining population.

When the age composition of pollock catches in the donut area are compared to those of the Aleutian Islands and Bogoslof Island areas at the southeastern extreme of the Aleutian Basin, they appear to be from the same group of fish. The catch in the Bogoslof area in 1987 and 1988 was primarily composed of age 9-10 fish from the 1978 year-class, similar to that from the Aleutian Islands and donut hole areas (Wespestad 1989). Observations on the progression of fisheries in 1988 suggested that fish left the donut hole area in February prior to spawning, migrated towards the Aleutian Islands-Bogoslof Island areas to spawn, and later returned to the central Bering Sea in a post spawning condition. The similarities in age composition and the appearance of movement in and out of the U.S. EEZ suggested that fisheries in the donut hole area and Aleutian Islands-Bogoslof Island areas were harvesting the same group of fish. The dominant age composition of these catches, however, very different from catches on the EBS shelf. In the EBS, younger fish as young as age 2 are significantly represented in catches.

In the BSFAB (1989) report, the

> "U.S. side presented the view that there may be two interrelated stocks of pollock in the eastern Bering Sea. One stock occupies the eastern Bering Sea shelf and the second occupies the Aleutian Basin. The principal spawning area for this Aleutian Basin stock is in the southeastern Aleutian Basin and at least since 1988 appears to be centered in the region of Bogoslof Island in the U.S. EEZ."

Based upon the discussion above, the pollock resource harvested in the donut hole is likely a mixture of Soviet and U.S. EEZ stocks. The percentage mix is not known, although Soviet scientists have suggested that about two-thirds of the pollock located in the donut hole originate from U.S. waters and about one-third from U.S.S.R. waters (BSFAB 1989).

Tagging studies on pollock have been difficult to conduct. Survival of tagged fish is low and recovery of tagged fish is unlikely. Out of more than 13,000 pollock tagged between 1966 and 1973, only 9 tagged fish were recovered. One was recovered in the donut hole, and this fish was tagged off Siberia in June 1973 and recovered 4 years later in July 1977.

Inferences from the pattern of spawning activities and oceanography suggest that much of the donut hole pollock must be originate from the U.S. EEZ (Hinckley 1987). During spawning, pollock tend to migrate in a southeasterly and easterly direction from the donut hole towards the Aleutians and the EBS. The ocean current pattern (Figure 5) suggests that the eggs and larvae must get swept onto the EBS shelf where they rear as juveniles and young adults. At these stages, they are inter-mixed with juveniles and adult pollock that resulted from spawning on the EBS shelf proper. At about age 5 or older, some of the adults that resulted from spawning in the Bogoslof Island area emigrate into the Aleutian Basin.

ESTIMATION OF EXPLOITABLE BIOMASS

For the purpose of biomass estimation, the following five major areas are considered--the eastern Bering Sea area, the Aleutian area, the Bogoslof Island area, the western Bering Sea area, and the Aleutian Basin area.

Eastern Bering Sea

The most detailed data for biomass estimation are from the EBS shelf and slope regions. The long 20-plus years of historical catch data, age composition data from the fisheries and research surveys, and estimates of growth and mortality from this region are sufficiently detailed to perform reliable age structured analyses. In addition, standardized trawl and hydro-acoustic surveys have been conducted to delineate distribution and estimate biomass of the stock.

Table 1 shows the biomass estimates from the EBS population from the standardized bottom-trawl surveys and combined bottom-trawl and hydroacoustic surveys. The combined surveys have been repeated triennially. The combined surveys provide biomass estimates of both the demersal and pelagic components of the stock. The 1979 combined surveys estimated the total EBS stock at 10.5 million t. In 1988, the estimated total biomass was 11.6 million t.

Several age-structured population dynamics models have been employed to assess pollock. The traditional cohort analysis model (Pope 1972) as well as the newer catch-age (CAGEAN) model by Deriso et al. (1985) have been used. Cohort analysis and CAGEAN models were "tuned" using auxiliary information based on the combined hydroacoustic and bottom-trawl surveys of EBS pollock from 1979, 1982, 1985 and 1988. The details of these analyses are given in Wespestad (1989).

Biomass estimates from the age structured models are presented in Table 1 and Figure 6. The analyses indicated that abundance was low around the time the fishery began in 1964 but then increased 4-6 fold in the following 8-9 years. The cohort analysis estimated peak abundance in 1971 at 10.0 million t. Following this peak, the biomass declined to a low of 4.0 million t in the late 1970s. From 1979 to 1983 the biomass increased, but has been declining in the most recent years following lower levels of recruitment in the early 1980s. The exploitable biomass (ages 3-9) was 8.0 million t in 1988. The CAGEAN model results are essentially the same as from cohort analysis.

The results of cohort analysis indicate that pollock have been exploited relatively lightly. Catch rates on age groups 3-9 have varied from 12 to 24% since 1979 as shown below:

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Biomass (million t)	4.01	4.01	7.09	7.77	7.39	7.28	9.03	8.41	8.26	7.99
Catch (million t)	0.91	0.96	0.97	0.96	0.98	1.10	1.18	1.19	1.24	1.23
Catch ratio	0.23	0.24	0.14	0.12	0.13	0.15	0.13	0.14	0.15	0.15

Aleutian Island Region

Survey effort has not been as extensive in the Aleutian region as in the EBS. Bottom trawl surveys were conducted in 1980, 1983 and 1986. These surveys estimated biomass at 397,362 t in 1980, 822,063 t in 1983, and 527,074 t in 1986. The estimates do not include mid-water pollock and therefore represent only a portion of the biomass. There is insufficient data to perform cohort analysis for the Aleutian Islands stock. Therefore, the best estimate of the current exploitable biomass for the Aleutian Islands region was 600,000 t based on 1986 trawl survey and assumptions of population trends between 1986 and 1990.

Bogoslof Island Area

Two hydroacoustic surveys were conducted in the Bogoslof Island area during January-March of 1988 and 1989. These surveys detected large concentrations of spawning pollock during February. The estimated biomass was about 2.5 million t in 1988. Preliminary results from the 1989 survey (Traynor 1990) indicates that the biomass had declined slightly to 2.1 million t.

Western Bering Sea

At the November 1989 U.S.-U.S.S.R. bilateral meeting (BSFAB 1989), Soviet scientists reported that estimates of the spawning stock biomass of pollock in the western Bering Sea has ranged from 1.2 to 2.5 million t. In 1988 the estimate ranged from 1.8 to 2.0 million t. These estimates refer primarily to age 4 and older pollock spawning on the western Bering Sea shelf in the spring. Not included is the biomass of pollock spawning in the region of the Komandorskiye Islands.

Aleutian Basin

Biomass levels reported for portions of the Aleutian Basin have been quite variable over time and are summarized in Table 3. The first U.S. quantitative trawl/acoustic survey of the donut hole occurred in February 1988 in the southern portion of this area where very few pollock were found. That same survey found 2.5 million t of pollock spawning in the vicinity of Bogoslof Island in 1988. In 1989 a cooperative U.S.-Japan trawl/acoustic survey of the entire Aleutian Basin east of the U.S.-U.S.S.R. convention line again found very few fish in the donut hole or anywhere outside of the Bogoslof Island area. Spawning was again substantial in the Bogoslof Island area, but preliminary information suggests that the spawning biomass was reduced from the 1988 level (Traynor 1990).

An attempt to estimate the biomass of the Aleutian Basin population using the cohort analysis procedure was performed by Horbowy and Janusz (1989). Their analysis produced an estimate of 12.8 million t for 1988 and suggest that the exploitation rate for Basin pollock was low (11.7%) in 1988.

Another attempt at estimating the biomass and allowable catch for the Aleutian Basin stock was performed by Mito (1989) using the prey-predator consumption approach. This analysis suggested that the total allowable catch from the entire Bering Sea could be 4.09 million t (1.98 million t for the Aleutian Basin stock, 1.69 million t for the EBS shelf stock, and 0.42 million t for the western Bering Sea shelf stock.)

At the November 1989 U.S.-U.S.S.R. bilateral meeting, both U.S. and U.S.S.R. scientists concluded that there are substantial problems with the data and assumptions with the Horbowy and Janusz (1989) and Mito (1989) analyses. These problems cannot be easily rectified as there are substantial gaps in our knowledge on the quantitative aspects of stock interactions. As such, the U.S and Soviet scientists could not accept the results presented by the two analyses.

It is also important to note that the donut hole area occupies only 19% of the Aleutian Basin. Since much of the Aleutian Basin is within the U.S. and U.S.S.R. EEZs and the donut hole fish are part of the broader Basin stock, it is not feasible to estimate the biomass of the donut hole fish alone.

Entire Bering Sea: Based upon data presented at the November 1989 U.S.-U.S.S.R. bilateral meeting, the following Table was compiled to summarize the exploitable biomass (ages 3 and above) of pollock estimated in 1988 for the Bering Sea:

YEAR/REGION	Exploitable Biomass (million t)	Comments
Western Bering Sea	1.9	Range is 1.2 to 2.5 million t Mostly spawning biomass Estimate is conservative
Eastern Bering Sea		
EBS Shelf	8.0	As high as 11.6 million t based on surveys
Aleutians	0.6	Based on survey
Bogoslof	2.5	Based on survey
Entire Bering Sea	13.0	

Biomass Projections

At the November 1989 bilateral meeting,

> "the Soviet side reported that the biomass of pollock in the eastern Bering Sea has been declining over the last few years by about 10-15% each year. For example the 1988 eastern Bering Sea spawning stock estimated at 8-10 million t declined by 1 million t by 1989. The abundance of eggs decreased 1.4 times between 1988 and 1989 at Unimak Island and Pribilof Islands. The decrease was 1.7 times at Bogoslof Island between 1984 and 1989.
>
> Probable causes of the decline in biomass and spawning potential are the absence of strong year-classes in the 1980s as compared to the strong 1978 year class, and simultaneous increase of fishing effort, particularly, on the large size pollock in the central Bering Sea. These age groups accounted for the most significant reproduction."

As mentioned earlier, U.S. scientists had estimated the exploitable pollock to be 8 million t from a cohort analysis model. This estimate is in addition to the 2.5 million t spawning biomass at Bogoslof surveyed in 1988 and 600,000 t estimated for the Aleutian Islands region. Projections were also made for the EBS biomass for 1989 and 1990. Although there are uncertainties in these projections because of unknown levels of recruitment, they show a decline for the EBS shelf stock as follows:

YEAR	Exploitable biomass (million t)
1988	8.00
1989	7.03
1990	5.84
1991	5.02

The BSFAB (1989) report assumed that the Bering Sea pollock resources have been declining by about 10-15% per year in recent years. Assuming a 10% decline per year, the 1988 exploitable biomass of 13 million t is projected to decline to about 10.53 million t by 1990.

APPROPRIATE HARVEST LEVEL

The gist of BSFAB's determination of appropriate harvest level (AHL) is simple:

$$AHL = E \times B$$

where E = appropriate rate of exploitation, and
B = estimate of exploitable biomass

The BSFAB (1989) report indicated that

> "the latest year when a complete set of estimated pollock biomass is available is 1988. A summary table above indicated that the exploitable biomass (ages 3 and above) for pollock resources in the entire Bering Sea was about 13 million t. Assuming, at the present time, that a 25 percent exploitation rate is

appropriate for the pollock resource, the harvest level would be 3,250,000 t. The total catch in 1988 from the entire Bering Sea was 3,950,000 t, which means that the appropriate harvest level calculated above was exceeded by 700,000 t in 1988

Stock assessments by both sides further indicate that the abundance of pollock in the Bering Sea has been declining since 1985. These assessments suggest that the harvest of pollock in the Bering Sea should be lower or not exceed 2.63 million t in 1990. The level of pollock harvest in the central Bering Sea or donut hole area appears to be increasing and has continued to be disproportionately high relative to the small size of the area when compared to the U.S. and USSR EEZs of the Bering Sea where pollock are predominantly located.

Consequently, there must be some management of the harvest level in the donut hole area, since there are already substantial management in both the U.S. and USSR EEZs. The suggested level of harvest may range from no fishing to some regulated level of "minimum" fishing.

The level of "minimum" fishing for 1990 may be more appropriately determined by the Bering Sea Fisheries Advisory Body. Both the U.S. and USSR scientists suggested that the "minimum" level of fishing may be allowed only if necessary biological information is gathered by a scientifically designed observer program for assessing the impact of such fishing on the status of the stocks in the Bering Sea."

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Table 1.--Biomass of eastern Bering Sea walleye pollock (in million t) as estimated by various assessment methods, 1964-1988. Survey biomass estimates are expressed as means with two standard deviations.

Year	Trawl Survey	Cohort Analysis[a]	CAGEAN[b]
1964		1.8	3.5 ± 2.1
1965		2.0	3.0 ± 1.6
1966		2.9	3.2 ± 1.3
1967		4.0	3.6 ± 1.1
1968		6.4	4.9 ± 1.3
1969		8.0	6.0 ± 1.4
1970		9.0	6.9 ± 1.4
1971		10.0	7.2 ± 1.3
1972		9.9	6.8 ± 1.2
1973		9.0	6.0 ± 1.0
1974		6.4	4.0 ± 0.7
1975		6.1	3.8 ± 0.7
1976		5.4	4.4 ± 0.8
1977		5.0	4.4 ± 0.9
1978		4.4	4.3 ± 0.9
1979	10.5[c] ± 3.1	4.0	4.5 ± 0.9
1980	1.5[d] ± 0.4	4.0	5.0 ± 1.0
1981	2.5[e] ± 0.6	7.1	9.3 ± 1.9
1982	7.8[c] ± 1.2	7.8	10.5 ± 2.1
1983	6.1[d] ± 1.0	7.4	10.8 ± 2.1
1984	4.6[d] ± 1.0	7.3	10.3 ± 1.9
1985	9.4[c] ± 1.6	9.0	11.3 ± 2.0
1986	5.0[d] ± 1.0	8.4	10.3 ± 1.9
1987	5.2[d] ± 1.2	8.3	9.4 ± 1.8
1988	11.6[f] ± 2.6	8.0	8.0 ± 1.8

Footnotes:

- [a] Cohort analysis (Pope 1972): age 3 and older tuned to hydroacoustic-trawl survey estimates for 1979, 1982, 1985 and 1988.
- [b] CAGEAN model (Deriso et al. 1985) tuned to hydroacoustic-trawl survey estimates for 1979, 1982, 1985 and 1988
- [c] Survey estimates include midwater, shelf bottom, and slope bottom components.
- [d] Survey estimates are for shelf bottom component only.
- [e] Survey estimates include shelf and slope bottom components.
- [f] Survey estimates include midwater and shelf bottom components.

Table 2.--Estimated biomass of pollock (in 1,000 t) in the eastern Bering Sea by age and total biomass estimated by cohort analysis.

Year	Age 2	3	4	5	6	7	8	9	Total
1977	844	1,409	1,330	613	320	422	384	463	5,783
1978	764	1,071	1,279	781	481	239	325	264	5,205
1979	1,130	1,020	906	700	590	373	178	240	5,137
1980	2,792	1,531	797	490	422	378	267	121	6,797
1981	888	4,031	1,481	499	380	279	255	168	7,980
1982	830	1,338	4,359	982	433	294	196	169	8,600
1983	668	1,259	1,540	3,084	799	351	227	134	8,062
1984	2,139	999	1,454	1,125	2,683	584	265	167	9,417
1985	540	3,246	1,160	1,045	930	2,074	394	178	9,567
1986	1,271	799	3,726	907	867	591	1,325	197	9,684
1987	782	1,926	935	2,934	816	502	297	854	9,046
1988	599	1,189	2,289	745	2,704	632	293	142	8,594

Table 3. Biomass estimates for the Aleutian Basin and donut hole.

Area	Year	Season	Methods	Population Estimate	Source
Aleutian Basin	1977	summer	midwater trawl	2.7 million t	Sasaki 1989
Aleutian Basin	1978	summer	midwater trawl	5.4 million t 0.8 million t[a]	Sasaki 1989
Aleutian Basin	1979	summer	midwater trawl	1.3 million t	Sasaki 1989
Basin within US EEZ	1983	winter	midwater trawl/quant. echo sounder	1.1 million t	Sasaki 1989
Doughnut hole	1988	winter	quant. echo-integrator/ midwater trawl	0-.1 million t	Traynor (Personal comm.)
Bogoslof area	1988	winter	quant. echo-integrator/ midwater trawl	2.5 million t	Traynor (1990)
Aleutian Basin outside Bogoslof	1988-89	winter	quant. echo-integrator/ midwater trawl	very few fish	Traynor (1990)
Bogoslof area	1988-89	winter	quant. echo-integrator/ midwater trawl	2.1 million t	Traynor (1990)
Doughnut Hole	1987	August	midwater trawl	0.3 million t	Bulatov and Sobolevsky (1989)
Doughnut Hole	1987	October	midwater trawl	1.1 million t	Bulatov and Sobolevsky (1989)
U.S.S.R. deep water zone	1986	Autumn	midwater trawl	2.6 million t	Bulatov and Sobolevsky (1989)
U.S.S.R. deep water zone	1987	Sept.	midwater trawl	1.3 million t	Bulatov and Sobolevsky (1989)
U.S.S.R. deep water zone	1987	Oct.	midwater trawl	2.0 million t	Bulatov and Sobolevsky (1989)
Aleutian Basin	1988	Annual	Cohort Analysis	12.8 million t	Horbowy and Janusz (1989)
Aleutian Basin	1988	Annual	Consumption Model	--	Mito (1989)

[1a]Both biomass estimates are based on the same midwater trawl catch data. The larger biomass is from Japanese analyses; the smaller biomass is from U.S. analyses. The U.S. result is probably somewhat conservative. The biomass estimates for both 1977 and 1978 are probably high due to the inclusion of some shelf samples.

A biomass estimate of 9.1 million t in the donut hole in August-September, 1987 has been reported; but since many problems were discovered when the results were reviewed, this value has been largely discounted.

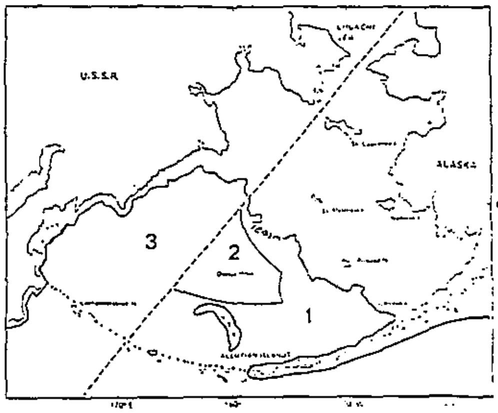

Figure 1. Map of the Bering Sea showing the Donut Hole Area within the Aleutian Basin that is deeper than 1,000 m.

Legend: 1 = area of the Basin within the U.S. exclusive economic zone (EEZ)
2 = donut hole area outside the U.S. and USSR EEZs
3 = area of the Basin within the USSR EEZ

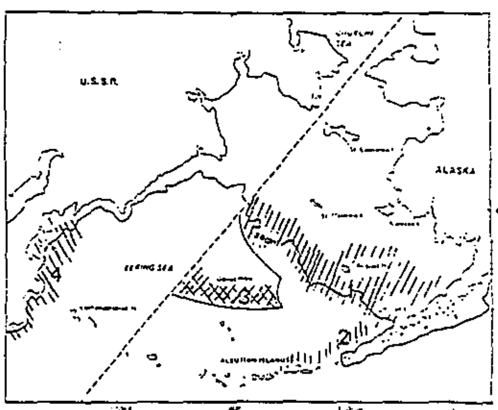

Figure 2. Map of the Bering Sea showing the major fishing grounds.

Legend: 1 = eastern Bering Sea continental shelf and slope
2 = Bogoslof Island and Aleutians
3 = Donut area
4 = westren Bering Sea continental shelf and slope

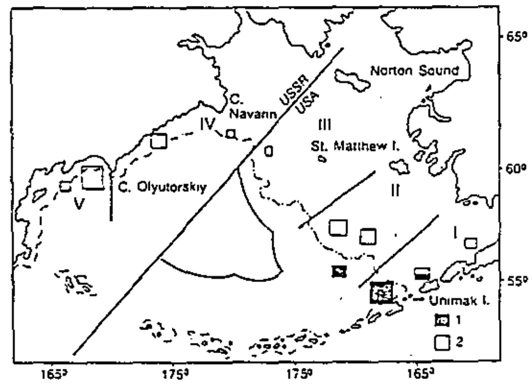

Figure 3. Generalized spawning grounds for walleye pollock in the Bering Sea.

Legend: I = Unimak grounds
II = Pribilof grounds
III = St. Mathews grounds
IV = Olyutorskiy-Navarin grounds
V = Korfa-Karagin grounds
1 = winter spawning
2 = spring spawning

(Adapted from Bulatov (1989) p. 202 in Proocedings of the International Symposium on Biology and Management of Walleye Pollock, Alaska Sea Grant Report No. 89-1.)

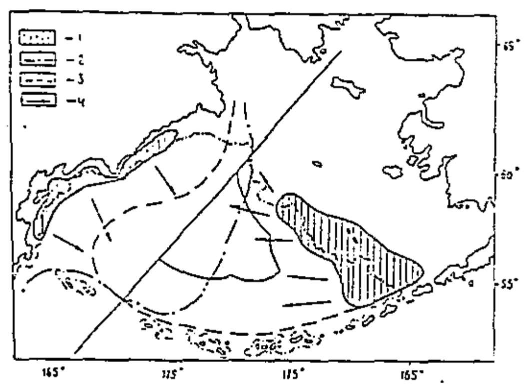

Figure 4. A schematic of pollock distribution from the main areas of spawning in the Bering Sea.

Legend: 1 = major spawning areas
2 = boundary of migration for Asian stock
3 = boundary of migration for U.S. stock
4 = arrows show main directions of post-spawning migration

(Adapted from Stepanenko (1989) p. 539 in Proocedings of the International Symposium on Biology and Management of Walleye Pollock, Alaska Sea Grant Report No. 89-1.)

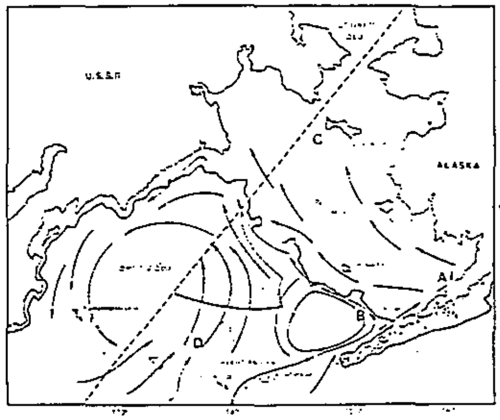

Figure 5. Synthesized surface circulation in the Bering Sea

(Adapted from Mulligan et. al (1989) p. 486 in Proocedings of the International Symposium on Biology and Management of Walleye Pollock, Alaska Sea Grant Report No. 89-1.)

Assessment trends for eastern Bering Sea pollock,1979-1988.

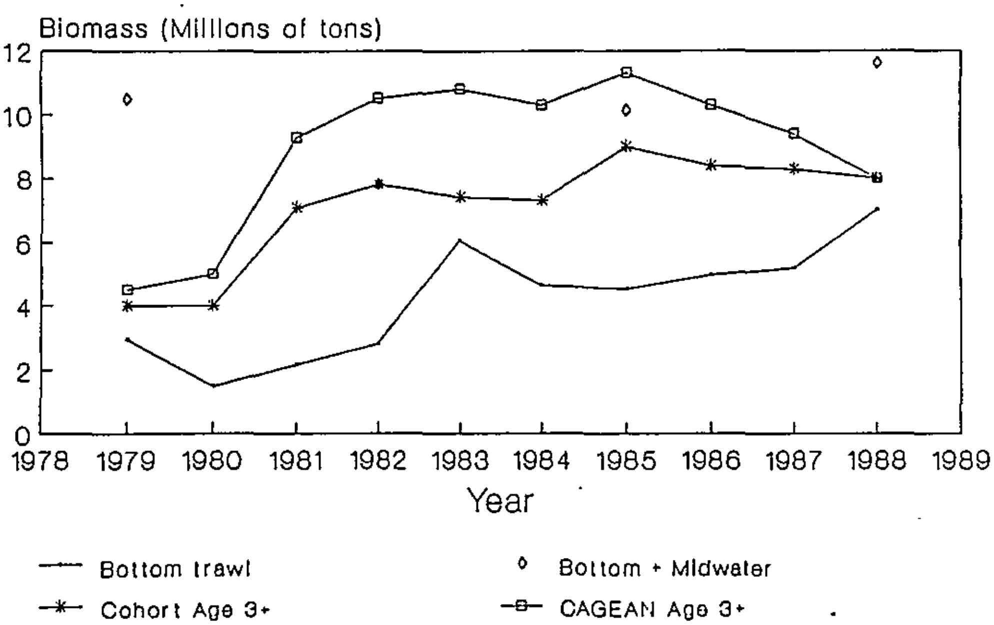

Figure 6. Assessment trends for eastern Bering Sea pollock, 1979-1988.

An Examination of Age Determination Structure of Walleye Pollock, (Theragra chalcogramma) from Five Stocks in the Northeast Pacific Ocean

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Accurate age determinations are essential to our understanding of the biology, and the development of reliable stock assessments of a species. Fin rays, otoliths and scales have all been used to estimate the age of walleye pollock (Theragra chalcogramma). Various investigators have rejected one or all of these structures for specific stocks, however a comprehensive comparison of ages produced from all of these structures has not been conducted. We examined all three structures from five stocks in the Northeast Pacific Ocean to determine, on a stock basis, which structure produced the most consistent pattern of growth and the most obvious annuli.

Introduction

Walleye pollock (Theragra chalcogramma) is the most abundant fish species in the North Pacific Ocean. It ranges along the continental shelf from southern Oregon to the Gulf of Alaska, through the Bering Sea, throughout waters off the Kurile Islands and Okhotsh Sea, to the southern Chukchi Sea (Bakkala et al. 1986). Pollock supports the largest single fishery in the world with recent catches averaging in excess of 6 million tonnes annually (Megrey 1989). In the past year, the expansion of this fishery into international waters of the Bering Sea has caused international concern that overfishing may be occurring.

Stock assessments and management strategies developed for pollock stocks are directly dependent on age determination estimates. Fin rays, otoliths and scales have all been used to estimate the age of pollock (Ogata 1956; Beamish 1981; La Lanne 1975; Lai and Yeh 1986) and one or all have been rejected for specific stocks.

The effects of using erroneous age estimates in stock assessments have been discussed by Lai and Gunderson (1987) and Tyler et al. (1989). Beamish and McFarlane (1983) outline the importance of validating an ageing technique. Although a mark-recapture study is the only true means of validation (Beamish and McFarlane 1983), an alternative indirect means of assessing the usefulness of a structure is to compare several structures and techniques. In a study comparing age estimates of scales, fin rays and otoliths from pollock from one stock, Lai and Yeh (1986) found substantial differences in age estimates obtained using different structures. The purpose of this report is to present the results of our examination of fin rays, scales, otolith surfaces and otolith cross-sections (break and burn method) from fish from five stocks of walleye pollock in the North Pacific Ocean.

Methods

Samples of walleye pollock were obtained from five geographic areas (Fig. 1); two in Canadian waters (Strait of Georgia and northern Hecate Strait); two in United States waters (Shelikof Strait and eastern Bering Sea/ Aleutian area) and one in international waters of the Aleutian Basin (Donut Hole). All fish were captured in trawl nets between January and March 1989. Scales, pectoral fins and paired sagitta otoliths were collected from each fish. Each fish was measured for fork length and sex was determined. All structures were collected, processed and ages estimated according to the procedures outlined in Chilton and Beamish (1982). For otoliths, ages were estimated using both the surface and burnt cross sections. Criteria for identifying an annulus on each structure and/or method are presented in Beamish (1981) and Chilton and Beamish (1982). Examples of annuli identified on each structure for each area are presented in Figures 2-10.

Results

Scales, pectoral fin rays and paired otoliths were collected from 54 walleye pollock from the Strait of Georgia, 41 from northern Hecate Strait, 60 from Shelikof Strait, 49 from the eastern Bering Sea/Aleutian area and 48 from international waters of the Bering Sea (Donut Hole).

For the Strait of Georgia stock, the scale method produced the youngest estimated ages (Fig. 17A). Age estimates determined using the other methods were similar. There was no significant difference (anova, P>0.05) in the growth curves produced using the fin-ray section ages or those produced using either of the otolith methods. The younger ages resulting from the scale method produced faster rates of growth (Fig. 11A). For the northern Hecate Strait sample, age estimates using scales were younger (Fig. 12B) and produced a slightly but not significantly faster growth rate (anova, P>0.05, F=6.39).

In the Gulf of Alaska sample, there was no difference in the estimated age composition or growth rates of the fish using any of the methods (Fig. 11C; 12C). No fish older than age 6 were present in the sample. Fish from this area were smaller at age than those from other areas (Fig. 11C).

The two samples from the Bering Sea (Aleutian area and Donut Hole) contained the oldest fish in this study. In the

Aleutian area the burnt otolith section method produced the oldest ages (Fig. 12D) resulting in a slower rate (anova, $P \leq 0.05$; $F=111.48$) of growth than that resulting from using pectoral fin ray section ages or otolith surface ages (Fig. 11D). In the Donut Hole area all four methods produced different age compositions (Fig. 12E). This resulted in significant differences (anova, $P \leq 0.05$; $F=64.65$) in the rates of growth determined from the four methods. The slowest rate of growth was determined using the burnt otolith sections. Ages estimated using this method were as old as 28 years; the oldest age reported for walleye pollock.

When ages estimated from scales, pectoral fin- ray sections and otolith surfaces were compared to ages estimated from the burnt otolith section method for the five stocks (Fig. 12-16) the only deviations occurred for the two Bering Sea samples. In the other three samples, deviations from the burnt section method were small and varied without trend. In the Aleutian area sample, the greatest deviation occurred for ages estimated from scales, followed by pectoral fin ray section ages and otolith surface ages. Similar differences were found for the Donut Hole sample and these deviations increased linearly with age. In the most extreme example, scale ages underestimated otolith section ages by 20 years (Fig. 16). The deviation for ages estimated using the otolith surface was less than for ages estimated from pectoral fin rays.

The ability to identify annuli on any particular structure varied among areas. For example, the annuli on fin ray sections for fish captured in northern Hecate Strait were the most easily identified (Fig. 4,5) and annuli on the otolith surface, the most difficult. This was also true for the Strait of Georgia sample (Fig. 2). In contrast, for Bering Sea stocks, annuli on the burnt otolith section were consistently the clearest and easiest to identify (Fig. 7,9,10).

Annuli on scales from all areas appeared to be distinct (Fig. 2,4,6,7,10). However, ages estimated from scales were similar to ages determined from other structures only for younger fish. Scales from older fish (Fig. 7,9,10) did not show any crowding of circuli around the edge or any irregular growth. Thus, there was no indication that scale growth was reduced or had stopped. In contrast, fin-ray sections from older fish had a wide translucent band on the edge (Fig. 7D,10D). Higher magnification showed that this band consisted of a number of annuli. Although the annuli could not be differentiated, it was clear that the number of visible annuli underestimated the actual age. Thus sections of fin rays are suitable structures to estimate the age of pollock because, unlike scales, an accumulation of annuli on the edge of the section provides evidence that the fish is older. When ageing older fish, the burnt otolith section is the only acceptable structure. As the

fish ages, the otolith grows almost exclusively on the ventral surfaces (Fig. 7A,B; 10A,B). This asymmetrical or allometric growth is most obvious when an otolith section from a younger fish (Fig 4A,8A) is compared to a section of an older fish (Fig. 7A,B; 10A,B). The increased thickness of the otolith from the 28-yr-old fish clearly is an indication of older age. The amount of annual growth in this area of increased thickness becomes progressively reduced with age. Although the interpretation of annuli in this area may be difficult, there is no doubt that a large number of annuli exist.

Discussion

Our study indicated that the most appropriate structure/method for age determination may vary among stocks. Pectoral fin-ray sections, otolith surfaces and burnt otolith sections are all suitable structures for stocks consisting of mainly younger fish. For these stocks, the pectoral fin ray annuli were the easiest to identify. However, for some stocks, such as the Strait of Georgia pollock, fin-ray section annuli may become crowded on the section edges at a younger age (Beamish 1981). Unlike scales, it was possible to identify an accumulation of annuli on the edge of the fin ray section indicating that burnt otolith sections should be used. For other stocks, the burnt otolith section consistently produced older age estimates.

Our study examined the same structures as Lai (1985) in the eastern Bering Sea. His results for this area were similar to ours for the pectoral fin ray and otolith surface methods. However, our estimates of age from burnt otolith sections were older for some fish. Lai found no significant difference between the otolith surface and burnt section methods for this area and recommended that otolith surfaces be used for production ageing because of the time involved in preparing fin sections. However, Lai used thin sections of otoliths and not the less time-consuming burnt section technique.

We recognize that the age estimates in this report have not been validated. In particular, the older ages from the international waters of the Bering Sea may appear to be in error. We applied the same age determination criteria to the burnt otolith sections of pollock as were applied to other species (i.e., sablefish, rockfish). The older ages for these species have been shown to be correct (Bennett et al. 1982; Beamish 1979; Beamish et al. 1983; Leaman and Nagtegaal 1987). The oldest age previously reported for pollock is 18 yr (Karp and Traynor 1989), determined using the otolith surface reading method. In our study and in other studies comparing otolith surface and section readings (reviewed in Beamish and McFarlane 1987) it was shown that otolith burnt sections do produce older age estimates than otolith surface readings. Thus an age of 28 yr may not be unreasonable.

Accurate age estimates are important for determining a number of biological parameters. In particular, accurate age estimates are required to determine mortality rates and identify strong year-classes. If the "Donut Hole" sample can be considered representative of a relatively lightly exploited population the natural mortality estimate from this small sample is lower than the estimates used for management of pollock stocks. A more accurate mortality estimate only requires that larger samples be collected and analysed using the burnt otolith section method.

Another example of the problems of age determination of pollock is seen in the difference of opinion of the year of production of the strong year-class in the late 1970s. In the eastern Bering Sea (Wespestad and Traynor 1988) identified the 1978 year-class as being exceptionally strong using ages estimated from otolith surfaces. Samples collected in the same area and aged using the same method (Moiseyev 1983) identified the 1977 year-class as being strong. Considering this strong year-class was produced by a relatively small number of spawners, it is important to accurately identify this year-class in order to examine the influence of the ocean environment on year-class success. In our study, although sample size was small, we observed a larger number of 11-year-olds, indicating the strong year-class occurred in 1978. While the 1978 year-class has been recognized as being strong, our analysis indicates that the 1973 year-class was also strong, possibly as strong as the 1978 year-class. It is interesting that 16-year-old fish are still an important component of the population. We believe these examples serve to illustrate the importance of continuing to examine age determination methods, particularly where a misinterpretation of age composition information may lead to overharvesting.

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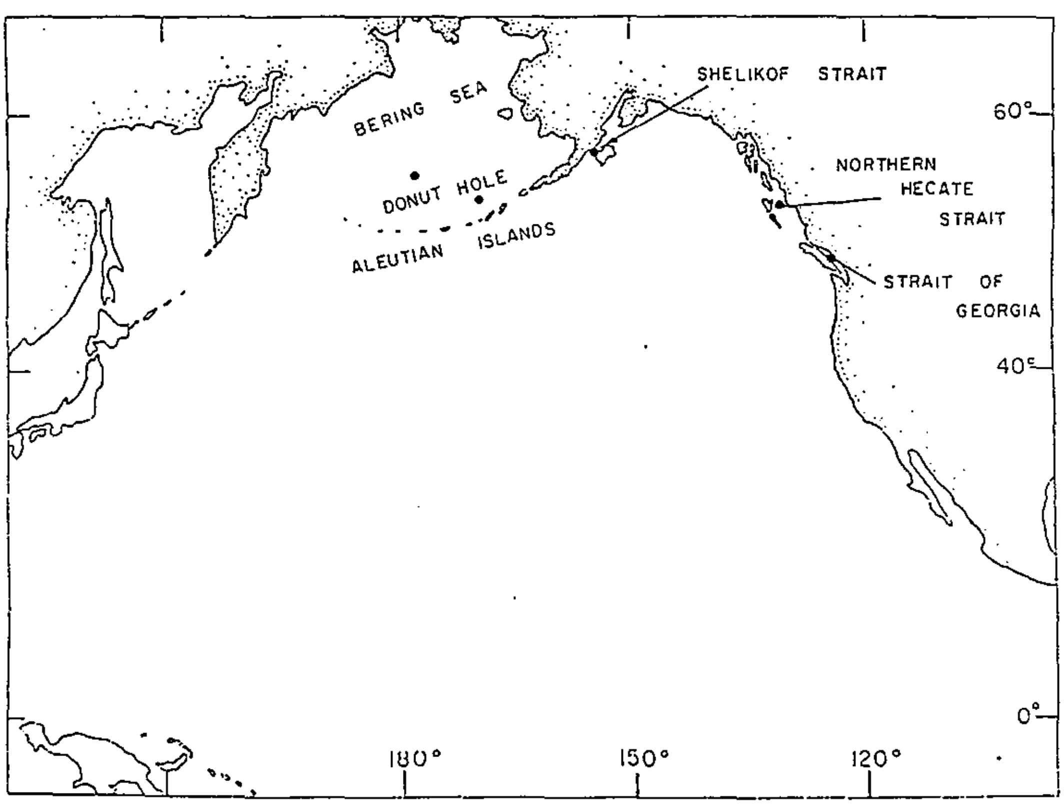

Fig. 1. Five areas (•) where walleye pollock age structures were collected.

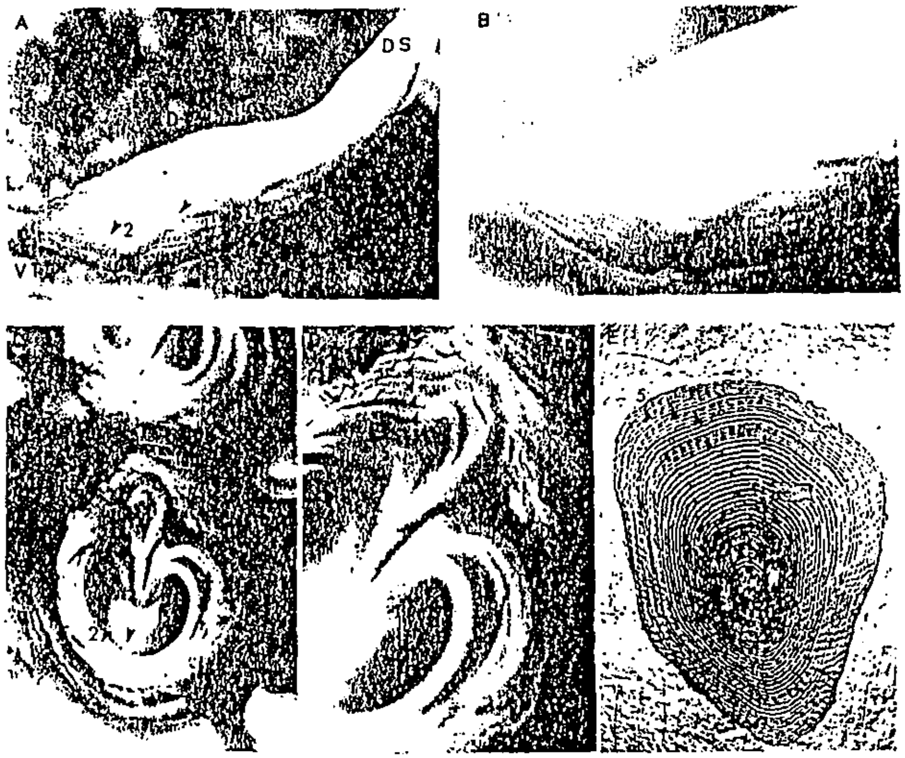

Fig. 2. Structures used for age determination collected from a 40 cm walleye pollock captured in the Strait of Georgia:
A. Burnt otolith section.
B. Close-up of sulcus area of ventral side.
C. Pectoral fin-ray section.
D. Close-up of fin-ray section showing annuli 3-8.
E. Scale: DT=distal; DS=dorsal; SL=sulcus; PX=proximal; VT=ventral.

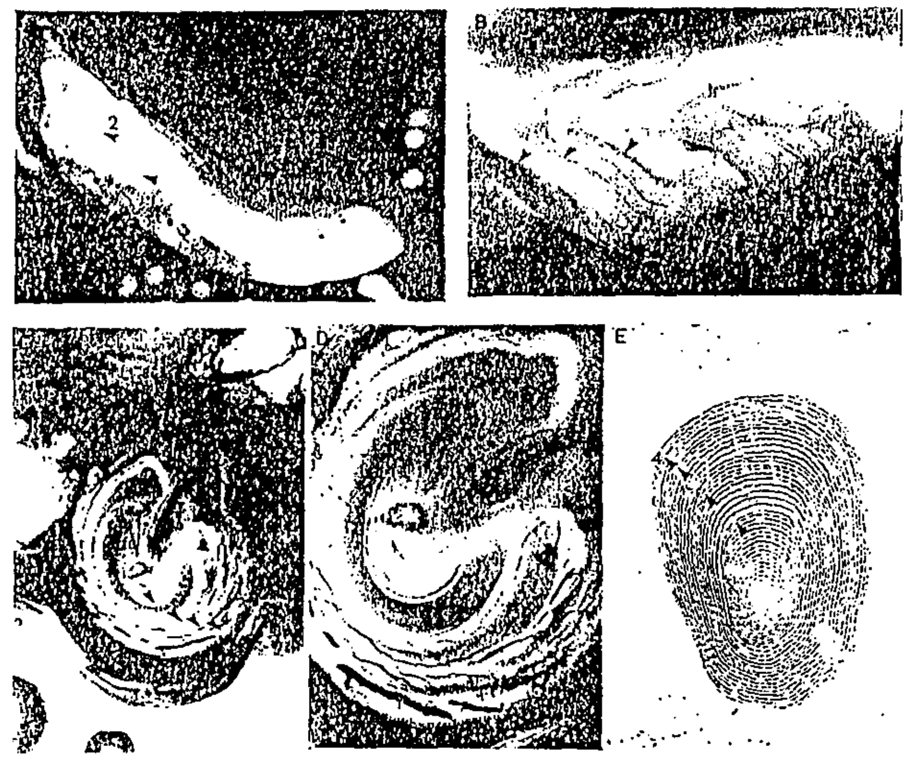

Fig. 3. Structures used for age determination collected from a 44 cm walleye pollock captured in Hecate Strait.
A. Burnt otolith section.
B. Close-up of sulcus area of ventral side.
C and D. Pectoral fin ray section.
E. Scale.

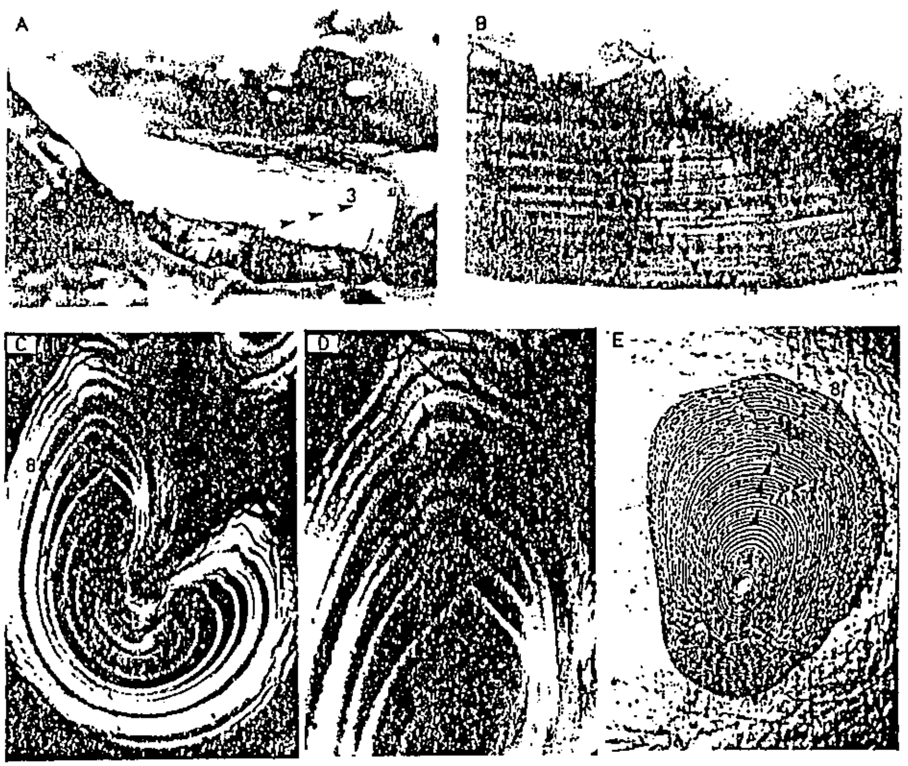

Fig. 4. Structures used for age determination collected from a 52 cm walleye pollock captured in Hecate Strait.
A and B. Burnt otolith sections showing 14 annuli.
C and D. Pectoral fin ray section showing 13 annuli.
E. Scale showing 8 annuli.

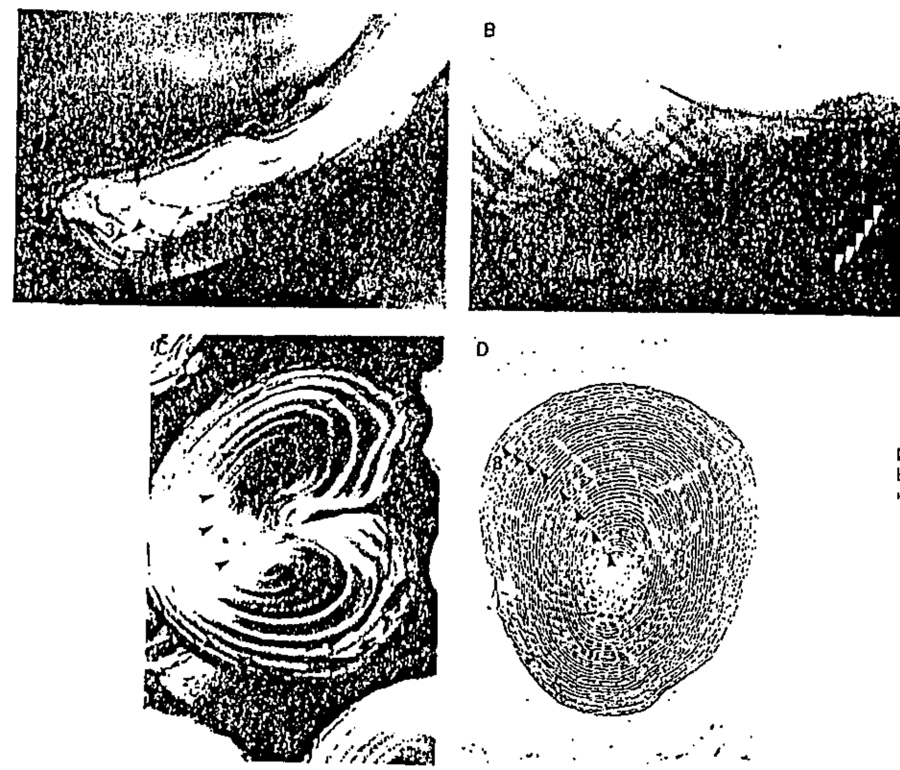

Fig. 5. Structures used for age determination collected from a 54 cm walleye pollock captured in Hecate Strait.
A and B. Burnt otolith section showing 8 annuli.
C. Pectoral fin ray section showing 9 annuli.
D. Scale showing 8 annuli.

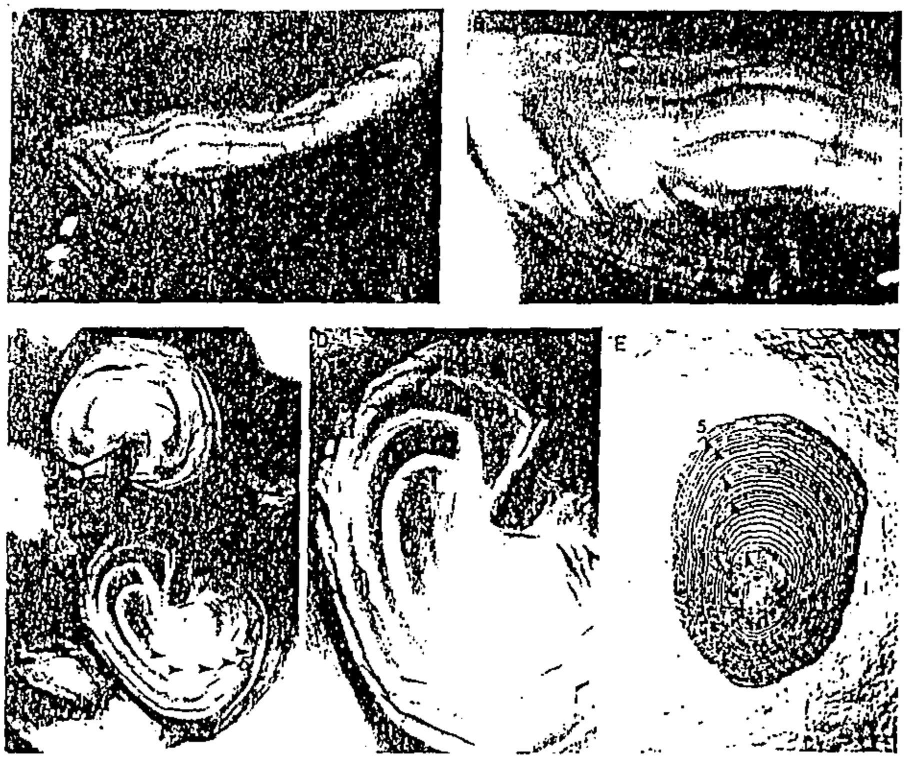

Fig. 6. Structures used for age determination collected from a 39 cm walleye pollock captured in Shelikof Strait.
A and B. Burnt otolith section.
C and D. Pectoral fin ray section.
E. Scale.
Note: All structures show 5 annuli.

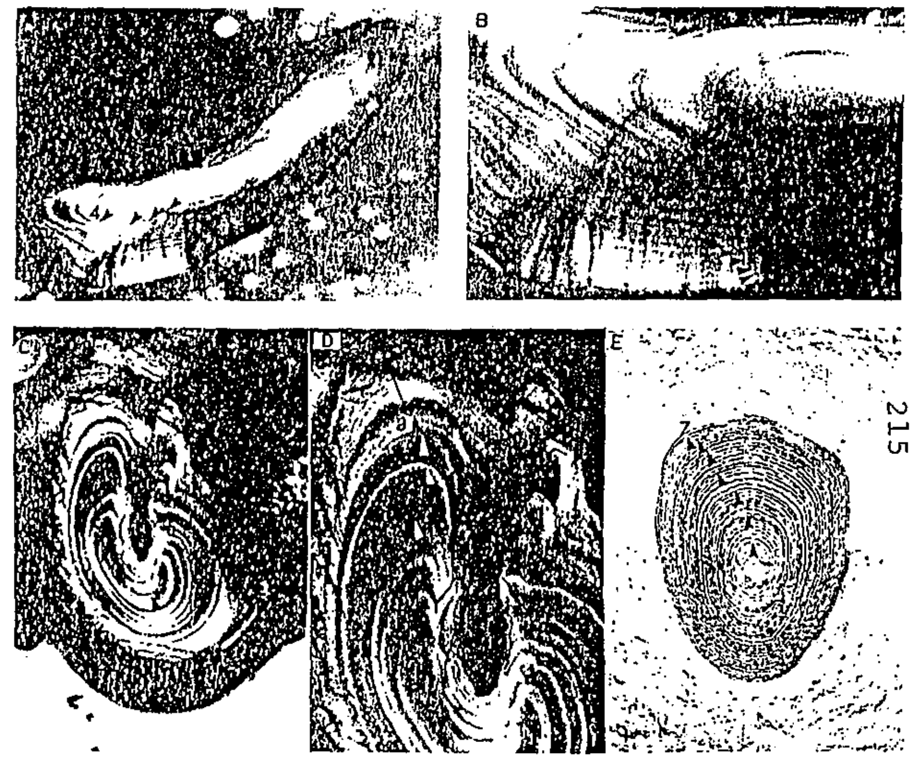

Fig. 7. Structures used for age determination collected from a 49 cm walleye pollock captured in the eastern Bering Sea (Aleutian area).
A and B. Burnt otolith section showing 17 annuli.
C and D. Pectoral fin ray showing 8 annuli and a large area between 8th annulus and the edge where annuli could not be identified.
E. Scale showing 7 annuli.

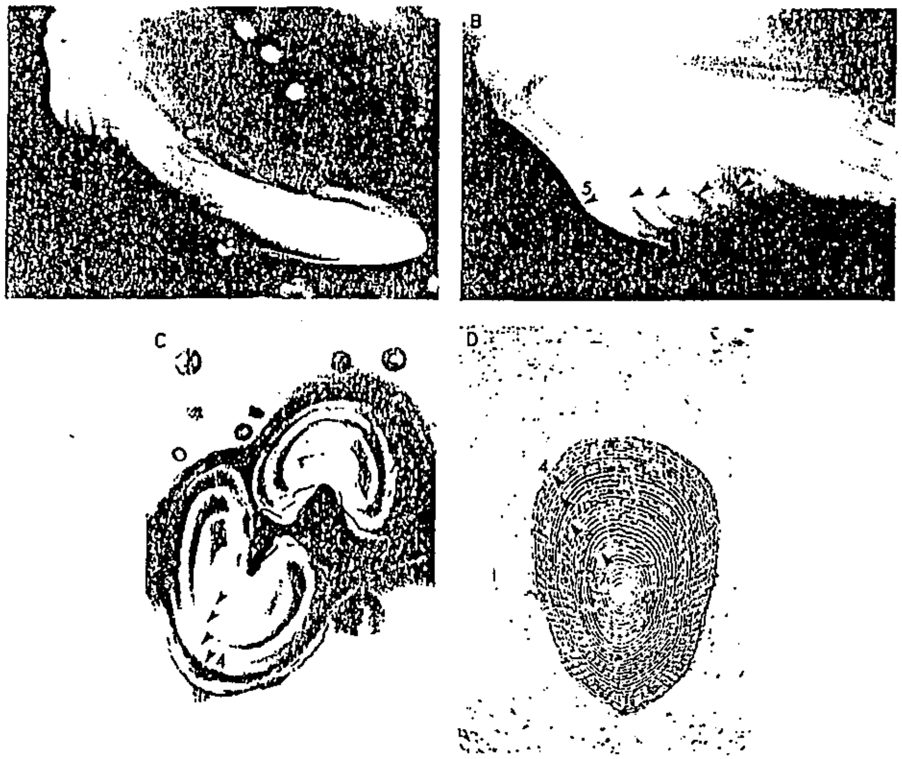

Fig. 8. Structures used for age determination collected from a 44 cm walleye pollock captured in the international waters of the Bering Sea (Donut Hole).
A and B. Burnt otolith section showing 5 annuli.
C. Pectoral-fin ray section showing 4 annuli.
D. Scale showing 4 annuli.

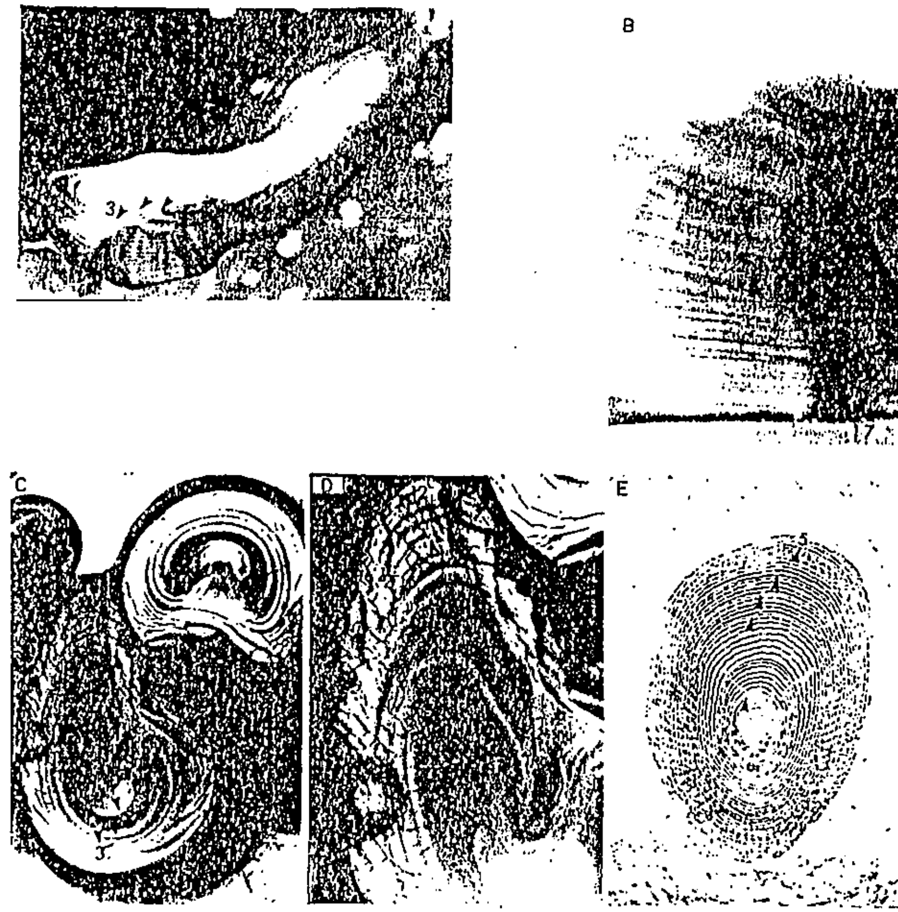

Fig. 9. Structures used for age determination collected from a 50 cm walleye pollock captured in the international waters of the Bering Sea (Donut Hole).
A and B. Burnt otolith section showing 17 annuli.
C and D. Pectoral fin-ray section showing 12 annuli.
E. Scale showing 5 annuli.

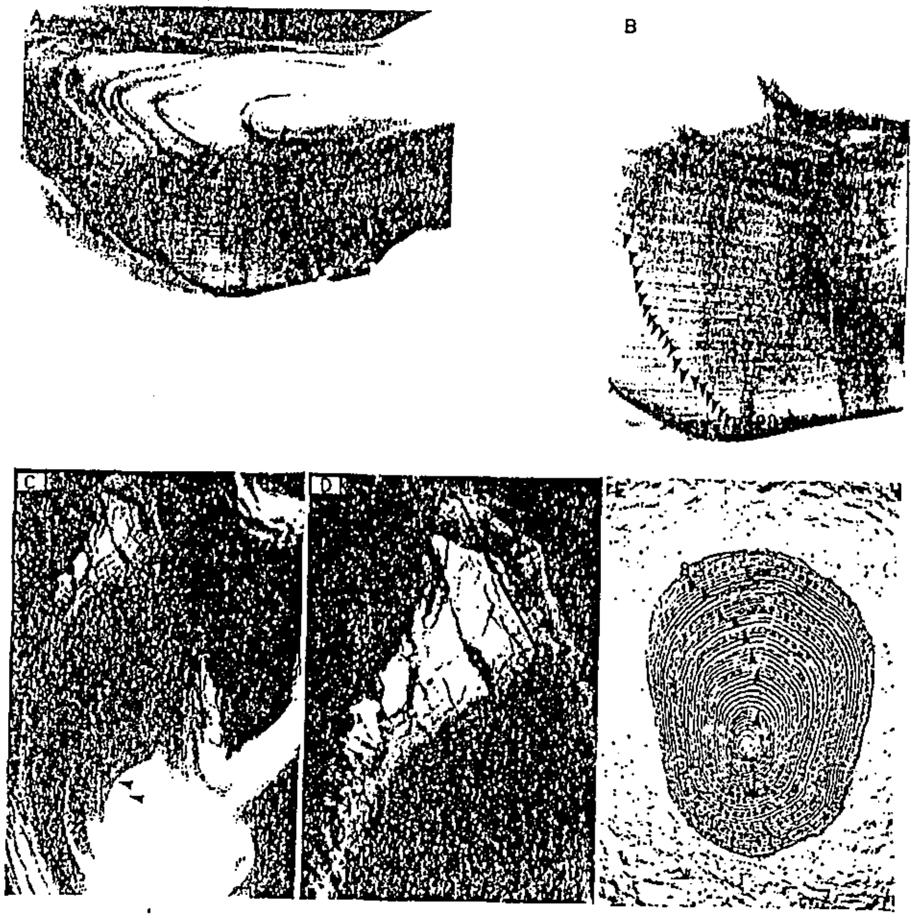

Fig. 10. Structures used for age determination collected from a 53 cm walleye pollock captured in the international waters of the Bering Sea (Donut Hole).
A and B. Burnt otolith section showing 28 annuli.
C and D. Pectoral fin-ray section showing 6 annuli and a large area containing annuli difficult to distinguish.
E. Scale showing 8 annuli.

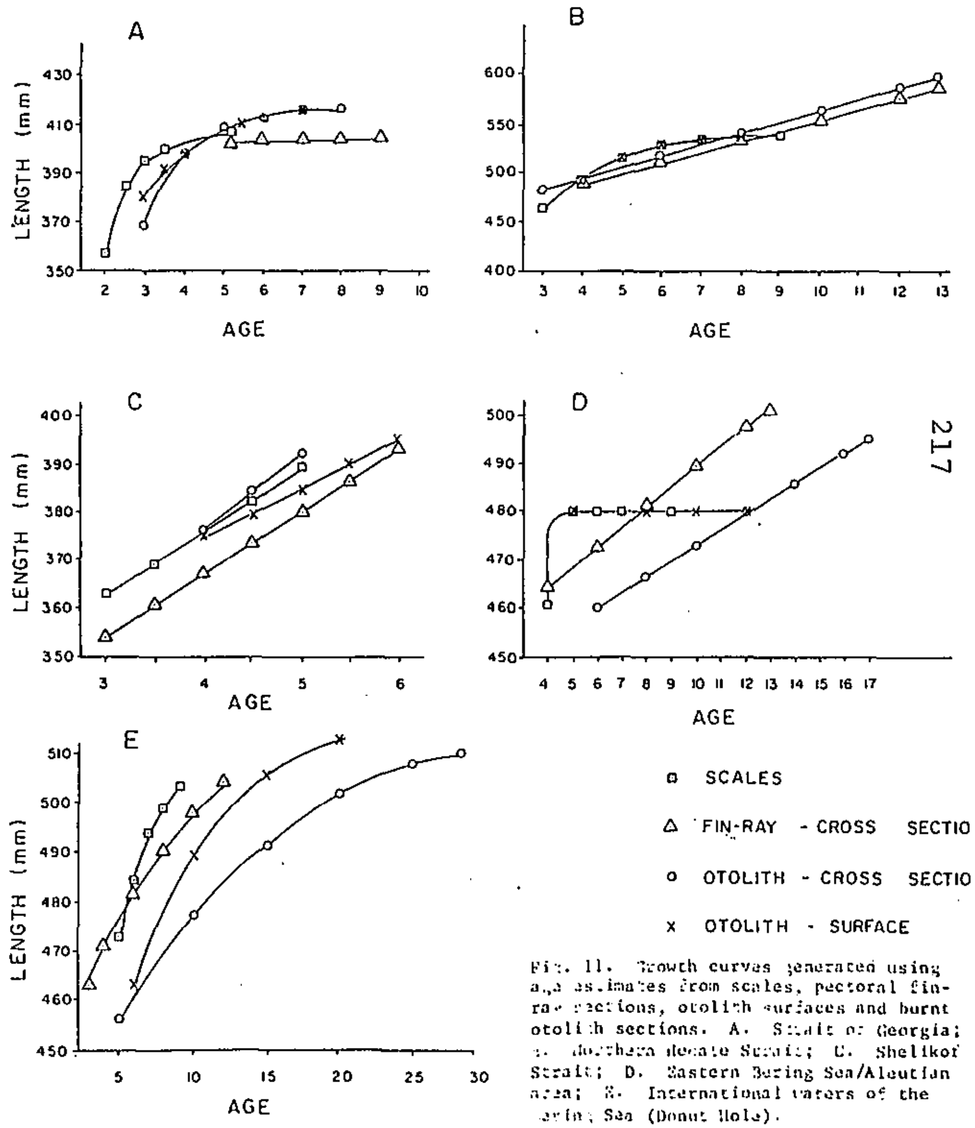

Fig. 11. Growth curves generated using age estimates from scales, pectoral fin-ray sections, otolith surfaces and burnt otolith sections. A. Strait of Georgia; B. Northern Hecate Strait; C. Shelikof Strait; D. Eastern Bering Sea/Aleutian area; E. International waters of the Bering Sea (Donut Hole).

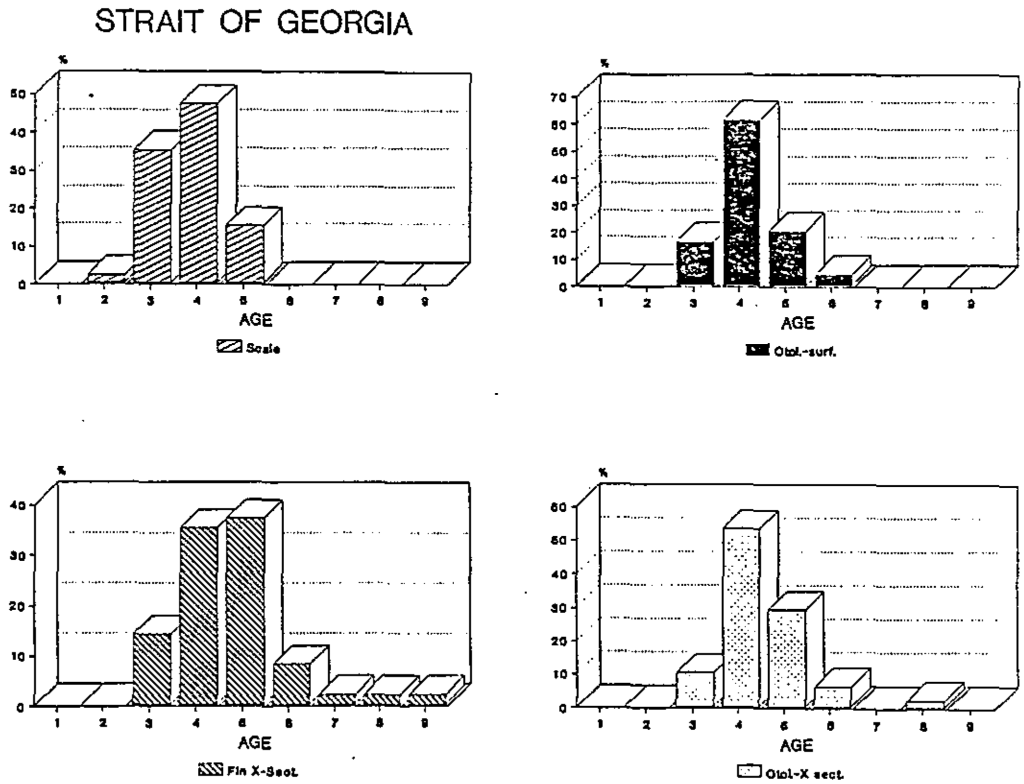

Fig. 12. Age composition produced using the four ageing methods. A. Strait of Georgia.

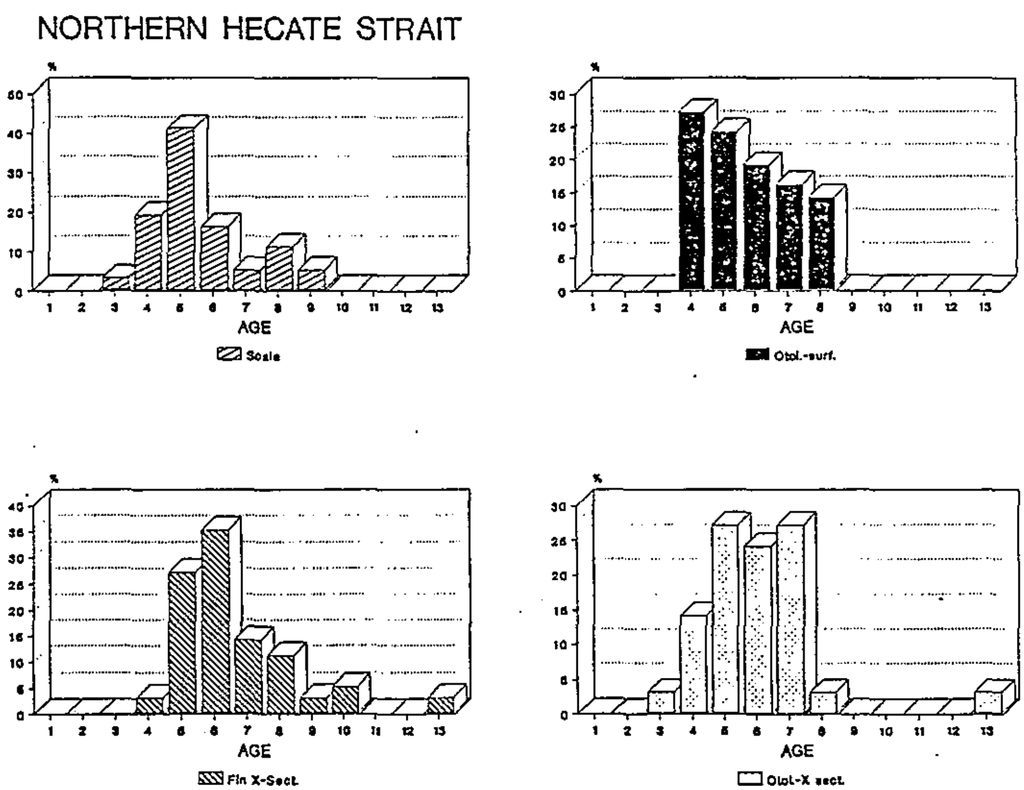

Fig. 12B. Northern Hecate Strait.

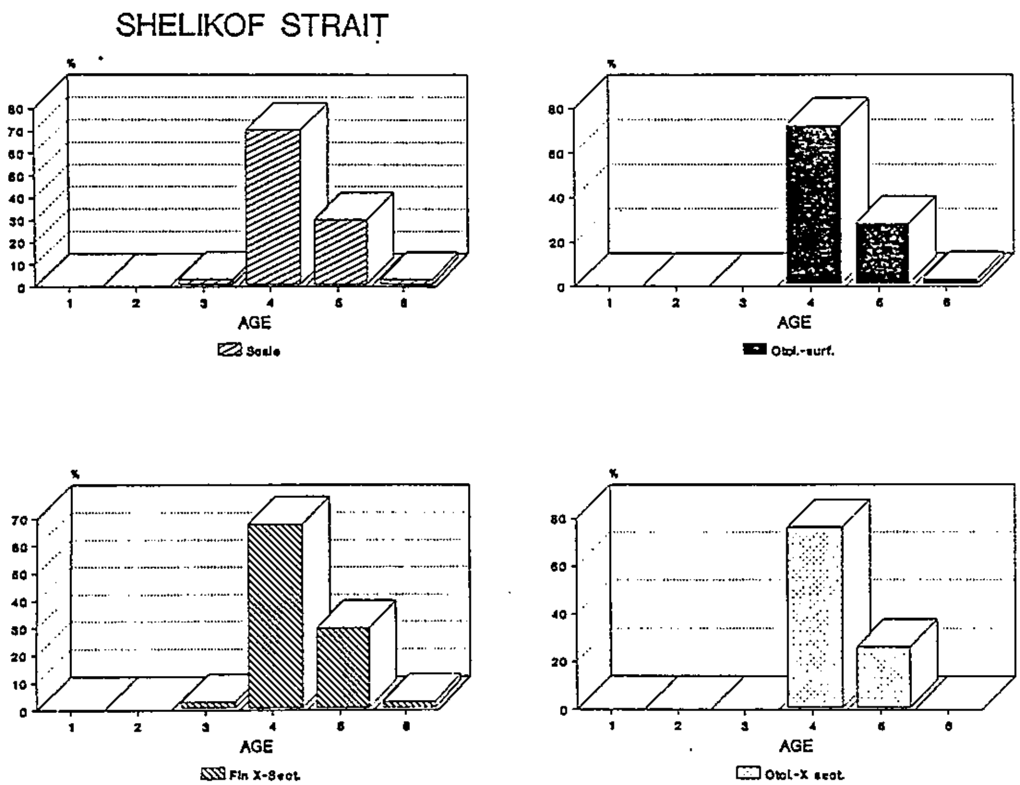

Fig. 12 C. Shelikof Strait (Gulf of Alaska).

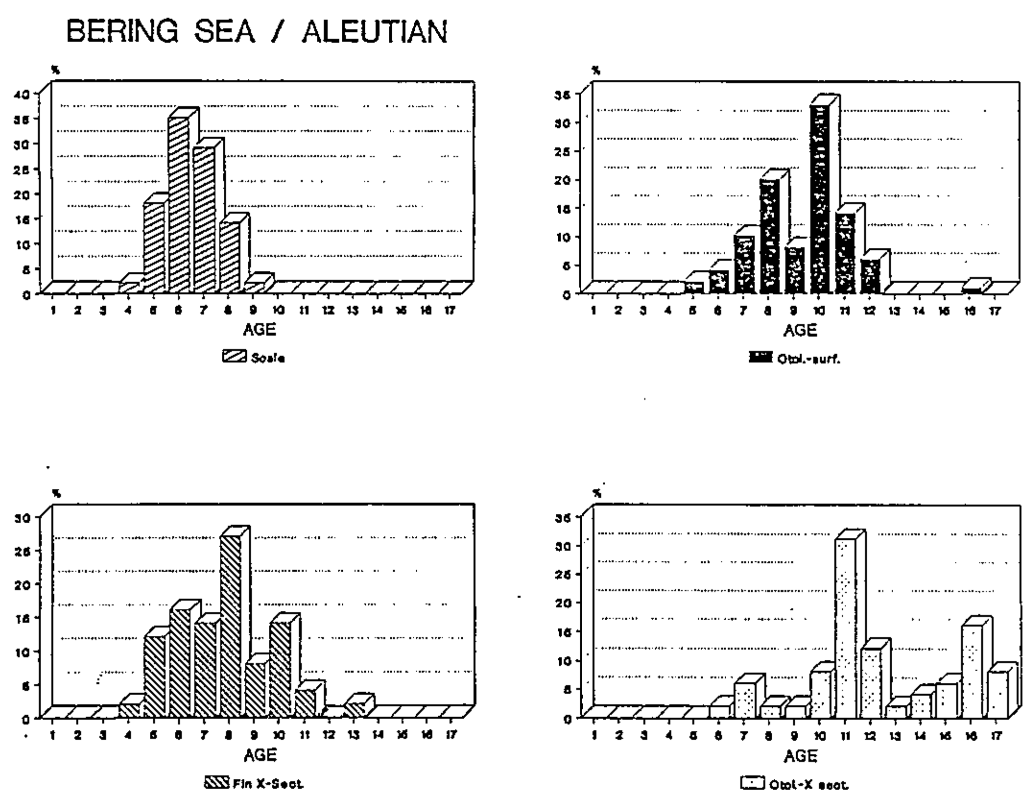

Fig. 12D. Eastern Bering Sea/Aleutian area.

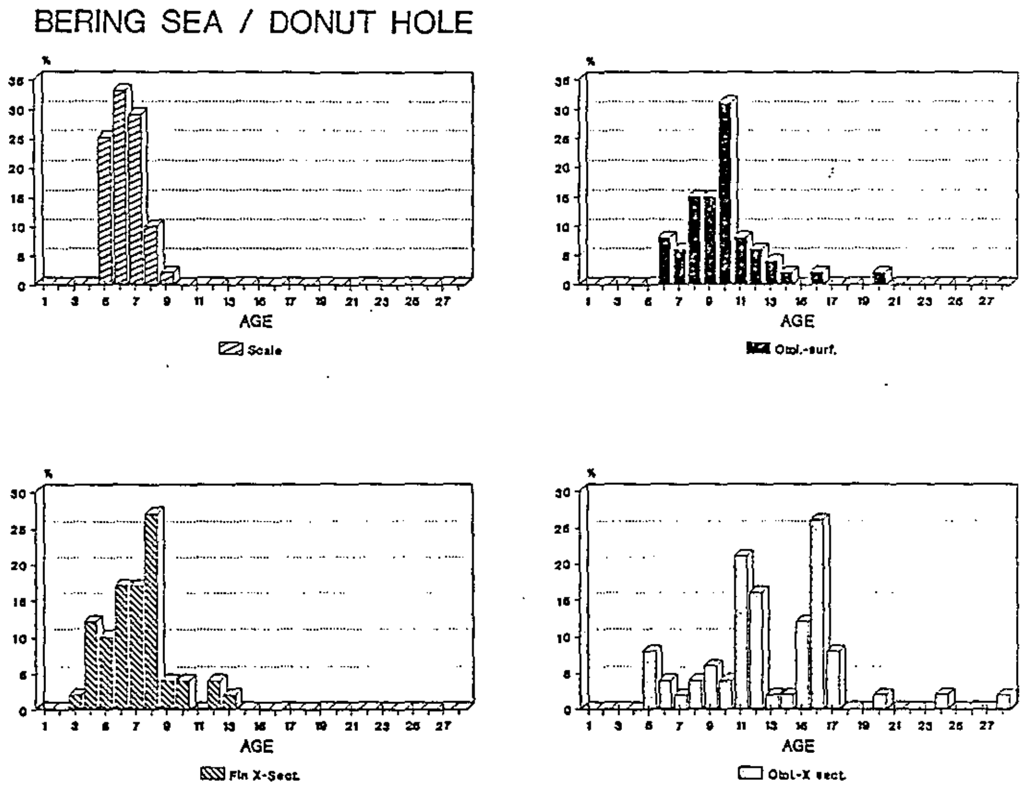

Fig. 12E. Eastern Bering Sea (Donut Hole).

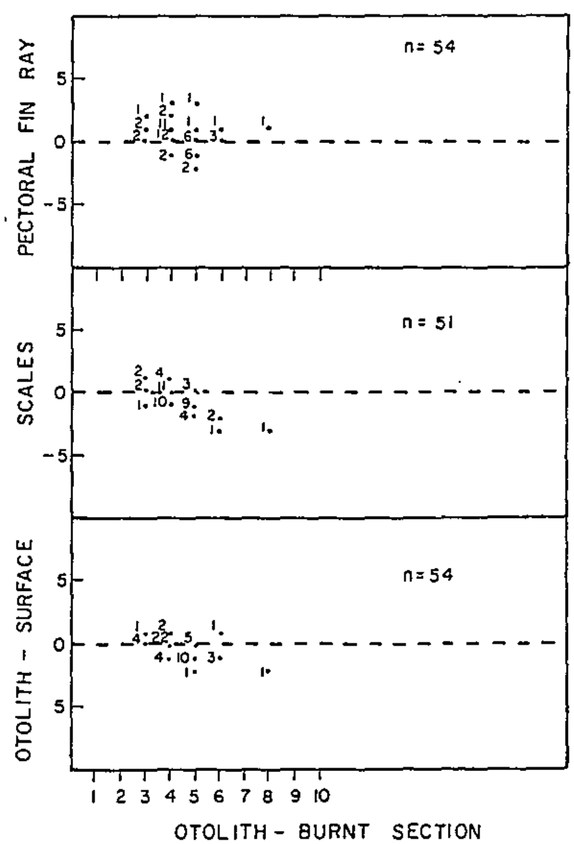

Fig. 13. Mean deviation of otolith surface, scales and pectoral fin ray ages from burnt otolith section ages for pollock collected in the Strait of Georgia.

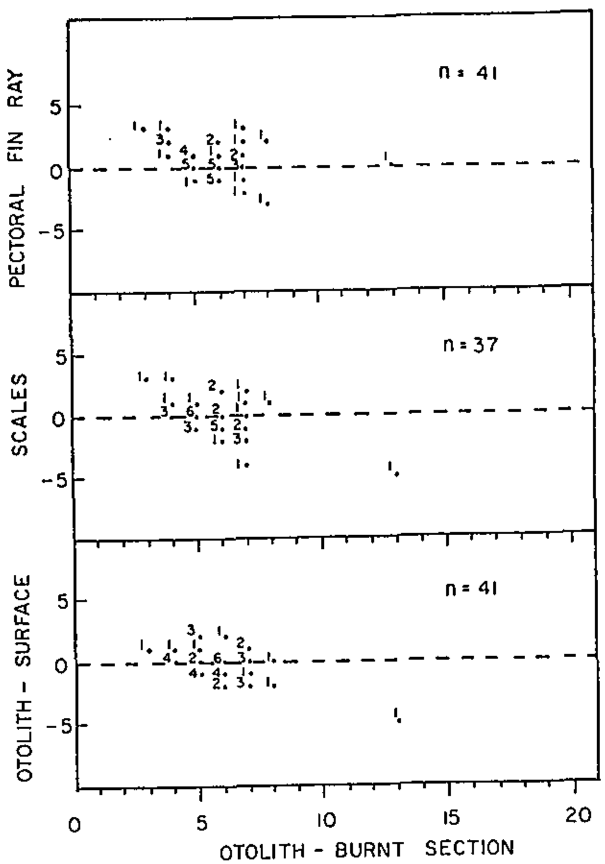

Fig. 14. Mean deviation of otolith surface, scales and pectoral fin ray ages from burnt otolith section ages for pollock collected in northern Hecate Strait.

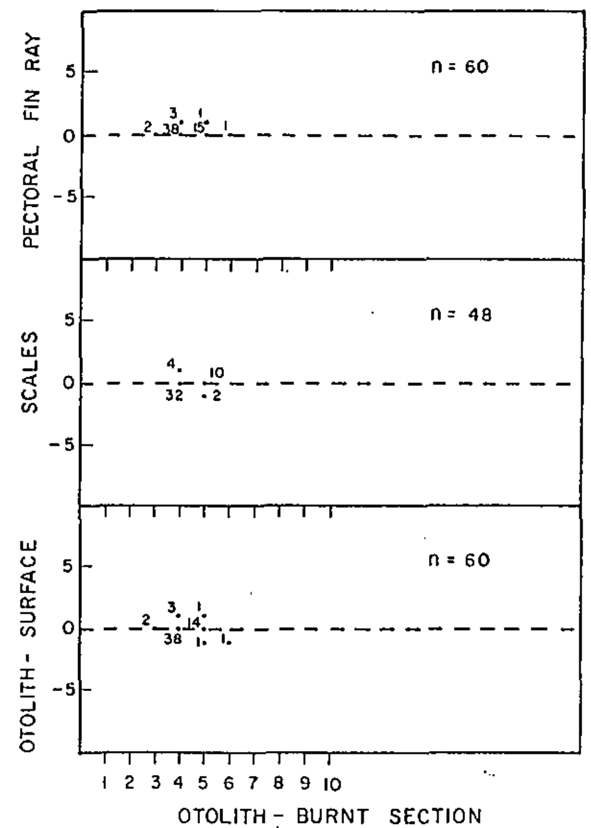

Fig. 15. Mean deviation of otolith surface, scales and pectoral fin ray ages from burnt otolith section ages for pollock collected in Shelikof Strait.

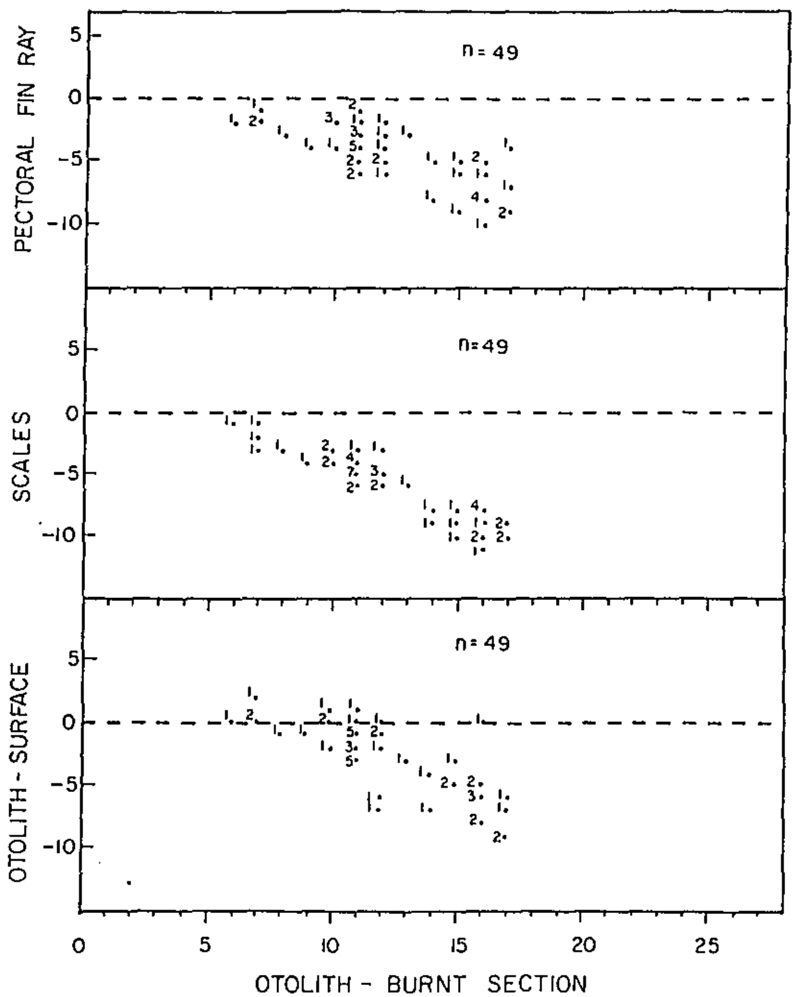

Fig. 16. Mean deviation of otolith surface, scales and pectoral fin ray ages from burnt otolith section ages for pollock collected in the Eastern Bering Sea/Aleutian area.

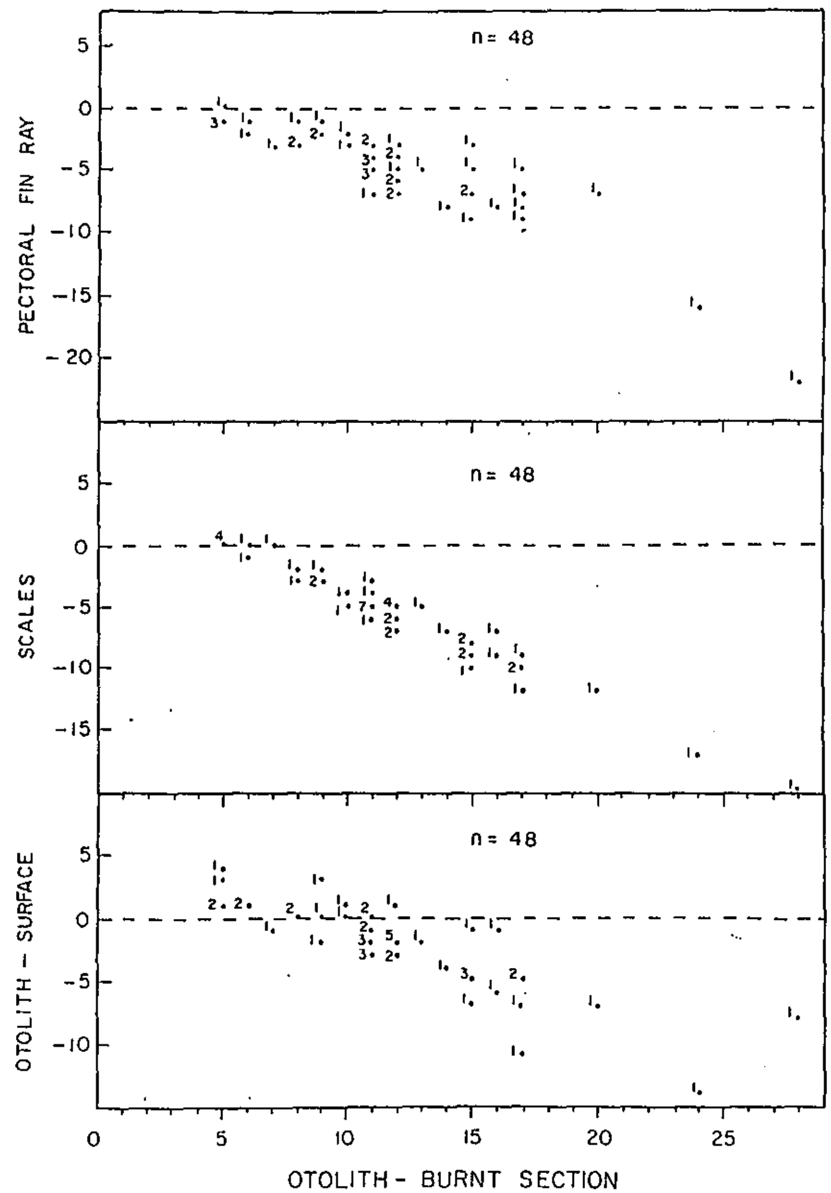

Fig. 17. Mean deviation of otolith surface, scales and pectoral fin ray ages from burnt otolith section ages for pollock collected in the International waters of the Eastern Bering Sea (Donut Hole).

Year-to-year Variation of Stocks and Community Structure of Western Bering Sea Pelagic fishes

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The main fishery fishes in the western Bering sea are pollock(Theragra chalcogramma), herring(Clupea pallasi), cod(Gadus macrocephalus), saffron cod(Eleginus gracilis), plaice(Pleuronectidae), pink(Oncorhynhus gorbuscha), chum salmon(Oncorhynchus keta). The abundance and commercial harvest of pelagic fishes greatly exceed those of bottom fishes. In the 1980s, the total harvest of all species in this region increased 4-fold compared to the previous decade.

There are carried out routine investigations in Karaginkii and Olutorskii bays over 50 years. Since 1958, trawl surveys were conducted and spawning herring stocks were estimated in relation to eggs deposited. Starting in 1970, the stocks of pollock and capelin(Mallotus villosus socialis) were evaluated using both data on egg sampling and trawl surveys, and results of mathematical modelling. As a result, the information is available concerning the absolute abundance of Korpho-Karaginskii herring for more than 50-year period; for western Bering sea pollock and capelin over 20-year period. The comparable information on catches of herring, pollock, capelin and arctic smelt(Osmerus mordax) by research vessels covers 32 years. In recent 3-4 decades, the community of pelagic fishes in the western Bering sea has shown considerable structural changes. There were established three periods in the community development. In the 1950s-early 1960s the most abundant community species was represented by herring. In 1953, the total herring number has reached maximum constituting 3,5 million tons. This resulted in shortage of food availability which was evident from biological herring condition. Actually, the growth and sexual maturatin were sharply reduced in the population. In addition, the decrease was found in the fecundity and reproduction indices of herring, while their natural mortality markedly increased. By the late 1950s, herring numbers decreased up to 2,3 mln tons because of too high density of fish, and by the mid-1960s they were equal to 0,8 mln tons resulted from the increased natural mortality. The number of other pelagic fishes in "herring" period was as follows: arctic smelt - about 100 ths tons (maximum), capelin - about 80 ths tons (average) and pollock - about 0,8 mln tons (maximum). In the mid-60s, the "herring" period has been completed. The new period in the development of the pelagic community lasted approximately till 1973. No prevalent pelagic species was found at that period of time. The community structure tended to change rapidly. In 1968-70, when the abundance of herring and pollock was close to minimum level, the number of capelin abruptly increased.

The latter were greatest in numbers for some period of time. However, in 1971 there appeared a fairly abundant herring generation which caused, as a consequence, the prevalence of herring among pelagic fishes. By the end of the period, herring and pollock were equal in their numbers, while biomass of the latter was 2 times more than of the former. The means for numbers of pelagic fishes in the 2-nd period were the following: 340 ths tons for herring, 1 mln tons for pollock, 130 ths tons for capelin and 40 ths tons for arctic smelt.

The period in community development started in the mid-1970s and lasted till now, is characterised as "pollock" one. The number of this species progressively increased and reached 3,5 mln tons by the early-1980s. Afterwards, the abundance was found to decrease. On the whole, over recent 15 years, the pollock biomass accounted for more than 85% of the total number of all four pelagic fishes. The number of herring, capelin and arctic smelt were stabilised at historical minimum level in the "pollock" period, 290,50 and 20 thousand tons, respectively. A more detailed analysis of causes and some regularities of variations in the community structure was undertaken using many years information on distribution of fishes during a year, their diets and food availability, and hydrometeorogical conditions of their habitat.

The common wintering areas are observod for capelin and pollock (about 66% of their total abundance), and for herring and pollock (over 65% of the total abundance). First two species are concentrated in the littoral zone of Karaginskii bay, other ones in Karaginskii and Olutorskii bay over the depth of 100 m. In spring, all four species spawn. Herring, capelin and smelt are concentrated in the coastal zone of Karaginskii bay. Pollock occupy the area over the depth of 100 m in Karaginskii bay and that of 50 m in Olutorskii bay. In summer, more even distribution over the whole area is observed for pelagic fishes. However, they show the main signs of winter bathymetrical subdivisions. Summer season is characterized by the highest interception of pelagic fishes: over 54% of the total number of herring and pollock, 68% of smelt and capelin, about half of herring and pollock numbers. Pollock and capèlin are found to coexist in summer period.

The principal food items of herring, capelin and small pollock are crustaceans. In summer they are assumed to eat copepoda in other seasons euphasiids. Pollock with the length of more than 50 cm prey mainly on fish: young pollock, young herring, capelin and sand launce. As for arctic smelt, they are typical predators, utilizing mostly pink and chum migrants, herring and pollock juveniles, capelin and sand launce(Ammodytes hexapterus). The proportion of pollock juveniles in the food of arctic smelt is lower. The degree of food similarity for herring, small pollock and capelin fairly high. Usually, all of them consume more abundant, available and suitable in sizes zooplankton organisms.

The composition and biomass of zooplankton in the western Bering sea varied considerably over the study period. In the 1950s-early 1960s, i.e. in the first period of community development, the biomass of mezoplankton was highest. Further, in the second period, there occurred two-fold decrease in its biomass, followed by large increase in the third period.

It is significant that the index of food availability to plankton-eaters (the relation of the average zooplankton biomass to the total abundance of herring, capelin and pollock) remained unchanged during all three periods: in 1958-1965 - 6,22; in 1966-1973 - 6,32; in 1974-1987 - 6,15.

Thus, specific distribution and diet of three most numerous species of the coastal waters of the western Bering sea and the condition of their food base do not exclude the intense trophic relationships among them. The food competition is believed to be highest between herring and young pollock begining from the larval stage. Finally, the total abundance of those species is related to trophic conditions of their habitat.

The dynamics of the community may result also from hydrological conditions changed. In fact, according to a number of such factors, "herring" period os entirely different from "pollock" one. The former is characterized by low water temperature in spring and summer months and maximum ice cover in winter, relatively mild winter (air temperature) and cool summer. In "pollock" period the hydrometeorological conditions have changed.

Distribution, Abundance, Length Composition and Potential Yield of Pacific Cod in the Gulf of Anadyrskiy, and Waters off Cape Navarin and Cape Olyutorskiy

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Introduction

Pacific cod (Gadus macrocephalus) is widely distributed in the continental shelf and the upper continental slope in the north of northern Yellow Sea on the Asian side and north of California on the North American side in the North Pacific (Bakkala et al., 1984) and has been used by nations concerned as an important fishery resource from olden times (Forrester et al., 1978; Moiseev, 1953). However, biological information concerning Pacific cod has been generally scarce. In the eastern Bering Sea, a large-scale groundfish survey was conducted using bottom trawl nets in 1979 for the first time under the U.S.-Japan cooperative survey program. Similar surveys were implemented in 1981, 1982, 1985 and 1988 in the eastern Bering Sea, and in 1980, 1983, 1986 in the Aleutian Islands region. Further, a large-scale groundfish survey, using bottom longline nets, was initiated in the Aleutian Islands region in 1979 under the Japan-U.S. cooperative survey program, and this was also conducted in the eastern Bering Sea from 1982. These surveys have enabled systematic accumulation of biological information on various groundfishes including Pacific cod.

On the other hand, there is no comprehensive report on Pacific cod stocks in the western Bering Sea, other than the one by Moiseev (1953). In the Gulf of Anadyrskiy and waters off Cape Navarin, bottom trawl surveys were conducted by Japanese trawl research vessels in 1969 (Wakabayashi, 1972) and in the waters west of 175°E in 1970 (Yoshida, 1971), 1971 (Yoshida and Kitano, 1972) and 1972 (Kanamaru, 1972) in order to obtain information on groundfishes including Pacific cod. However, virtually no information was made available concerning 1977 and thereafter, when U.S.S.R. introduced the 200 miles zone. Based on the agreement reached at the 5th Japan-U.S.S.R. Fishery Commission in 1988, the first Japan-U.S.S.R. joint groundfish survey using bottom longline nets was conducted in the U.S.S.R. 200 miles zone in the northwestern Bering Sea in January and February 1989 (Sasaki and Fujii, 1989). Later the second joint longline survey was conducted in more or less the same area in October 1989. From these surveys, biological information was made available concerning bottom fish in the continental shelf and continental slope of the northwestern Bering Sea. This paper reports distribution, abundance, length composition and potential yield of Pacific cod based on available data.

Materials used

1. Trawl

Bottom fish survey materials by Yoko maru in 1969, as reported by Wakabayashi (1972), were used. This survey was conducted in the Gulf of Anadyrskiy and the continental slope at the depth of 150-500 m east of 172°E (Figs 1 and 2). The survey in the Gulf of Anadyrskiy was conducted between July 21 and 29, that in the continental slope between July 30 and August 28, and that in area off Cape Navarin between July 30 and August 7.

2. Longline survey

The results of Japan-U.S.S.R. joint longline survey by Fukuyoshi maru No.26 in January-February 1989, as reported by Sasaki and Fujii (1989), and the results of a similar survey (unpublished) by Ebisu maru No.88 in October 1989 were used. The survey by Fukuyoshi maru No.26 was conducted in the area off and around Cape Navarin and Cape Olyutorskiy between January 24 and February 9 (Fig. 3), and that by Ebisu maru No.88 was conducted in the Gulf of Anadyrskiy and the area off Cape Navarin (Fig. 4).

The survey was programmed so that its results could be directly compared with those obtained from the Japan-U.S. cooperative longline survey which had been conducted in the U.S. 200 miles zone since 1979. For this purpose, the more or less same survey methods as the one established in the Japan-U.S. survey was adopted. The structure of one hachi of longline used in the survey was the same as that used in the Japan-U.S. survey. It had ground line of 100 m long, which had 45 hooked lines of 1.2 m long spaced 2m. A fishing hook was tied at the tip of each hooked line. Pacific cod hook No. 18 was used and squid, cut in the form of ring or vertically, was used as bait.

Distribution and Abundance

According to the results of the trawl survey in 1969, the abundance of Pacific cod in the Gulf of Anadyrskiy was high at the inner part and the mouth of the bay and low in the central part (Fig. 5). The water temperature in the bottom layer was within the range of -1.9 degrees centigrade and +2.6 degrees of centigrade, and water temperature of below 0 degree was distributed in the innermost part and eastern part of the bay (Fig. 6). The abundance of Pacific cod was high even in the water temperature zone of zero degree centigrade or lower, but no distribution was observed in the water temperature zone of -1 degree centigrade or lower. In the continental slope area, the highest abundance was observed at the middle point of Cape Navarin and Cape Rubicon (Fig. 7). The abundance of Pacific cod decreased sharply in the 300 m dept layer, and no distribution was observed in the 400 m depth layer.

According to the longline survey results in January-February 1989, the abundance of Pacific cod was high in the area around Cape Olyutorskiy for both the number of fish and weight, as compared with Navarin-Olyutorskiy area (Table 1). By depth, abundance was the highest in the 100-200 m depth layer, and was lowered as the depth got deeper. No distribution was observed in the layer of 500 m or deeper. The highest abundance was 20.19 fishes (86.6 kg)/hachi in the 100-200 m depth layer in the area around Cape Olyutorskiy. As far as the distribution of abundance by survey point was concerned, very dense schools of fish was found distributed at the survey point off Cape Olyutorskiy (L-1) (Table 1; Fig. 8). Here more or less the same abundance of fish schools were found distributed within the depth layers from 100 m to 400 m, and the range of abundance was 25.83-29.27 fishes (109.5-132.0 kg)/hachi.

In the survey conducted in October 1989, the abundance of Pacific cod was the highest in the 100-200 m depth layer off Cape Navarin both in terms of the number of fish and weight, and no distribution was observed in the waters of 400 m or deeper (Table 2). The abundance in the area of 100 m or shallower, which mainly distributed in the Gulf of Anadyrskiy, was 6.75 fish (27.7 kg)/hachi. This showed no great difference in terms of the number of fish as compared with 7.88 fish (41.1 kg)/hachi in the 100-200 m depth layer distributed out of the bay, but differed substantially in terms of weight. The difference was mainly due to the fact that length composition of Pacific cod living in the bay was somewhat smaller than those living outside the bay. As far as distribution of abundance by survey point, the highest abundance was 19.58 fish (108.1 kg)/hachi at the survey point off Cape Navarin (L-15) and depth layer was 100-200 m (Table 2; Fig. 9).

In the 200-300 m depth layers from Cape Navarin to Cape Olyutorskiy, data obtained from the two longline surveys could be compared. The abundance in January-February was 11.25 fish (38.9 kg)/hachi, fairly higher than 3.32 fish (11.2 kg)/hachi in October. This was deemed due to the difference in the manner of Pacific cod distribution in the spawning and feeding periods.

Comparing the abundance of Pacific cod in the Anadyrskiy-Navarin area in October 1989 with the results obtained from the Japan-U.S. cooperative longline survey conducted in the summer of 1988 in the eastern Bering Sea, the abundance in the 100-200 m depth layer was 13.25-14.40 fish (42.9-57.2 kg)/hachi in the eastern Bering Sea and 7.88 fish (41.1 kg)/hachi in the Anadyrskiy-Navarin area. In other words, the abundance of Pacific cod in the Anadyrskiy-Navarin area was lower than that in eastern Bering Sea in terms of the number of fish but, in terms of weight, was at more or less the same level as with the abundance in some part of the eastern Bering Sea (Table 3). The abundance in the 200-300 m depth layer was 3.32 fish (11.2 kg)/hachi in the Anadyrskiy-Navarin area, a level considerably lower than 7.59-11.93 fish (24.4-43.2 kg)/hachi in the eastern Bering Sea. In the Anadyrskiy-Navarin area, Pacific cods were not distributed in the 400 m depth layer or deeper. But in the eastern Bering Sea they were distributed in the 400-500 m depth layer, although small in number. The abundance of 20.19 fish (86.6 kg) observed in the 100-200 m depth layer in waters around Cape Olyutorskiy in January-February 1989 was at such a high level that had been observed rarely in the summer survey in the eastern Bering Sea.

Length Composition

The length compositions of Pacific cod caught in the 1969 trawl survey differed entirely in the Gulf of Anadyrskiy and the continental slope outside the bay (Fig. 10). In the Gulf of Anadyrskiy, pollock of wide-ranging size from 12 cm to 98 cm were caught, but most of them were juveniles of 40 cm and smaller, with the modes of 28-30 cm. It was assumed from this that the Gulf of Anadyrskiy plays an important role as the nursery ground for juvenile Pacific cod living in the northwestern Bering Sea. On the other hand, on the continental slope outside the bay, the modes were 58-62 cm, and the average body length was 61.4 cm.

The length composition of Pacific cod caught in the January-February period in 1989 stayed within the range of 32 cm to 106 cm, with the modes of 62-64 cm and the average size of 62.5 cm (Fig. 11). Further, the average weight per fish was 3.40 kg. By sex, the proportion of large female individuals was higher than large male individuals, and the average size of females was 63.2 cm as compared with 61.5 cm of males. By water depth, no conspicuous tendency was observed (Fig. 12). The average length in the 100-200 m depth layer was 63.6 cm and somewhat larger than those in other depth layers. But the modes stayed at a relatively small range of 58-60 cm. By area, the length composition in the area around Cape Olyutorskiy showed larger percentage of large fish than the Navarin-Olyutorskiy area. The average length was 64.7 cm in waters around Cape Olyutorskiy and 61.6 cm in the Navarin-Olyutorskiy area (Fig. 13). This difference was also observed in average weight. The average weight of Pacific cod in waters around Cape Olyutorskiy was 3.81 kg, considerably heavier than 3.24 kg in the Navarin-Olyutorskiy area.

In the survey conducted in October 1989, the length composition of Pacific cod stayed within the range of 34 cm to 108 cm, with the modes and average length standing at 66-68 cm and 69.1 cm, respectively (Fig. 11). The average weight was 4.54 kg. The proportion of large fish obviously increased by a large margin, when compared with the results obtained in the survey in January-February 1989. By depth layer, the average length in the area of 100 m or shallower in the Gulf of Anadyrskiy and 200-300 m depth layer outside the bay were 64.1 cm and 64.4 cm, respectively. The composition in the medium 100-200 m depth layer was mostly occupied by large fish above 60 cm having their modes at 70-72 cm. The average length was 73.4 cm (Fig. 14) and the average weight was 5.22 kg. When compared with the average length in the 100-200 m depth layer in January-February 1989, the average length in the 100-200 m depth layer in October was larger by about 10 cm. This difference cannot be explained by the increment in growth of Pacific cod from March to September. Large fish observed in October is deemed to have distributed outside the survey areas in the winter, i.e. in January and February.

In the length composition of Pacific cod caught in the Gulf of Anadyrskiy in the survey conducted in October 1989, few fish of 49 cm or smaller could be found, indicating their length composition was completely different from that of Pacific cod caught in the trawl surveys in 1969. This was because of the fact that longline gear tends to catch large Pacific cods selectively, as was also observed in the longline surveys in the eastern Bering Sea, and does not mean that there was no distribution of juvenile Pacific cods.

Comparing the length compositions of Pacific cod in the two areas of northwestern Bering Sea (U.S.S.R. waters) and the eastern Bering Sea (U.S. waters) in a way of areas combined (Fig. 11), the composition in the northwestern Bering Sea in January-February 1989 showed slightly larger percentage of small fish as compared with the composition in the summer in the eastern Bering Sea, and, in terms of average length and weight, that in the northwestern Bering Sea were 62.5 cm and 3.40 kg, and that in the eastern Bering Sea were 64.7 cm and 3.71 kg, respectively. The composition in the northwestern Bering Sea in October 1989 differed from that in January-February 1989, showing larger percentage of large fish as compared with the eastern Bering Sea.

Potential Yield

Based on the bottom trawl survey in 1969, Wakabayashi (personal communication) estimated the biomass of Pacific cod in the Gulf of Anadyrskiy and the Navarin-Olyutorskiy area as shown in Fig. 15 at 180,126 t. Of the total, 80,885 t accounted for the Gulf of Anadyrskiy and 99,241 t for Navarin-Olyutorskiy. As these estimates do not include part of the Gulf of Anadyrskiy and areas of 100 m or shallower outside the bay, the biomass of Pacific cod in the entire area is estimated to be 200,000 t or more.

It has not been possible in recent years to directly estimate biomass due to the absence of trawl survey data. Therefore, Pacific cod stock size in the Gulf of Anadyrskiy and Cape Navarin area, as shown in Fig. 16, was here estimated on a provisional basis using longline survey data of October 1989. Only relative abundance could be obtained from longline survey, other information is needed to estimate stock size. In the eastern Bering Sea and Aleutian Islands region, Japan-U.S. cooperative trawl surveys and longline surveys have been conducted. Concerning the same year, the same area and the same depth layer, estimates of population density per space (kg/ha) were obtained from trawl surveys, and estimates of relative stock abundance (kg/hachi) were obtained from longline surveys (Bakkala et al., 1985; Ronholt et al., 1986; Sasaki, 1980; Sasaki et al., 1983; Sasaki and Fukui, 1987; Walters et al., 1986). On the basis of the relations of these data, it is possible to convert into biomass the relative stock abundance of Pacific cod in the Anadyrskiy-Navarin area obtained from longline surveys in October 1989. Table 4 summarizes stock abundance estimates by trawl surveys and relative stock abundance estimates, which have been reported to date. In the longline survey reports for fiscal 1980 and 1982, only the number of fish caught per hachi was reported as relative abundance. The weight of fish caught per hachi, shown in Table 4, has been obtained from data file of the North Pacific Groundfish Section of the National Research Institute of Far Seas Fisheries. Further; reports of longline surveys and trawl surveys for fiscal 1988 have not been published. But as draft texts of those reports have been completed, citations were made from them. The relations between stock abundance and relative stock abundance was the linear relations, as shown in Fig. 17, except 100-200 m depth layer of area B-1 and 100-200 m and 200-300 m of area

EA in 1980. The following formula was obtained by applying regression line.

Y = 0.52 . X

Here Y is the stock abundance estimate by trawl survey (kg/ha).

X is the relative stock abundance estimate by longline survey (kg/hachi).

By using this relation, it is possible to convert any estimates concerning relative stock abundance of Pacific cod obtained from longline surveys into abundance (kg) per hectare. Overall biomass can be obtained by extending the abundance per hectare by size of area by means of space by depth layer of targeted survey areas. By using this method, Pacific cod biomass in the Anadyrskiy-Navarin area was estimated as 197,400 tons from relative stock abundance of Pacific cod obtained from longline surveys in October 1989 (Table 5). As regards relations used here, there was no problem when fish of the same length composition is caught by trawl gear and longline, but, as mentioned previously, even when operation is targeted at the same fish school, trawl nets tended to take smaller fish and longline tended to catch larger ones, as their fishing selectivity toward fish length differed. Therefore, the relations between stock abundance by trawl surveys and relative stock abundance by longline surveys are considered to be somewhat different from the relations shown here. But, in case there is no data available, it is considered to be fully effective in making approximate estimates.

It is necessary to conduct more detailed population analysis in order to obtain potential yield, but necessary biological parameters have not been made available concerning Pacific cod stock in the Anadyrskiy-Navarin area. Concerning the Pacific cod stock in the eastern Bering Sea and the Aleutian Islands region, Thompson (1989) conducted far-reaching population analysis. The results indicated that allowable biological catch (ABC) differs according to exploitation strategy, and the rate of ABC vis-a-vis biomass (exploitation rate) was within a range of 19.4% and 46.4%. Population analysis of Pacific cod in the eastern Bering Sea was also conducted by Teshima (1987), and optimum exploitation rate of Pacific cod was estimated at 29%.

Biological parameter of Pacific cod stock in the northwestern Bering Sea could differ from that of the eastern Bering Sea stock, but preliminary exploitation rate could be obtained on the basis of exploitation rate in the eastern Bering Sea. As clarified earlier, the length composition of Pacific cod in the northwestern Bering Sea was considerably large as compared with those in the eastern Bering Sea. Although the situation of U.S.S.R. fishing is not well known, fishing intensity on Pacific cod are assumed to be relatively low judging from length composition. It is deemed to be reasonable to set exploitation at a high level in the initial stage in order to exploit such stocks. Therefore, as a matter of strategy, it is deemed appropriate to promote exploitation at about 35% in the initial stage to carefully monitor the stock trend. When the exploitation rate of 35% is applied to 197,400 tons of Pacific cod biomass, potential yield of Pacific cod in the Anadyrskiy-Navarin area is assumed at 69,100 tons on a preliminary basis.

The results of trawl surveys conducted by Hokkaido National Fisheries Research Institute from 1970 to 1972 (Kanamaru, 1973; Yoshida, 1971; Yoshida and Kitano, 1972) and the results of the Japan-U.S.S.R. joint longline surveys conducted in January-February 1989 (Sasaki and Fujii, 1989) showed abundant distribution of Pacific cod in waters off Siberian coasts west of 175°E and Komandorskiye Island. Further, Moiseev (1953) reported that Pacific cod abundance is extremely high throughout western Bering Sea. It is assumed from this information that potential yield of Pacific cod stock in the western Bering Sea is considerably large. Effective utilization of these stocks will be promoted in the days ahead. It will be desirable to exploit Pacific cod stocks not by means of trawlers but by longline vessels because longline fishing is a passive operation which does not allow voluminous catch and catch large fish on a selective nature. Further, unlike bottom trawl nets, it present no threat of destroying invertebrata community living at the sea bottom. Appropriate operation period should be from April-May to around November because, in winter time, operable waters are limited extremely due to extension of drifted ice and large fish cannot be caught.

Issues To Be Solved

Survey effort in the two Japan-U.S.S.R. longline surveys conducted in 1989 was not sufficient as compared with the Japan-U.S. cooperative longline surveys in the eastern Bering Sea. In the days ahead, it is necessary to further expand research effort in the areas covered up to the present time and widen survey areas to the eastern Kamchatka coast and obtain comprehensive information such as distribution, abundance and length composition of Pacific cod in the areas from the western Bering Sea to Kamchatka coast. Further, it is essential to monitor annual changes in stock abundance, length composition and recruitment.

Potential yield of Pacific cod in the Anadyrskiy-Navarin reported in this paper is of preliminary nature. Particularly, biomass estimates which form the basis of potential yield contain uncertain elements as they had been obtained through indirect methods. It is necessary to accurately grasp stock size through systematic trawl surveys in the days ahead. No less important is to continue collection of biological parameters and promote studies on population analysis.

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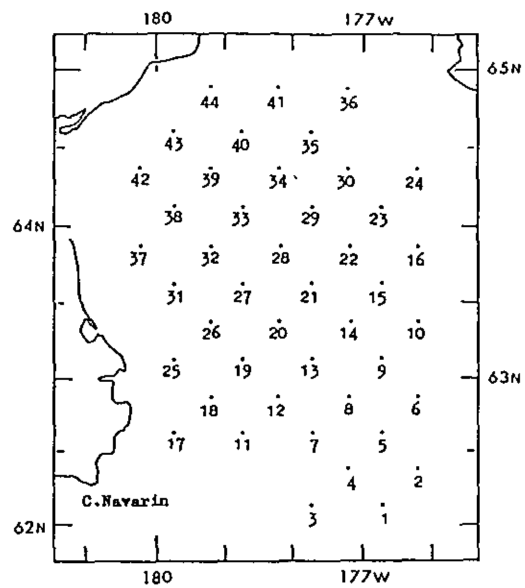

Figure 1. Sampling stations in the Gulf of Anadyrskiy used during the Japanese trawl survey by Yoko maru in July of 1969 (Wakabayashi, 1972).

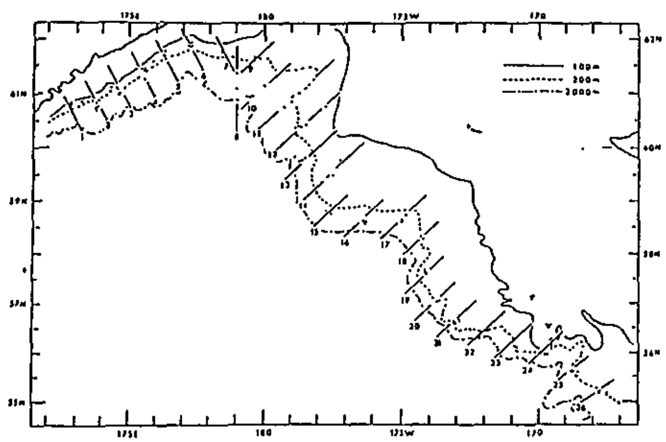

Figure 2. Sampling stations in the continental slope area from northwest to southeast Bering Sea used during the Japanese trawl survey by Yoko maru in July to August of 1969 (Wakabayashi, 1972).

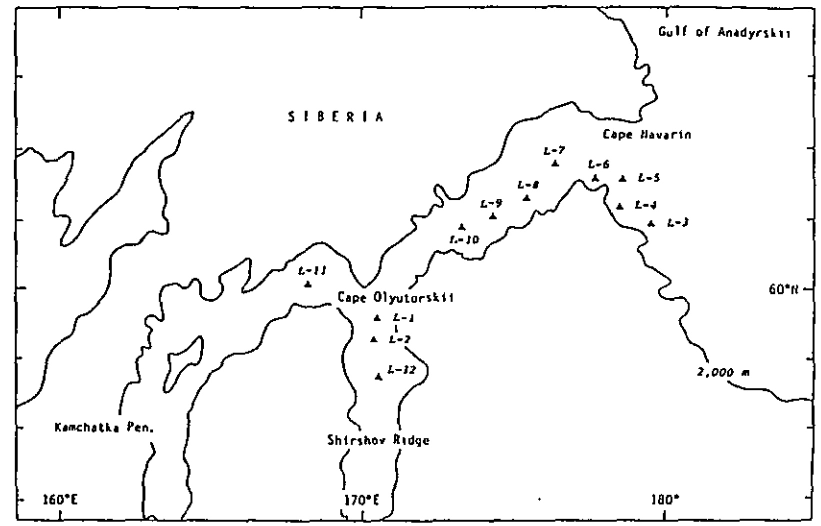

Figure 3. Survey area and sampling stations in the northwestern Bering Sea used during the Japan-U.S.S.R. joint longline survey by Fukuyoshi maru No. 26 in January to February of 1989 (Sasaki and Fujii, 1989).

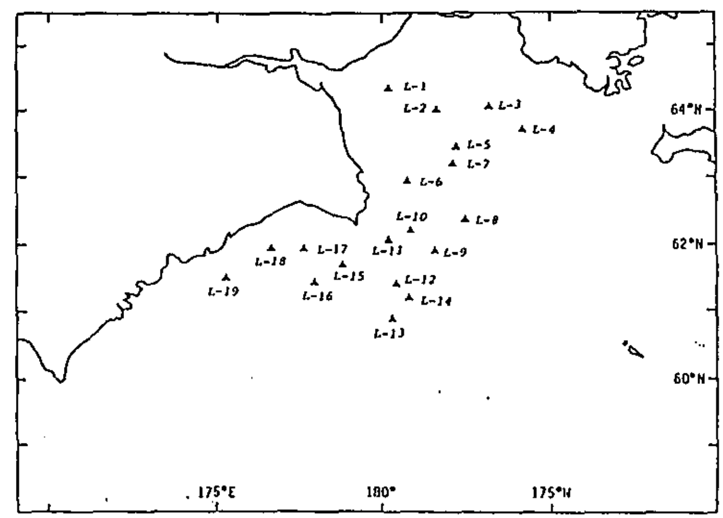

Figure 4. Survey area and sampling stations in the Anadyrskiy and Navarin area used during the Japan-U.S.S.R. joint long-line survey by Ebisu maru No. 88 in October of 1989.

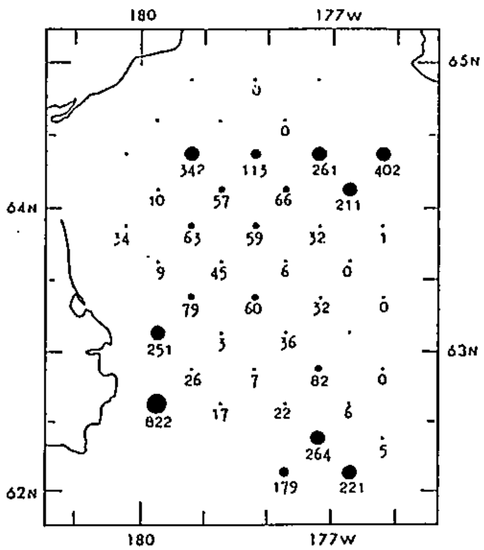

Figure 5. CPUE (kg/30 minutes) of Pacific cod by sampling station in the Gulf of Anadyrskiy caught in the trawl survey by Yoko maru in July of 1969 (Wakabayashi, 1972).

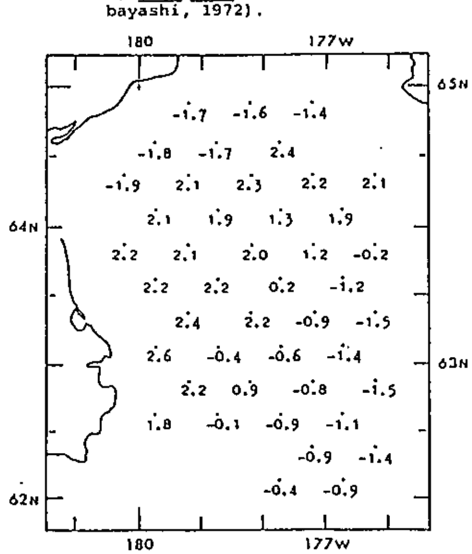

Figure 6. Bottom temperature (°C) by trawl sampling station in the Gulf of Anadyrskiy observed during the trawl survey by Yoko maru in July of 1969 (Wakabayashi, 1972).

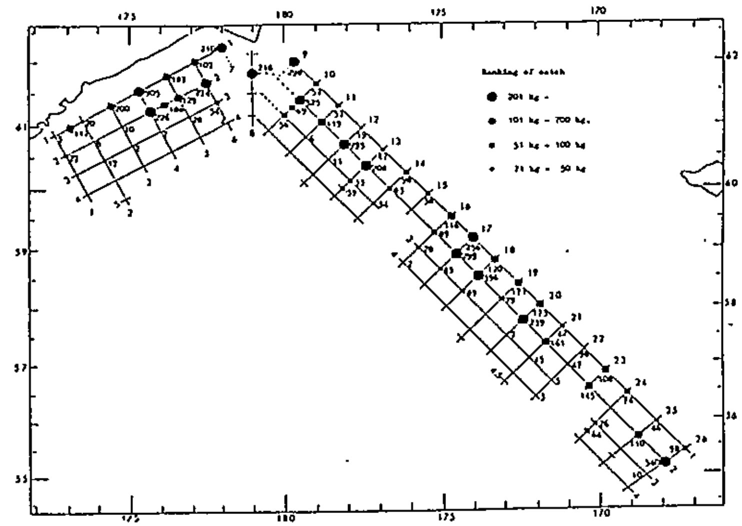

Figure 7. CPUE (kg/30 minutes) of Pacific cod by sampling station in the continental slope area from northwest to southeast Bering Sea caught in the trawl survey by Yoko maru in July to August of 1969 (Wakabayashi, 1972).

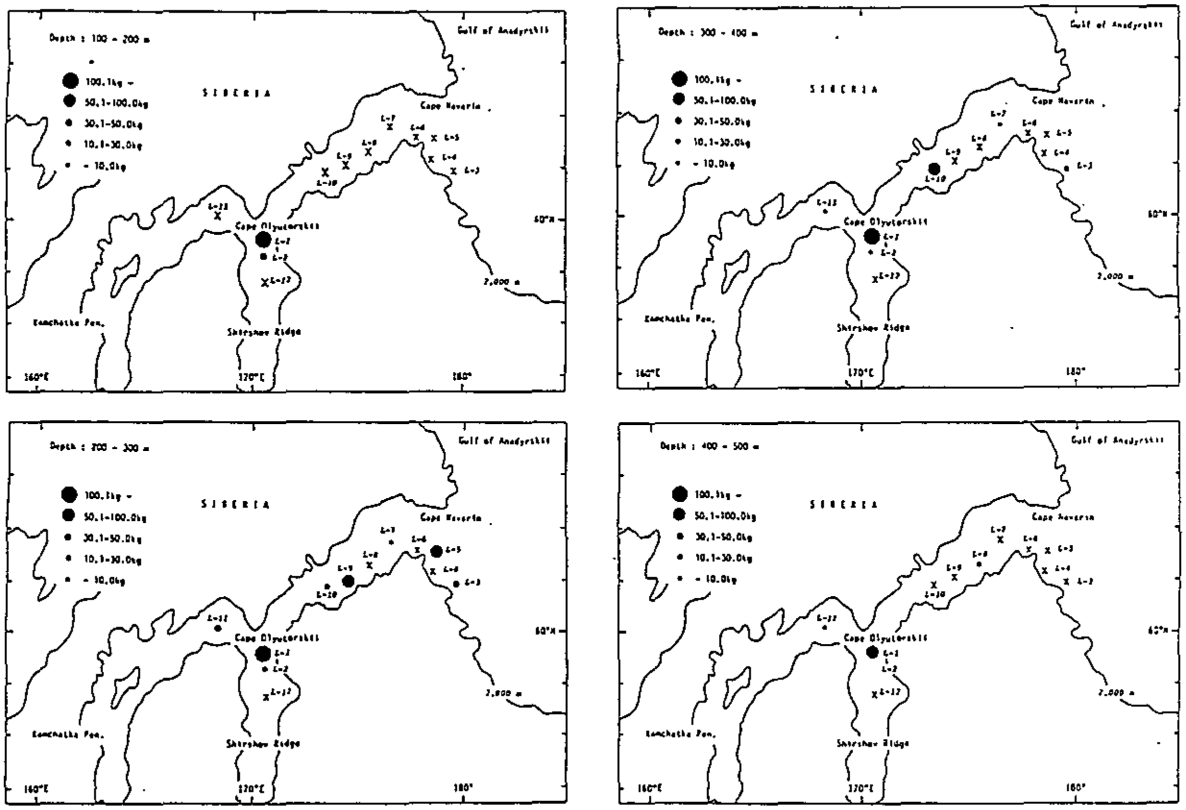

Figure 8. Mean CPUE (kg/hachi) of Pacific cod by depth zone at sampling station in the northwestern Bering Sea caught during the Japan-U.S.S.R. joint longline survey by _Fukuyoshi maru No. 26_ in January to February of 1989 (Sasaki and Fujii, 1989). Stations with mark of X show no fishing effort.

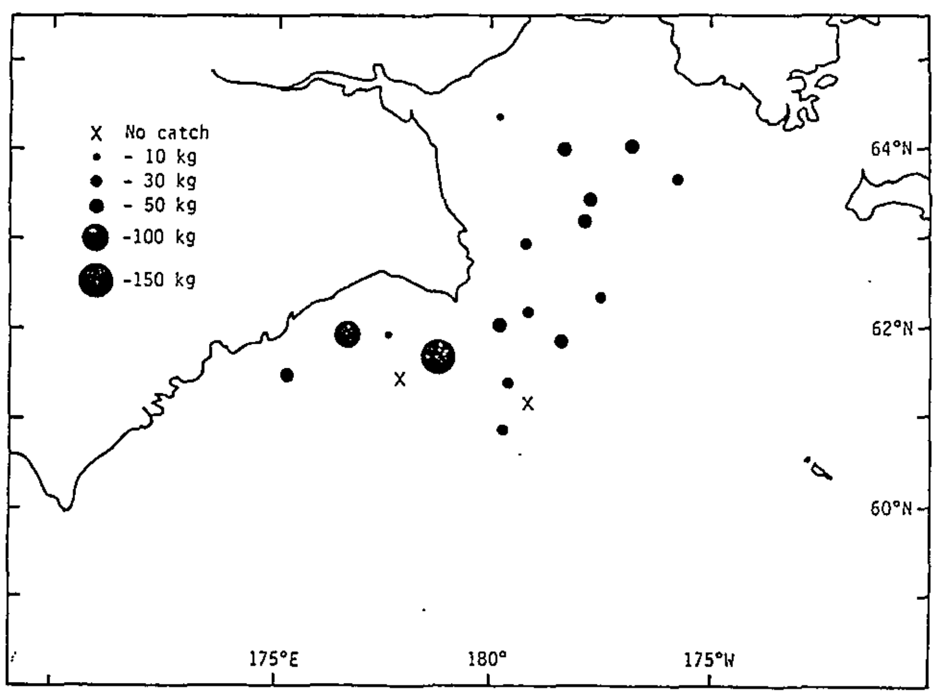

Figure 9. CPUE of Pacific cod (kg/hachi) by sampling station in the Anadyrskiy and Navarin area caught during the Japan-U.S.S.R. joint longline survey by _Ebisu maru No. 88_ in October of 1989.

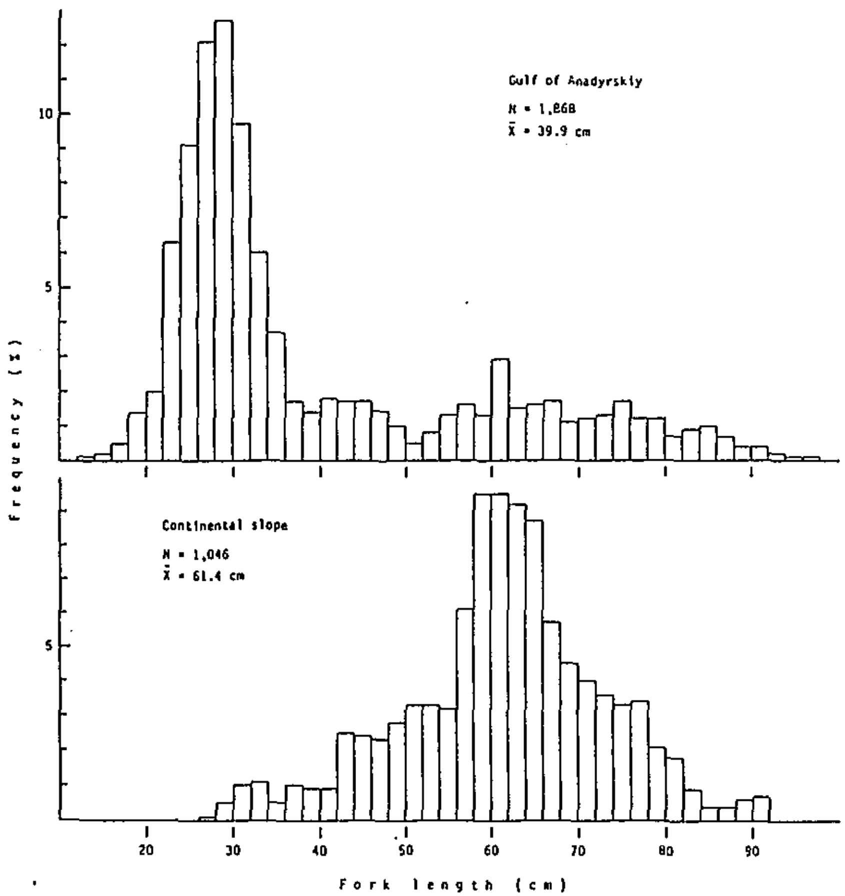

Figure 10. Size composition of Pacific cod in the Gulf of Anadyrskiy and the continental slope area off Cape Navarin caught during the trawl survey by Yoko maru in July and August of 1969.

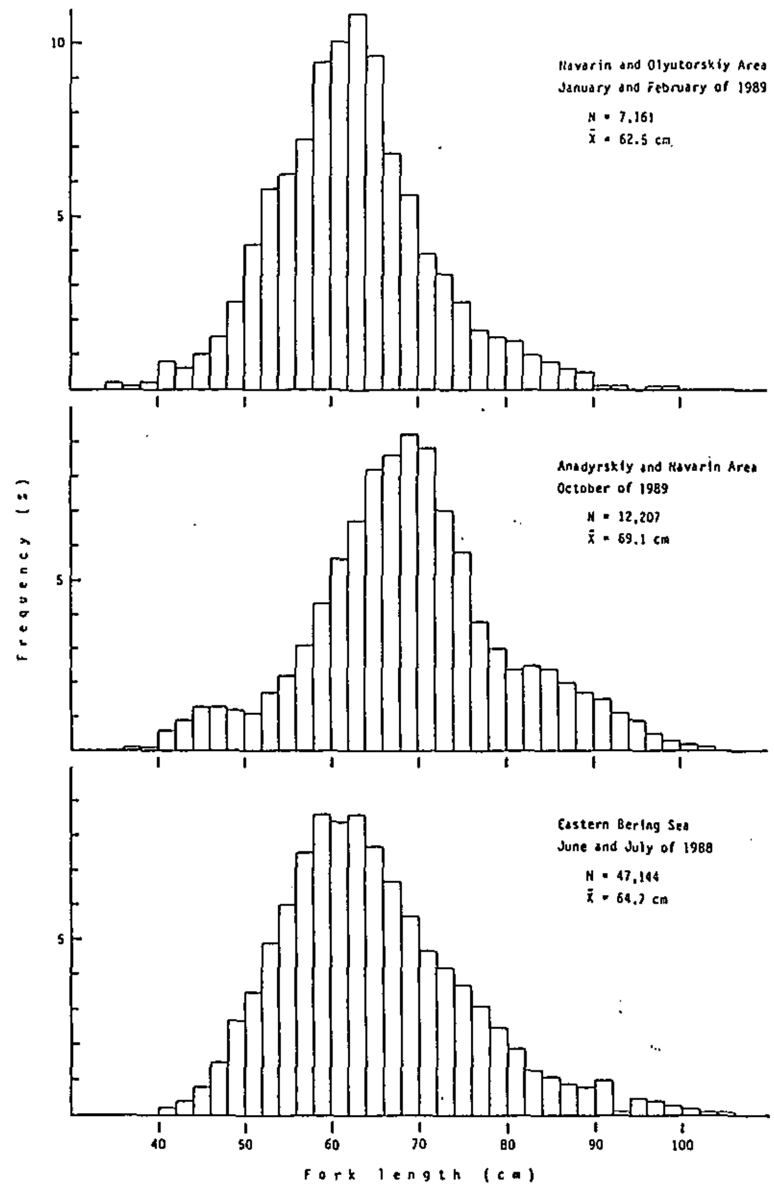

Figure 11. Size composition of Pacific cod in the northwestern and eastern Bering Sea caught during the Japan-U.S.S.R. and Japan-U.S. joint longline surveys.

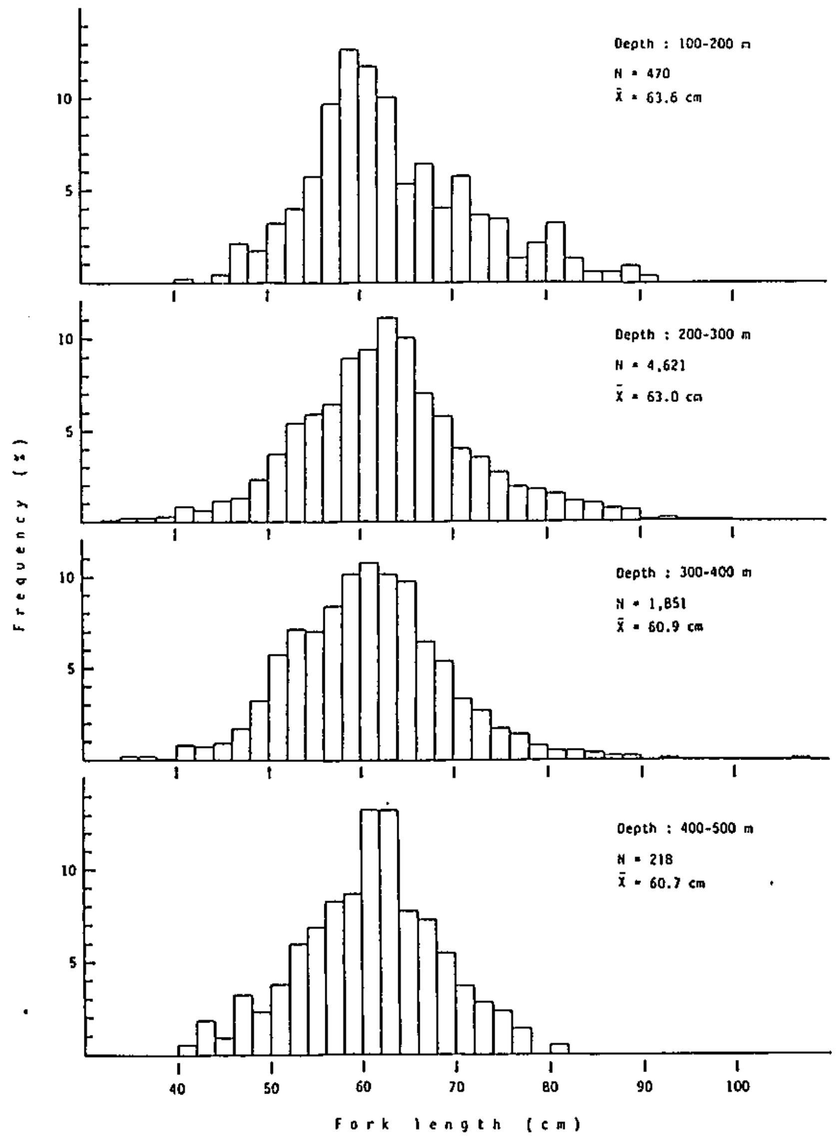

Figure 12. Size composition of Pacific cod by depth in the northwestern Bering Sea caught during the Japan-U.S.S.R. joint longline survey by Fukuyoshi maru No. 26 in January to February of 1989.

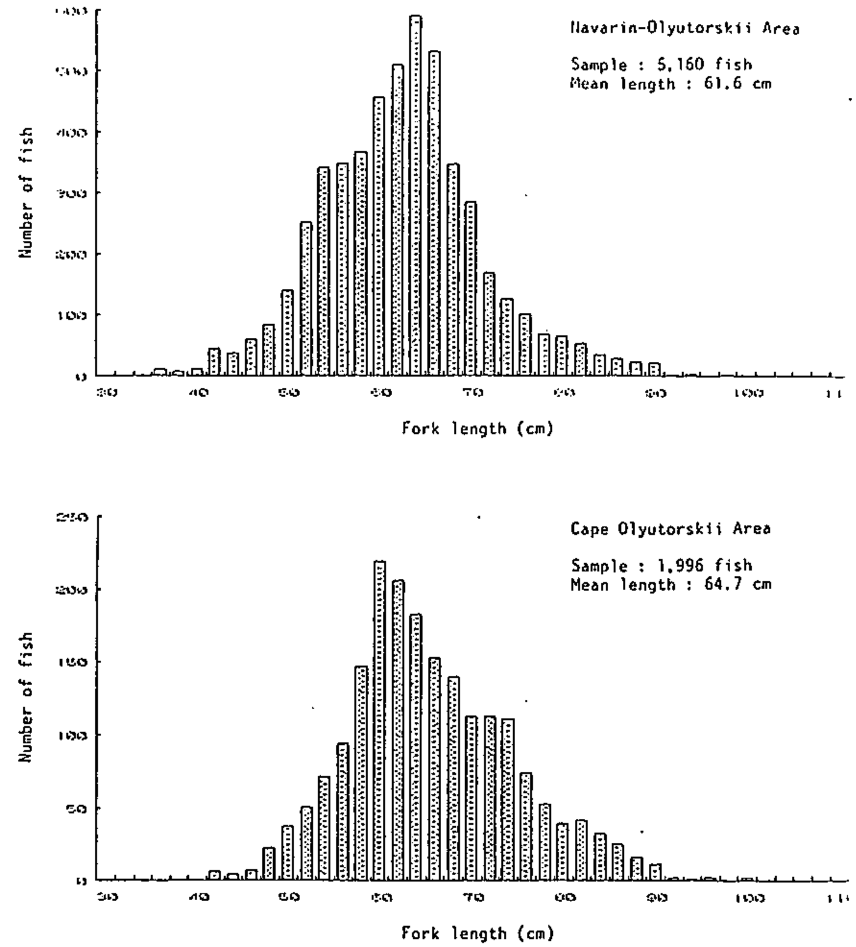

Figure 13. Size composition of Pacific cod by area in the northwestern Bering Sea caught during the Japan-U.S.S.R. joint longline survey by Fukuyoshi maru No. 26 in January to February of 1989 (Sasaki and Fujii, 1989).

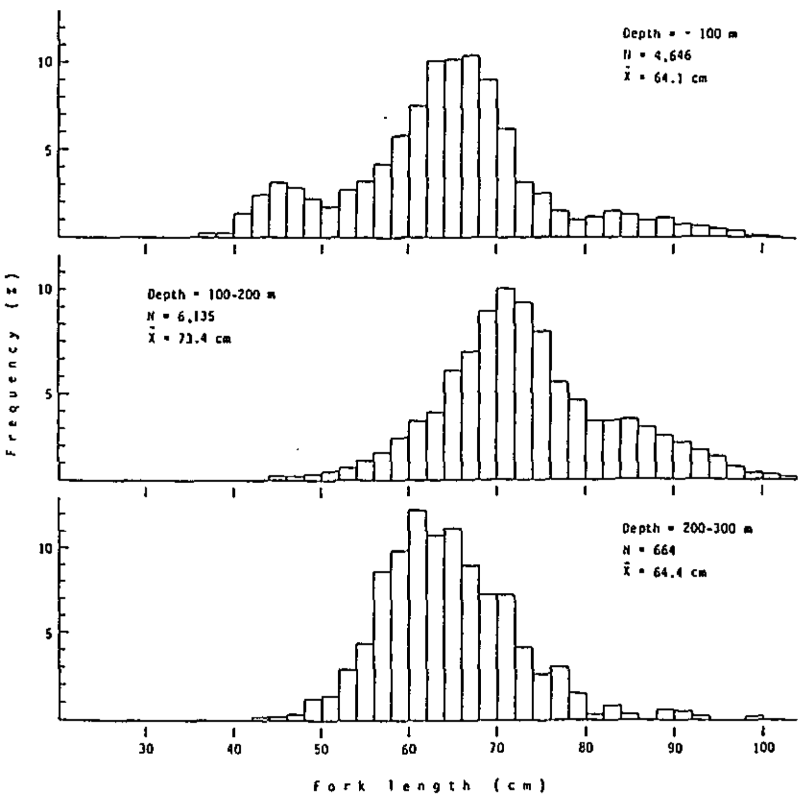

Figure 14. Size composition of Pacific cod by depth in the Anadyrskiy and Navarin area caught during the Japan-U.S.S.R. joint longline survey by Ebisu maru No. 88 in October of 1989.

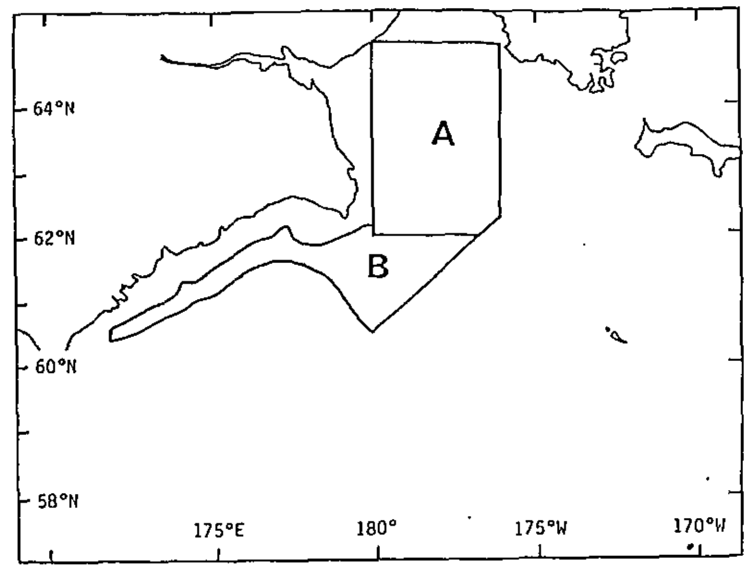

Figure 15. Area applied to estimate biomass of Pacific cod based on results of trawl survey by Yoko maru in the Gulf of Anadyrskiy and continental slope area off Cape Navarin in July and August of 1969.

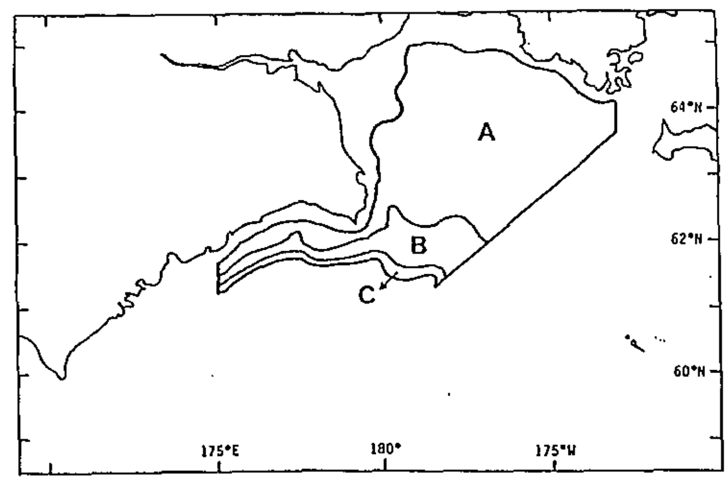

Figure 16. Area applied to estimate biomass of Pacific cod based on results of longline survey by Ebisu maru No. 88 in the Gulf of Anadyrskiy and waters off Cape Navarin in October of 1989.

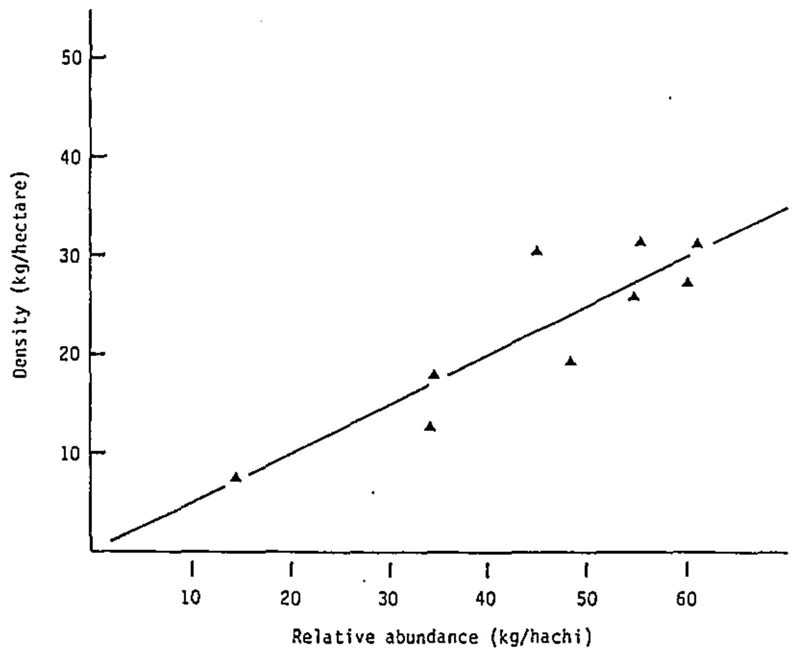

Figure 17. Relationship between estimated population density and relative abundance of Pacific cod obtained in the comparable survey stratum from the U.S.-Japan joint trawl surveys and the Japan-U.S. joint longline surveys in the eastern Bering Sea and Aleutian Islands region.

Table 1. Catch per unit of effort of Pacific cod by depth at survey station chaught during the Japan-U.S.S.R. joint longline survey by Fukuyoshi maru No. 26 in the northwestern Bering Sea in January to February of 1989.

Depth (m)	Navarin-Olyutorskii Area									Cape Olyutorskii Area				
	L-3	L-4	L-5	L-6	L-7	L-8	L-9	L-10	Average	L-1	L-2	L-11	L-12	Average
Catch in number / hachi														
100- 200	-	-	-	-	-	-	-	-	-	25.83	14.55	-	-	20.19
200- 300	13.67	-	16.87	-	0.40	-	17.02	7.40	11.25	28.44	10.00	7.39	-	15.28
300- 400	8.60	-	-	-	3.23	-	-	17.08	9.84	29.27	0.40	1.13	-	10.27
400- 500	-	-	-	-	-	5.07	-	-	5.07	16.25	0.00	0.13	-	5.46
500- 600	-	-	-	-	-	0.00	-	-	0.00	0.00	0.00	-	0.00	0.00
600- 700	-	0.00	-	-	-	-	-	-	0.00	0.00	0.00	-	0.00	0.00
700- 800	-	0.00	-	-	-	-	-	-	0.00	0.00	-	-	-	0.00
800- 900	-	0.00	-	0.00	-	-	-	-	0.00	0.00	-	-	-	0.00
900-1,000	-	-	-	0.00	-	-	-	-	0.00	-	-	-	-	-
1,000-1,100	-	-	-	0.00	-	-	-	-	0.00	-	-	-	-	-
Catch in weight (kg) / hachi														
100- 200	-	-	-	-	-	-	-	-	-	132.0	41.2	-	-	86.6
200- 300	38.0	-	56.5	-	1.5	-	74.0	24.5	38.9	118.6	27.4	34.2	-	60.1
300- 400	23.2	-	-	-	9.6	-	-	52.2	28.3	109.5	1.7	2.7	-	38.0
400- 500	-	-	-	-	-	12.8	-	-	12.8	53.0	0.0	0.2	-	17.7
500- 600	-	-	-	-	-	0.0	-	-	0.0	0.0	0.0	-	0.0	0.0
600- 700	-	0.0	-	-	-	-	-	-	0.0	0.0	0.0	-	0.0	0.0
700- 800	-	0.0	-	-	-	-	-	-	0.0	0.0	-	-	-	0.0
800- 900	-	0.0	-	0.0	-	-	-	-	0.0	0.0	-	-	-	0.0
900-1,000	-	-	-	0.0	-	-	-	-	0.0	-	-	-	-	-
1,000-1,100	-	-	-	0.0	-	-	-	-	0.0	-	-	-	-	-

Table 2. Catch per unit of effort of Pacific cod by depth at survey station chaught during the Japan-U.S.S.R. joint longline survey by Ebisu maru No. 88 in the Gulf of Anadyrskiy and the waters off Cape Navarin in October of 1989.

Depth (m)	L-1	L-2	L-3	L-4	L-5	L-6	L-7	L-8	L-9	L-10	L-11	L-12	L-13	L-14	L-15	L-16	L-17	L-18	L-19	Average
Catch in number / hachi																				
50-100	0.18	8.12	8.36	5.01	9.51	5.94	10.15	-	-	-	-	-	-	-	-	-	-	-	-	6.75
100-200	-	-	-	-	-	-	-	4.73	5.55	5.80	8.59	5.38	-	-	19.58	-	1.54	11.86	-	7.88
200-300	-	-	-	-	-	-	-	-	-	-	-	-	6.64	0.00	-	-	-	-	-	3.32
300-400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
400-500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
500-600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
600-800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	0.00
100-300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.62	7.62
Catch in weight (kg) / hachi																				
50-100	0.9	30.8	34.4	17.8	40.5	21.4	34.4	-	-	-	-	-	-	-	-	-	-	-	-	25.7
100-200	-	-	-	-	-	-	-	28.3	30.4	27.1	40.3	29.2	-	-	108.1	-	8.3	57.4	-	41.1
200-300	-	-	-	-	-	-	-	-	-	-	-	-	22.4	0.0	-	-	-	-	-	11.2
300-400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
400-500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
500-600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
600-800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	0.0
100-300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34.0	34.0

Table 3. Comparison of CPUE of Pacific cod by depth in the northwestern and eastern Bering Sea obtained from Japan-U.S.S.R. joint longline survey in October of 1989 and Japan-U.S. joint longline survey in June-July of 1988.

Depth (m)	Anadyrskiy and Navarin Area	Eastern Bering Sea			
		Region-IV	Region-III	Region-II	Region-I
Catch in number / hachi					
50 - 100	6.75	-	-	-	-
100 - 200	7.88	13.25	14.16	14.40	13.54
200 - 300	3.32	7.59	11.24	11.93	9.74
300 - 400	-	2.80	4.64	4.23	3.65
400 - 500	0.00	0.07	0.08	0.22	0.22
Catch in weight (kg) / hachi					
50 - 100	25.7	-	-	-	-
100 - 200	41.1	48.2	57.2	54.7	42.9
200 - 300	11.2	24.4	37.3	43.2	30.5
300 - 400	-	8.8	14.0	11.1	10.8
400 - 500	0.00	0.3	0.3	0.6	0.5

Table 4. Estimated population density and relative abundance of Pacific cod obtained in the comparable survey stratum from the U.S.-Japan joint trawl surveys and the Japan-U.S. joint longline surveys in the eastern Bering Sea and the Aleutian Islands region.

Year	Area	Depth (m)	Trawl survey: Number of Stations	Trawl survey: Density (kg/ha)	Longline survey: Number of Stations	Longline survey: Number of hachis	Longline survey: Relative abundance (kg/hachi)
1980	B-I	100-200	12	104.1	4	57	59.3
		200-300	5	30.4	4	103	45.1
	WA	100-200	28	18.0	8	288	34.5
		200-300	31	7.5	9	147	14.6
	EA	100-200	48	41.9	12	368	21.7
		200-300	35	13.8	14	309	11.2
1982	B-II	100-200	21	12.7	8	895	34.2
	B-III	100-200	23	27.5	5	572	60.2
1985	B-II	100-200	23	19.4	9	1,013	47.1
	B-III	100-200	23	31.2	8	681	55.3
1988	B-II	100-200	27	26.1	9	1,062	54.7
	B-III	100-200	67	31.5	9	948	57.2

Table 5. Estimated biomass of Pacific cod in the Anadyrskiy and Navarin area as shown in Figure 16.

Depth (fathom)	Size of area (km^2)	Density (ton/km^2)	Biomass (ton)
20- 60	88,500	1.51	133,600
60-100	23,000	2.13	49,000
100-130	13,000	1.14	14,800
TOTAL	124,500		197,400

Present State of Salmon in the Northeastern Kamchatka and their Commercial Fisheries

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A great proportion of the Pacific salmon catches by the USSR is composed of salmon stocks reproduced in the rivers that fall into the western Bering sea. Over the last decades about half of the Kamchatka total salmon catch was taken there. The contribution of each salmon species to the commercial harvest and dynamics of the latter are represented in Tabl.1. As seen from above, pink and chum salmon provided the most share of the catch, therefore studying their biology and population dynamics is of great importance.

Tabl.1

Average proportion of salmon by species in commercial catches (%) captured in the north-eastern Bering sea

Years		Pink	Chum	Sockeye	Chinook	Coho
1960-1969	even years	80,5	19,2	0,3	+	+
	odd years	91,0	8,8	0,2	+	+
1970-1979	even years	88,8	7,3	+	3,9	+
	odd years	94,1	4,3	+	1,6	+
1980-1989	even years	56,0	40,1	2,3	1,6	+
	odd years	81,5	16,7	1,1	0,7	+

Note: + - less than 0,1%

To estimate the present state of salmon stocks and forecast the salmon returns and commercial catches, the following complex of information is used:

1. Since 1957, in all bodies of water of the region there was carried out aerial surveying of spawners. This included the number and density of spawners on the spawning grounds, and the distribution of spawners by species and races at the spawning grounds of different types (river, spring and lake). Since the observations were made by the same researcher over the study period, the individual error was constant. Data obtained make it possible to predict the number of progeny in advance of nearly two years.

2. Statistical information on species composition of the catches was collected from all fishery facilities to by groups of the rivers fished. The dynamics of harvest is analyzed by subregions as well as by the region as a whole.

3. Biostatistical information on salmon spawners was collected each year from the rivers Haylula, Karaga, Kichiga(Karaginskiy bay), Avjavayam (Korf bay), Apuka (Olutorskiy bay) and also from fish processing enterprizes.

4. To assess the number of young pink and chum migrated downstream by standard methods, the research stations were established in the above-mentioned rivers. Some number of migrants captured was analyzed to estimate their morphophysiological condition (size, weight, presence of a residue of yolk sac, stomach contents, etc.).

5. Since 1975, the environmental conditions and abundance of [illegible] coastal areas of Korfo-Karaginsk bay have been st[illegible], the methods has been developed to forecast the returns of Karaginsk pink stock in advance of 11 months. The major initial parametres included the number of parents, the catch of juveniles per effort, water temperature and condition of food base in the yearly marine life.

6. Since 1983, the routine trawl surveys have been made of

young salmon outmigrants in the western Bering sea in September-October. The works are under experiment, however, in some years they allowed to reduce the forecast error of pink return by 5-10%.

7. Forecasting of timing of commercial pink return and dynamics of fishing has been initiated since 1983 to promote timely involving of processing fleet into commercial fishery.

Begining in 1986, forecasts of time of pink return (error doesn't exceed 2 days) are produced in advance of more than 15 days. Timing of rise and decline of pink return is predicted in advance of 5-7 days.

Thus, the state of pink and chum salmon stocks in northeastern Kamchatka and dynamics of their harvest is almost fully controlled.

It is known that salmon stocks of northeastern Kamchatka coastal waters are exploited mainly by the USSR and Japanese fisheries. Year-to-year correlation between catches by these countries was variable. Prior to 1943, harvests by Japanese fishermen(inshore catching) were more than 1 1/2-2 times those by the USSR. From 1944 through 1957 there was observed only Soviet fishery. The activation of Japanese high seas fishery resulted in the considerable decline of catches taken by the USSR by 1977, due to the great decrease in the number of salmon returning to the coast. With high seas fishery restrictions, salmon stocks began restoring. Changes of the fishing area and fishery intensity of salmon stocks caused changes in their population structure and dynamics. However, the analysis of fishery statistics and biostatistical information makes it possible to reveal some characteristics of variations of pink and chum abundance in the study area.

Maximum catches of odd-year pink generations were observed in 1937, 1957 and 1981, minimum catches in 1927, 1947 and 1973. Thus, till recent time there was observed a long-term cyclicity concerning the changes in the abundance of odd-year broods which was close to 22 years. The latter allowed while preliminary forecasting of the return strength to use two equations (similar to Ricker's model) of correlations between parents and progeny. We have examined the periods of rize and decline of pink salmon numbers separately. After maximum in 1981, the number of pink stocks has been proposed to decrease by 1989. However, the change has been already evident in 1985. In 1989, the historical maximum of catch and abundance of Karaginsk pink stock was recorded. Nevertheless, preseason forecast of the maximum has been already made. In my opinion, the break in the long-term cyclicity was caused by the natural factors (considerable warming of coastal waters of Karaginskiy bay) as well as by lessening of the sea fishery pressure.

Commercial harvest and even-year pink broods over the study period are found to be considerably lower compared to those of odd-year generations. Moreover, while considering other pink stocks of lower abundance, they showed a tendency for increasing their size and weight. The reverse was observed for northeastern Kamchatka pink stocks: the fish were of the same size or even smaller in comparison to pink of odd-year broods, in spite of the 10-fold difference in their abundance. Fluctuations in the abundance of even-year pink broods have revealed the periodicity of about 8 years, and a tendency to correlate negatively with those of odd-year broods, i.e. the long-term periodicity of 22-24 years.

As a consequence of different-numbered brood lines (odd- and even-), the calculated optimum escapements greatly differ, the even-year broods being less than 4 times the odd-year broods. This may be affected by the area of spawning grounds as well as by different survival of juveniles in the early marine life. The latter may be related to quasi-two-year periodicity in water thermal regime and, as a consequence, changes in food availability for salmon juveniles.

The estimates of optimum density at the spawning grounds make it possible to control fishery in tensity of pink stocks. The rate of exploitation averages 60-65%. However, in some years it should be increased to 80-90%. Otherwise, the progeny from "surplus" escapement would dramatically decrease and the coefficient of return would be lower than average.

In the 1930s, harvesting of western Bering sea chum salmon accounted for 30 thousand tons. After depression in the late 1950s - early 1970s, the number of chum progressively increased but didn't attain many years' average of 1930s-1940s. The main reason of slow restoration of stocks is an inadequate escapement of adult fish in spite of moderate coastal fishing pressure on chum stocks. The second possible limiting factor may be attributed to increased abundance of chum stock cultured in Japan. The natural and artificial populations are assumed to compete acutely for food resouces in the ocean that results in increasing mortality of natural population.

Biological characteristics of chum stocks also have changed in consequence of depression; specifically fish mature earlier.

Population dynamics of northeastern Kamchatka chum has shown 4-5-year short-term cyclicity as well as 11-year cyclicity. The main reason of long-term fluctuations as in the case of pink may be accounted for by fluctuations in solar activity with 11- and 22-year cyclicity.

Resources of sockeye and chinook salmon in the rivers of northeastern Kamchatka are found to be relatively small. Their harvest in the historical aspect didn't exceed 1 thousand tons and 700 tons, respectively. At present, sockeye abundance tends to be restored after the depression and seems to be about many years' average of the 1930s-1940s. Also, there is evidence for the adequate number of brood stocks at the spawning grounds of major reproduction areas.

The abundance of chinook produced from the major rivers of the region - Apuka, Pakhacha, Avjavayam and Vyvenka - progressively decreases after jumping in the late 1970s. There are no grounds for expecting the increase in the sizes of chinook catches in the near future.

Our analysis of variations in the number of salmon stocks indicates the negative influence of the sea fishery on their population structure which is reflected in the changes in mean sizes and age at maturity of fish and in the loss of reproductive populations. The complete restoration of the number of salmon with long life history requires closure of oceanic fisheries or weakening of fishing pressure in the sea. Under further exploitation it's necessary to take into account the changes occured in salmon population dynamics.

Preliminary Results from Surveys of Walleye Pollock, (*Theragra chalcogramma*) in the Aleutian Basin in 1988 and 1989

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Abstract

Historically, most of the fishing for pollock in the Bering Sea has been conducted on or near the eastern and western Bering Sea shelves. In the 1980's, a large fishery developed in the international waters (the so-called donut hole) of the Bering Sea. Very little information is available about the stock structure and abundance of pollock in the Aleutian Basin. Of critical importance to understanding the biology of pollock in the Aleutian Basin and eastern Bering Sea is an understanding of the stock distribution during the spawning period, when the pollock presumably return to the vicinity of their point of origin. During winter 1988 the Alaska Fisheries Science Center conducted an echo integration-midwater trawl (EIMWT) survey of pelagic walleye pollock in the Aleutian Basin, including the area near Bogoslof Island and a portion of the international waters. During winter, 1989, a cooperative EIMWT survey of the entire Aleutian Basin, east of the U.S.-U.S.S.R. convention line and a portion of the eastern Bering Sea shelf was undertaken by the U.S. Alaska Fisheries Science Center and the Japanese National Research Institute for Far Seas Fisheries. During both years, very few fish were observed in the Aleutian Basin, except in the extreme southeast portion, near Bogoslof Island. During both years, the 1978 year class of pollock predominated in the Bogoslof area. The 1982 year class was the second most abundant year class in this area each year. Mature pollock on the shelf were younger, with the 1982 year class the most abundant, followed by the 1984 year class. During both 1988 and 1989, spawning near Bogoslof occurred near the 1st of March. For pollock observed on the shelf in 1989, very few fish were in spawning condition and it appeared that spawning would probably occur later in March or in April.

This report describes the general results of the 1988 survey and the U.S. portion of the 1989 survey. Data from the Japanese and U.S. surveys during 1989 will be combined to provide more detailed information about pollock abundance and biology in the eastern Bering Sea and Aleutian Basin during the winter.

Introduction

Eastern Bering Sea stocks of walleye pollock (*Theragra chalcogramma*) have been of substantial commercial importance since the early 1970s. Between 1983 and 1986 eastern Bering Sea catches of pollock averaged 1.1 million metric tons (t), a significant proportion of the annual worldwide catch of pollock which varied between 4.9 and 6.8 million t during the same period (Dawson 1989).

Historically, pollock have been harvested on the continental shelf of the eastern Bering Sea. Until the late 1970s none of this fishing was conducted by U.S. vessels and the principal fishing nation involved was Japan. With the implementation of the U.S. Exclusive Economic Zone (EEZ) in 1977 and the resultant extension of fisheries jurisdiction to 200 miles, U.S. fisheries for pollock in the eastern Bering Sea began to develop. By 1988 all pollock harvested in the U.S. zone of the eastern Bering Sea was by domestic fishing vessels.

Japanese scientists had documented the presence of substantial numbers of pollock in the pelagic zone of the Aleutian Basin during the late 1970s and early 1980s (Okada 1986). During the period of transition to an exclusively domestic fishery in the eastern Bering Sea, non-U.S. fleets began to explore the international waters of the Aleutian Basin. This exploration resulted in the development of a major fishery in the international portion of the basin with reported catches increasing rapidly from less than 180,000 t in 1983 to 1.3 million t in 1987 (Dawson 1989). The harvest of pollock in the international zone in 1987 slightly exceeded the U.S. pollock catch in domestic waters of the Bering Sea during the same period. Most fishing activities in the international zone occur in the early winter, prior to the spawning period. Catch rates generally decline during the spawning period. There is evidence to suggest that some fish migrate from the international zone to U.S waters to spawn in the extreme southeastern part of the basin in the vicinity of Bogoslof Island and the eastern Bering Sea continental slope. During the last few years, the U.S. fleet has begun to harvest fish in this latter area during the spawning period; the harvest was approximately 328,000 t in 1987 and 89,000 t in 1988.

The development of these Aleutian Basin pollock fisheries has raised management concerns regarding the relationships between basin and shelf pollock and about the dynamics of walleye pollock populations throughout the Bering Sea. As a result a major international research effort has been initiated by the nations which harvest pollock in the Bering Sea. Studies to investigate ecology and life history, and document spatial and temporal patterns of distribution and abundance have been initiated to address stock structure questions.

This paper provides information obtained during two surveys designed to locate and quantify significant concentrations of spawning or near-spawning walleye pollock in the Aleutian Basin and eastern Bering sea.

Methods

Techniques for the echo integration/ midwater trawl (EIMWT) surveys are described by Traynor and Nelson (1985). Additional details are reported by Bakkala and Wakabayashi (1985) and Walters et al. (1988). Transect lines were surveyed using a scientific quality 38 kHz echo sounding system consisting of a transmitter, towed transducer, receiver, and computer-based digital echo integrator and target strength measurement system. The acoustic system was installed in a portable container that could be located on the deck of the survey vessel. The transducer was mounted in a dead weight fin that was towed at an approximate depth of 12 m at vessel speeds of 9 to 11 kt. During routine survey operations echo integration data were collected every minute for each meter of distance between the transducer and the bottom to a maximum depth of 400 m. Data were generally collected continuously for 24 hours per day. When conditions were suitable, in situ target strength studies were conducted to collect target strength distribution information for a range of fish sizes and behavioral patterns.

A midwater trawl was used to collect biological samples when significant echo sign was encountered during the acoustic surveys. Midwater fish were sampled with a large midwater rope trawl which had ropes in the forward section and mesh sizes ranging from 163 cm forward to 8.9 cm in the cod end. The cod end was equipped with a 3.1 cm mesh liner. Biological samples collected during the processing of each midwater trawl included total catch and a random length frequency for each major species. Length-weight and maturity data were collected from selected samples and random otolith samples were collected in such a manner as to ensure adequate geographic coverage of the survey area. Age composition was derived by apportioning population estimates at length to age using an age-length key developed from otolith samples collected during the survey (see Traynor and Nelson, 1985, for details of the procedure).

The 1988 winter Aleutian Basin EIMWT survey was conducted aboard the NOAA Ship <u>Miller Freeman</u>, a 66 m, 2200 hp stern trawler, during January 28 through March 4, 1988. The region sampled included portions of the international zone, the region adjacent to Bowers Ridge (Figure 1), and the area near Bogoslof Island in the U.S. EEZ where a substantial winter fishery on spawning pollock has occurred in recent years (Figure 2). The international zone was sampled by means of parallel transects approximately 40 nmi apart; the Bower's Ridge area was surveyed with a zigzag transect design, and the Bogoslof area was surveyed by means of parallel transects spaced 10 to 20 nmi apart.

The 1989 winter Aleutian Basin/eastern Bering Sea (EBS) shelf survey was also conducted aboard the <u>Miller Freeman</u> (Figures 3-5). The survey was part of a cooperative survey between the U.S. Alaska Fisheries Science Center and the Japanese National Research Institute for Far Seas Fisheries. Further analysis of the combined data set is necessary for a complete description of the results of this cooperative survey. The description in this paper is only for the U.S. portion of the survey. The survey effort by the Japanese was approximately equal to that of the U.S. The survey period was from January 15 through March 8 and covered the Aleutian Basin as well as a significant portion of the EBS shelf. Survey tracklines in the western Aleutian Basin consisted of parallel transects spaced 80 nmi apart and oriented in a north-south direction. Transect spacing was reduced to 40 nmi east of St. Paul Island and further reduced to 20 nmi on the shelf north of Unimak Island. After completion of the large-scale survey, a more detailed survey of the spawning population in the vicinity of Bogoslof Island was undertaken during March 4-6. Transects were spaced 10 nmi apart and extended north from the Aleutian Chain approximately 40 nmi (Figure 5).

RESULTS

<u>Aleutian Basin Surveys in 1988 and 1989</u>

There was no significant echo sign outside of the Bogoslof Island area (southeast Aleutian Basin) during either the 1988 or 1989 surveys of the Aleutian Basin. The absence of echo sign observed with the echo integration system was supported by extremely small catches in midwater trawls in the region outside the immediate vicinity of Bogoslof Island. Very widely spaced acoustic returns from individual fish were observed and catch rates from midwater trawls were extremely low. The largest catch rate in the Aleutian Basin west of 172 degrees longitude was 61 pollock per hour in 1988 and 90 pollock per hour in 1989.

A large concentration of spawning pollock was encountered within a radius of approximately 40 nmi of Bogoslof Island in both 1988 and 1989. In 1988, two areas of high density were observed, one north and one south of Bogoslof Island (Figure 6). In 1989, only one high density area was encountered, south of Bogoslof Island (Figure 7). During 1988, the spawning aggregations were observed from mid-February through March 2. The maturity stage of males throughout the period of observation was "spawning" (able to extrude sperm) for most specimens. To determine the actual onset of spawning, the maturity of females appeared to be the most useful. Prior to February 29, most females were mature but not spawning (Figure 8). After this date most females were in spawning condition (able to extrude eggs). Increasing numbers of post-spawning females were observed by March 1-2, with 51 per cent in spawning condition and 20 percent in the spent category (eggs already released). The occurrence of spawning in these areas was confirmed by three bongo tows made within the aggregation which yielded large catches of pollock eggs. A similar spawning time was indicated for pollock in the Bogoslof region in 1989. In samples collected early in February, few spawning females were observed. By March 4-6, most females were observed to be spent (Figure 8).

The biomass estimate for the spawning concentration near Bogoslof Island in 1988 was 2.4 million metric tons (t). The 1978 year class was the predominant cohort, representing 37 percent of the population and 38 percent of the biomass (Table 1, Figure 9).

In 1989, the biomass estimate for the Bogoslof region was 2.1 million t. Again, the 1978 year class was the dominant cohort, representing 41 percent of the population. The 1982 year class was also important, accounting for 14 percent of the population (compared to 10 percent in 1988). The mean length of pollock in the spawning aggregations increased from 47.2 cm in 1988 to 48.6 cm in 1989 (Figure 10), primarily due to the increased mean age (9.8 in 1988 versus 10.6 for 1989) and the lack of any new large incoming year classes.

<u>1989 winter survey of EBS shelf</u>

The winter survey of pollock over the EBS shelf in 1989 indicated a low abundance of pollock in the shelf area near and north of the Pribilof Islands (Figure 11). Of the few samples collected in this area (three hauls), 43 percent of the walleye pollock were judged to be developing, suggesting that these pollock would not spawn within the next few months. Almost all of the remaining pollock were categorized as mature, but not spawning.

In the pollock population observed in the shelf area north of Unimak Island (Figure 11), most (> 94 %) female pollock were classified as mature, but not spawning (Figure 8). Examination of gonad size and condition of these pollock suggested that spawning would occur within the next one to two months. The maximum densities observed in these aggregations were an order of magnitude lower than those observed near Bogoslof in either 1988 or 1989. Most of the walleye pollock within these aggregations were from the 1982 and 1984 year classes (Figure 12). Population estimates are not yet available for this aggregation; however, the age composition of the sampled fish should, at least, indicate the primary year classes which contribute to this aggregation of fish.

Discussion

Although only a small portion of the basin was surveyed during the winter 1988 cruise, a deliberate attempt was made to survey areas where recent fishing activity had been reported. Nevertheless, the results indicated that pollock abundance in the basin was quite low during this period of the winter. Similarly, in 1989, there was no evidence of any substantial pollock abundance in the Aleutian Basin east of the U.S.-U.S.S.R. convention line except in the immediate vicinity of Bogoslof Island. Commercial fishery catch data support these observations (Dawson 1989). It has been documented that pollock migrate across the basin from west to east through the autumn and winter (Bulatov and Sobolevsky 1989; Dawson 1989; Sasaki 1988). Also, harvestable quantities of pollock have been seen to disappear from the southeastern portion of the international zone immediately before the spawning season (Dawson 1989; Jackowski and Trocinski 1989). These observations provide strong circumstantial evidence to suggest that some fish migrate from the international zone to spawn in the vicinity of Bogoslof Island.

Walleye pollock younger than 5 years of age are consistently absent from basin samples (Dawson, 1989). This provides strong evidence that recruitment of basin pollock is due to immigration of mature fish from elsewhere in the Bering Sea. For fish older than five years, the only dominant year classes in both the EBS shelf and basin were the 1978 and 1982 year classes (Figure 13), suggesting a strong relationship between these two areas. The observation that 1978 year class fish still represented the most substantial year class of pollock in the basin even though they were becoming less important on the shelf also supports the argument that basin pollock "stocks" are dependent on recruitment of older fish from the adjacent shelf areas.

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Table 1. Population and biomass estimates obtained during echo integration/midwater trawl survey of spawning pollock population near Bogoslof Island during winter, 1988 and 1989.

	1988 Survey			1989 Survey		
Year Class	Age	Numbers (millions)	Biomass (thous. t)	Age	Numbers (millions)	Biomass (thous. t)
1985	3	-	-	4	6	2
1984	4	-	-	5	15	7
1983	5	28	15	6	58	41
1982	6	327	192	7	363	241
1981	7	247	156	8	147	111
1980	8	164	115	9	194	149
1979	9	350	251	10	91	68
1978	10	1201	910	11	1105	895
1977	11	288	226	12	222	187
1976	12	287	233	13	223	194
1975	13	202	167	14	82	72
1974	14	89	82	15	90	81
1973	15	27	23	16	30	24
1972	16	17	16	17	60	52
1971	17	7	7	18	-	-
1970	18	3	3	19	-	-
Totals		3237	2396		2686	2124

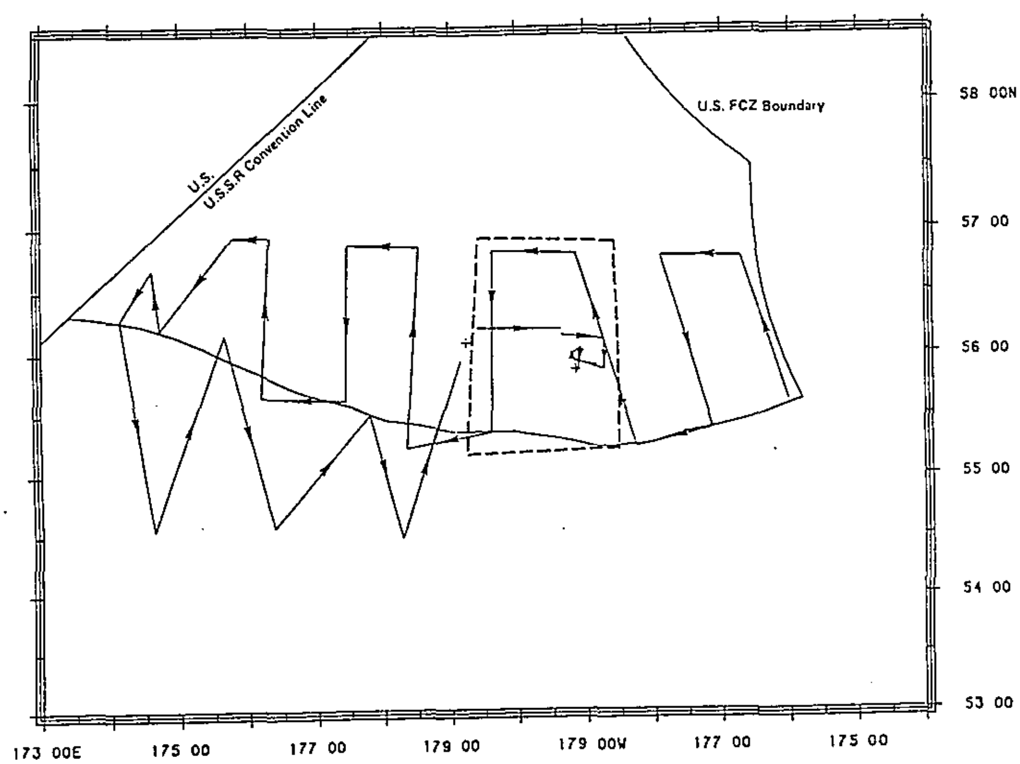

Fig. 1. Map of survey area, Miller Freeman Cruise 88-1, Leg II, showing acoustic survey tracklines. Special effort in vicinity of foreign vessels indicated by dashed line.

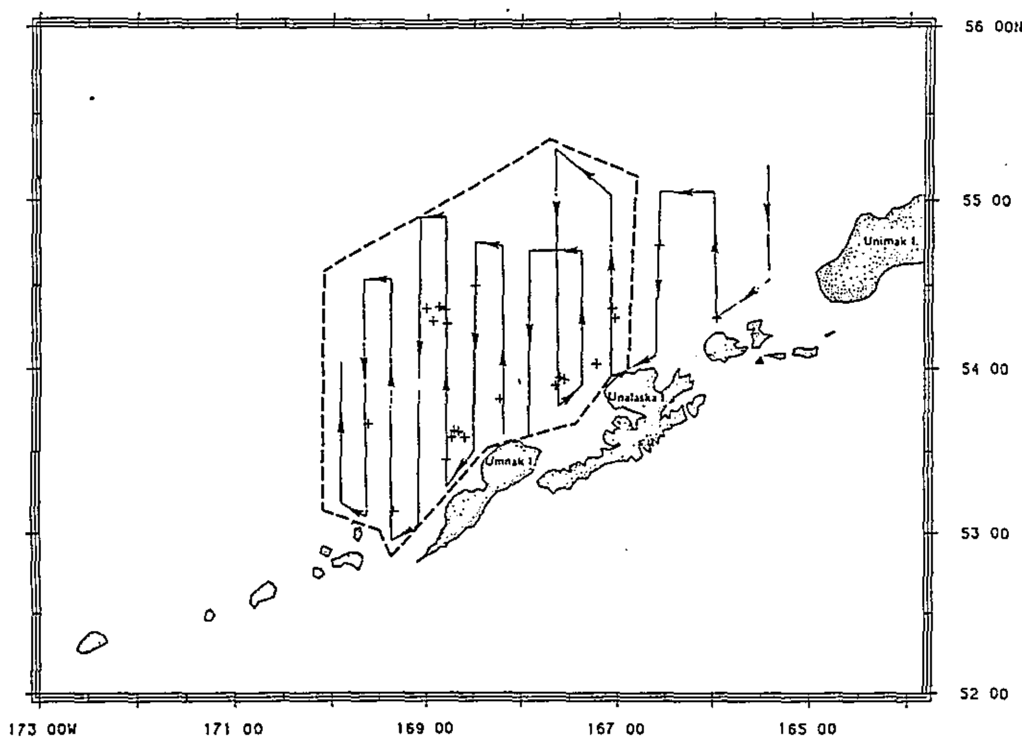

Fig. 2. Map of survey area, Miller Freeman Cruise 88-1, Leg III, showing acoustic survey tracklines. Approximate area of spawning aggregation is indicated by dashed line.

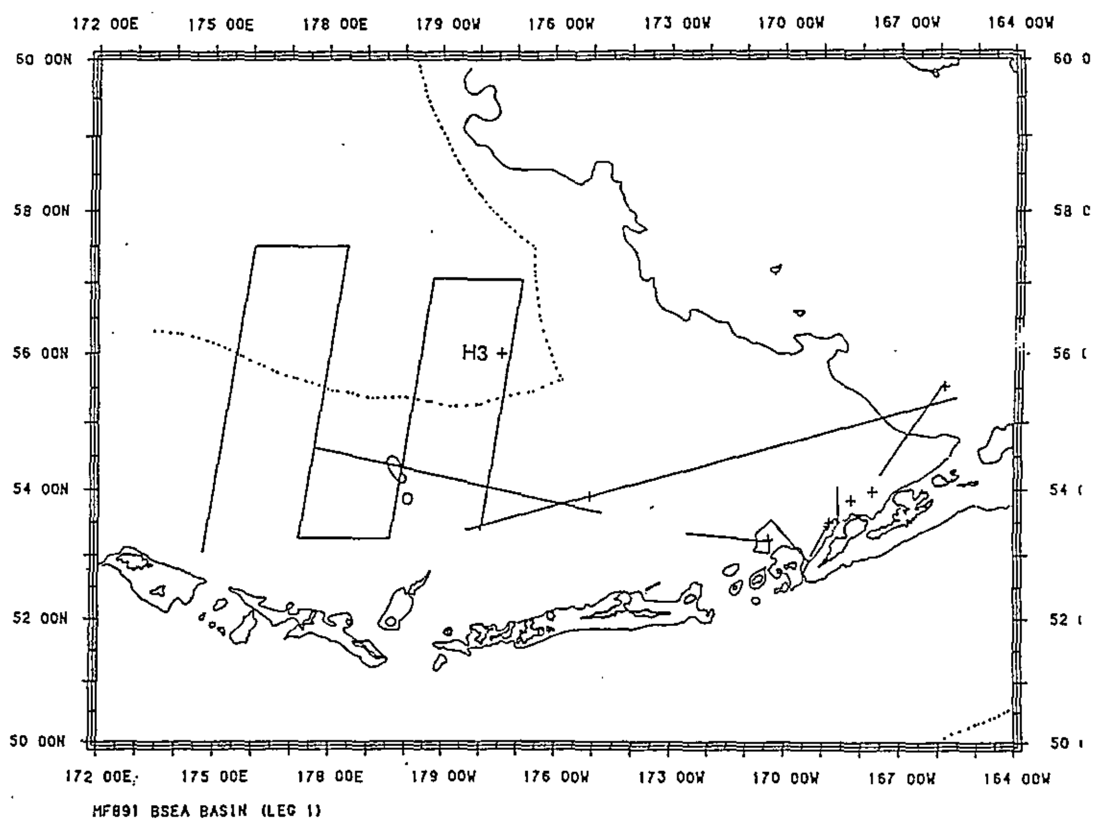

Fig. 3. Aleutian Basin survey (Leg 1) trackline (straight, solid lines) and midwater trawl stations (+), MF89-1. H3 indicates the location of haul 3, referred to in the test.

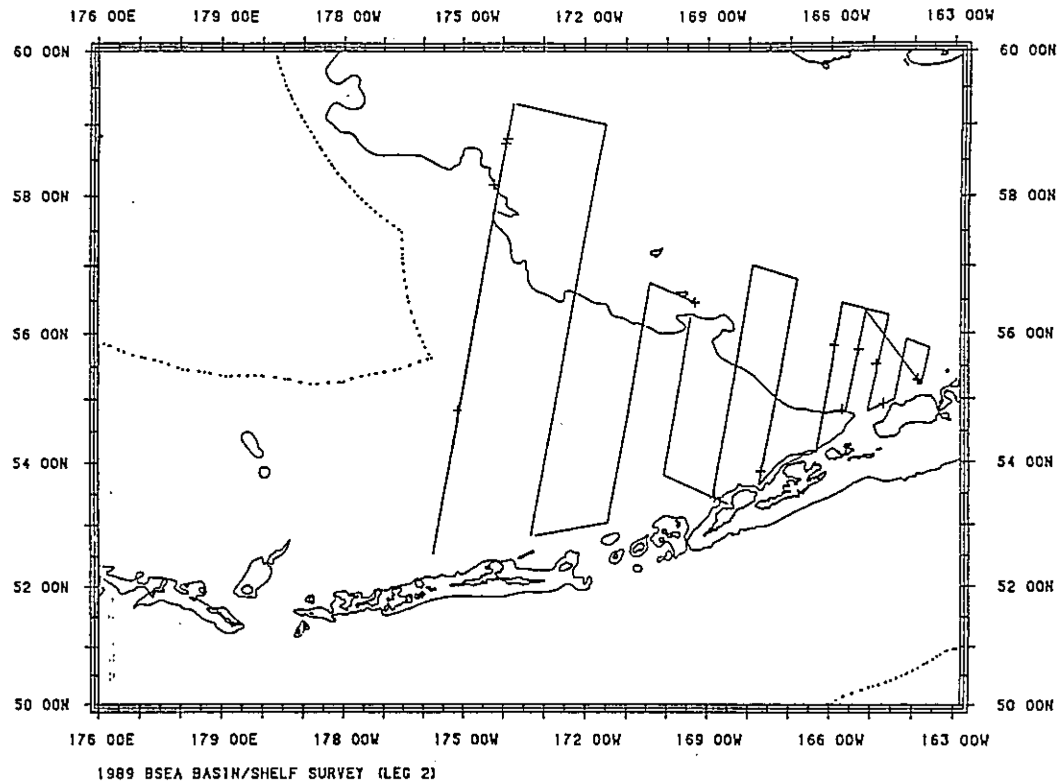

Fig. 4. Aleutian Basin survey (Leg 2) trackline (straight, solid lines) and midwater trawl stations (+), MF89-1.

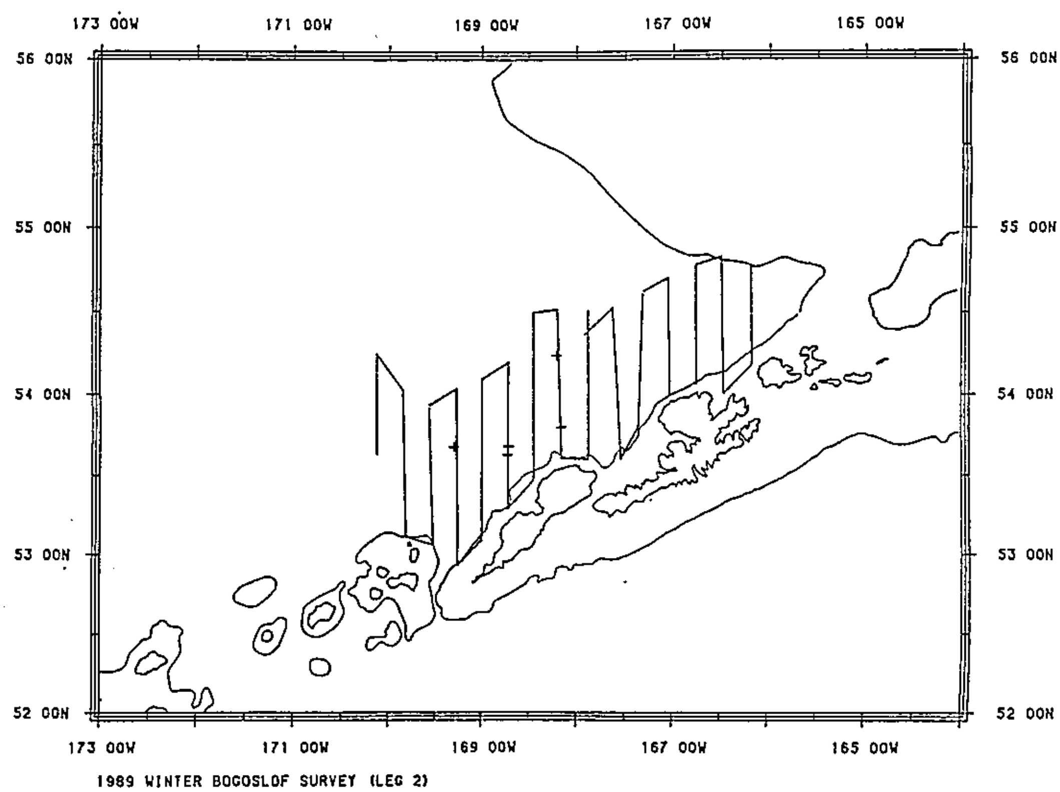

Fig. 5. Bogoslof survey (Leg 2) trackline (straight, solid lines) and midwater trawl stations (+), MF89-1.

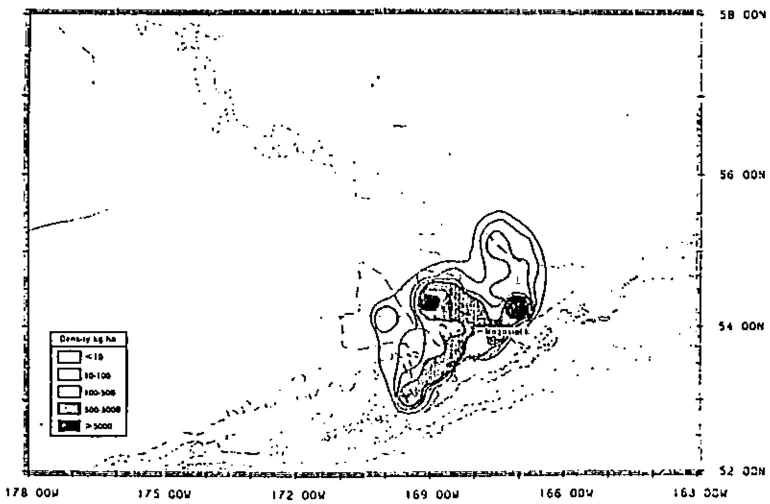

Figure 6. Midwater distribution and abundance of walleye pollock in the Aleutian Basin in winter 1988.

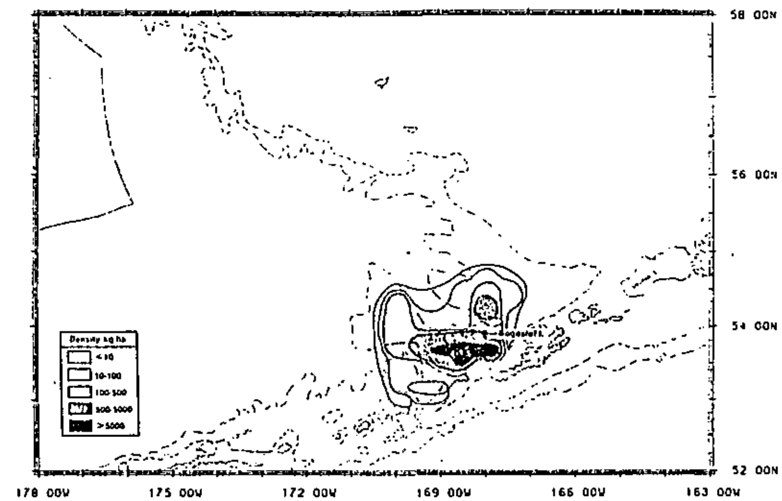

Figure 7. Midwater distribution and abundance of walleye pollock in the Aleutian Basin in winter 1989.

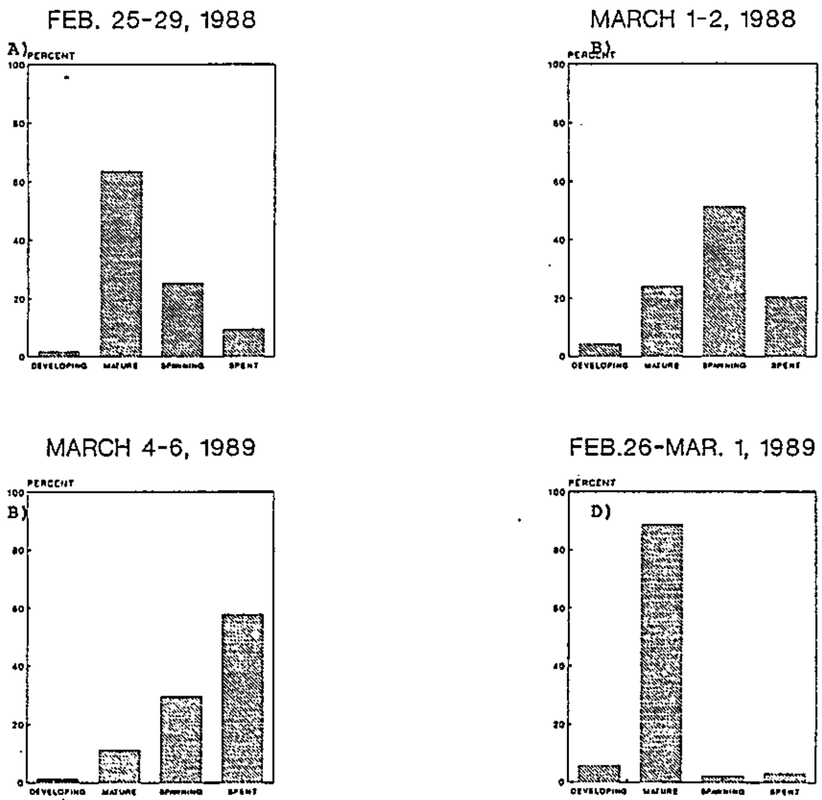

Figure 8. Maturity distributions of females from walleye pollock aggregations near Bogoslof Island in 1988 (A,B) and in 1989 (C) and from walleye pollock aggregations in the southern eastern Bering Sea shelf north of Unimak Island (D).

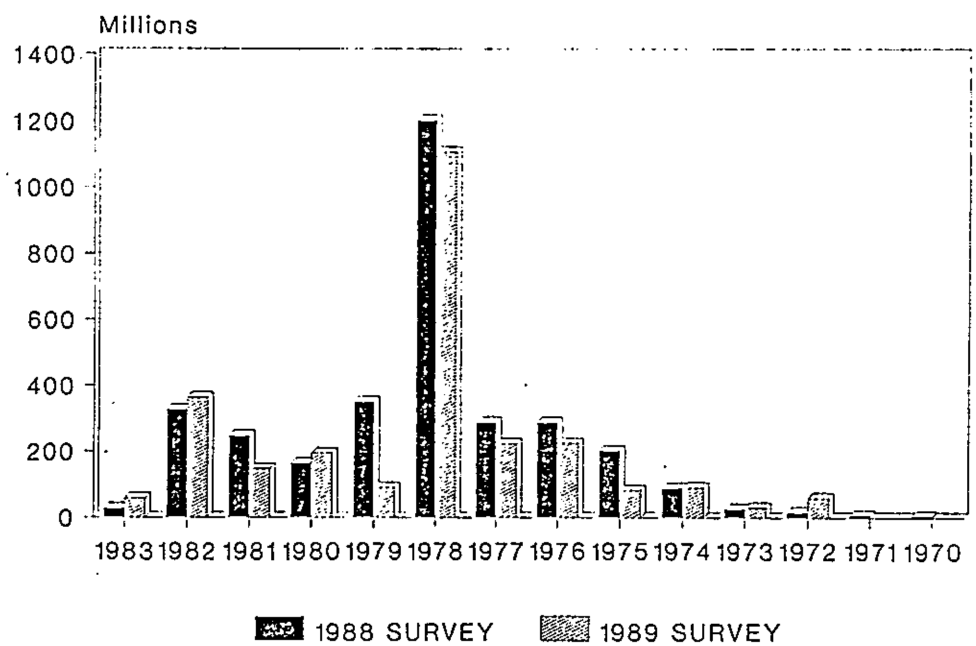

Figure 9. Comparison of population estimates of the spawning aggregations of walleye pollock near Bogoslof Island obtained during 1988 and 1989.

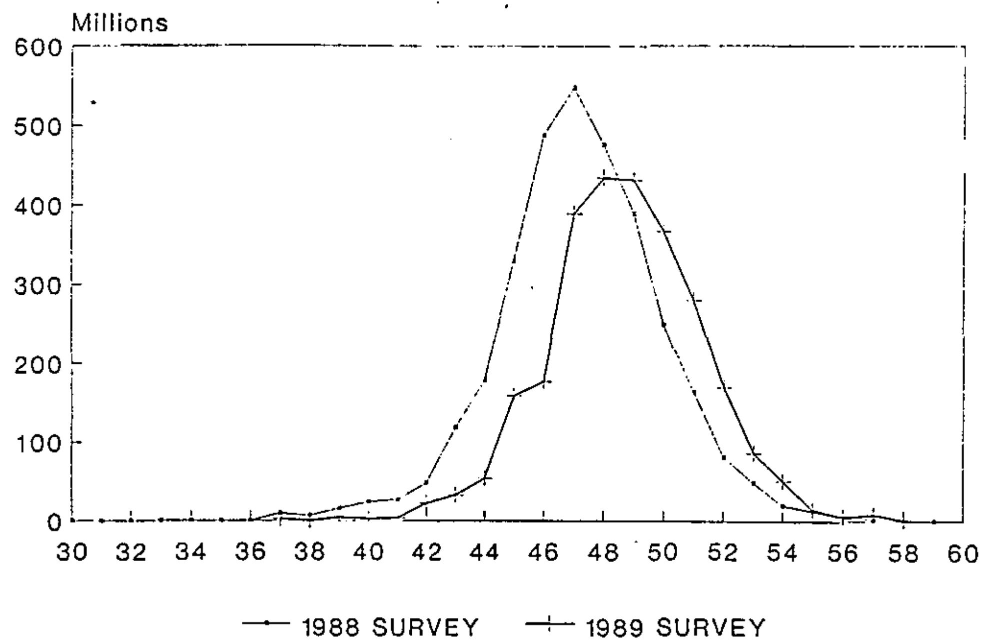

Figure 10. Comparison of the length compositions of the spawning aggregations of walleye pollock near Bogoslof Island obtained during 1988 and 1989.

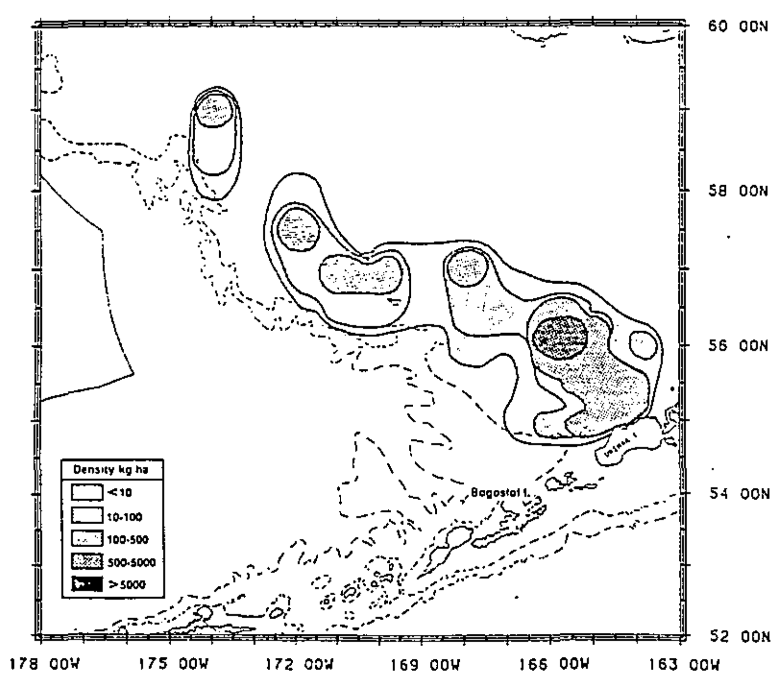

Figure 11. Midwater distribution and abundance of walleye pollock on the eastern Bering Sea shelf in winter 1989.

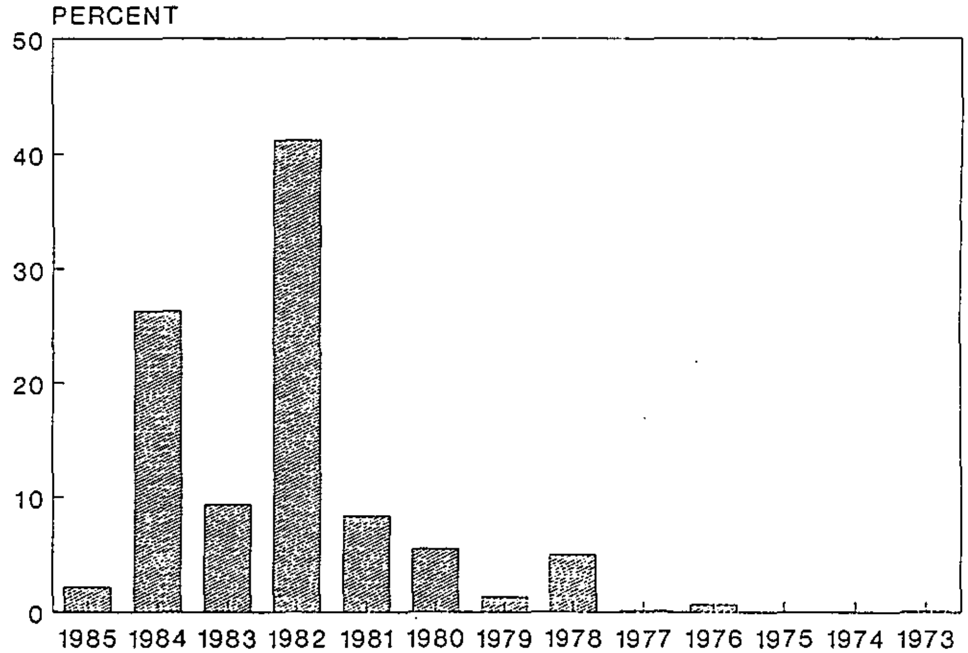

Figure 12. Age composition for walleye pollock aggregation north of Unimak Island on the eastern Bering Sea shelf. Age composition is for sampled fish only and is not weighted by population size.

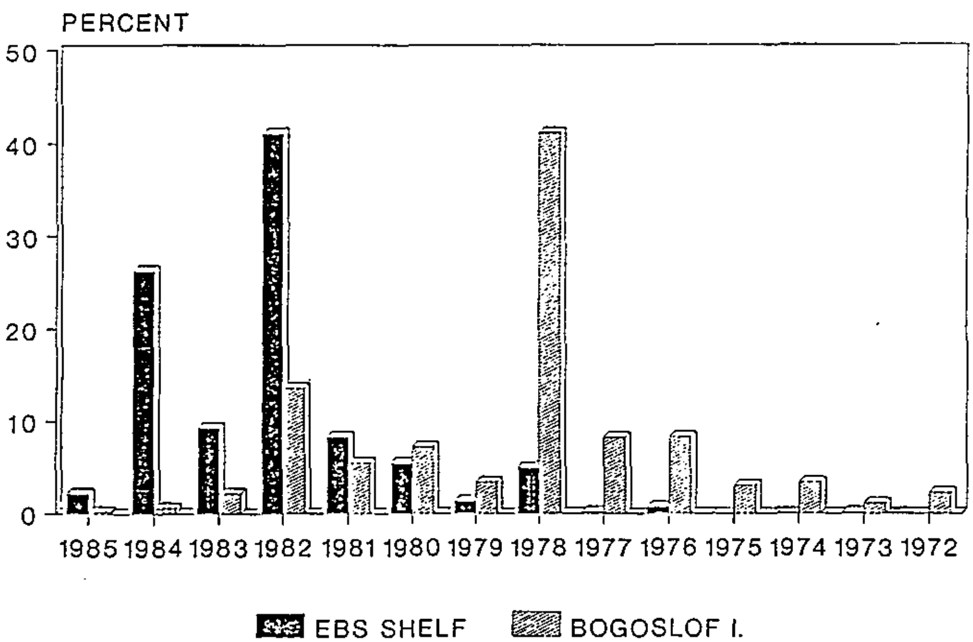

Figure 13. Comparison of age structure of walleye pollock near Bogoslof Island and north of Unimak Island on the eastern Bering Sea shelf from the 1989 survey. As indicated in Figure 12, age composition for the shelf population is for sampled fish only and is not weighted by population size.

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Population Abundance and Recruitment Interannual Variance of Yellowfin Sole, Alaska Plaice, Rock Sole and Bering Flounder of the Eastern Bering Sea

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Intensification of the flatfish commercial employment in the Eastern Bering Sea in 1970s requires constant monitoring of the stocks state, recruitment interannual variance, size-age structure dynamics of populations. The regulation of their commercial harvesting at present is carried out on the basis of the biomass estimates of the populations' mature part, including joint Soviet-American program data. The major part of the flatfish species is exploited by several countries' or joint enterprises' fisheries simultaneously, so this requires development of both bilateral and multilateral cooperation in the research activities.

Yellowfin sole has been one of the main commercial species of the Eastern Bering Sea since late 1950s, and nowadays it remains one of the main objects of commercial operations of joint enterprises. Modern tendency of increasing this species' harvests does not correspond to the changing character of this species stocks. The catch per effort has been analysed according to the standard trawl surveys' data collected by Soviet research vessels in 1980 - 1988 (1980 - "Artyom", 1981 - "Tikhookeansky", Ye.I.Moiseyev, 1982 - "8-459", O.A.Bulatov, 1983 - "Milogradovo", V.M.Pashchenko, 1984 - "Novodrutsk", A.L.Mandelshtam, 1985 - "Mys Dalny", O.A.Bulatov, 1986 - "Gissar", Ye.I.Moiseyev, 1987 - "Babayevsk", V.M.Pashchenko, 1988 - "Darwin", A.S.Fadeyev). This data demonstrated that the catch per effort was maximum in 1983 - 1984 (Fig. 1).

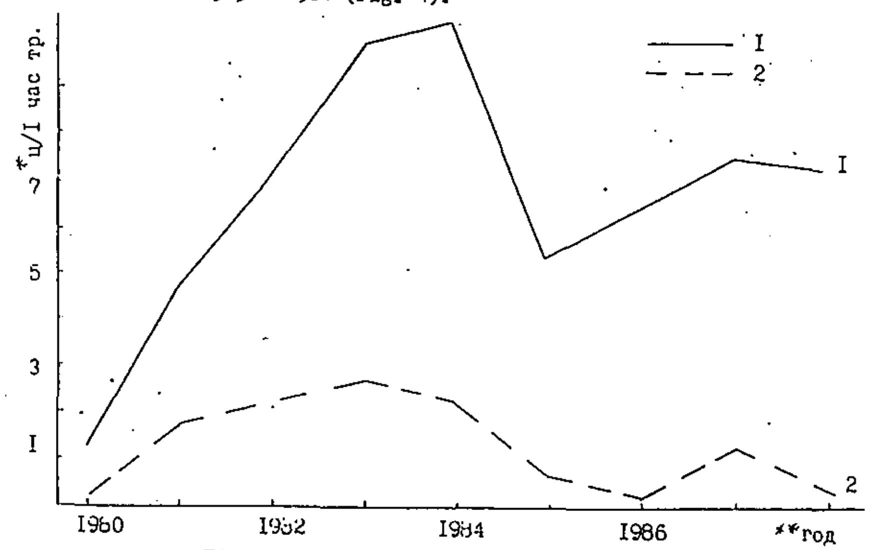

Fig. 1. The dynamics of the yellowfin sole catch per effort in Unimak (158 - 170°W) (1) and Pribyloff (170 - 180°W) (2) areas of the Eastern Bering Sea in 1980 - 1988 (* - centner per 1 hour of trawling; ** - year).

Sharp increase of the catch per effort took place in 1981 - 1984 (468 to 1045 kg per 1-hour trawling). Direct surveys also demonstrated considerable increase of the population commercial part's biomass. The commercial vessels' catch per effort in that period also increased.

Anyway, the analysis of the yellowfin sole population size-age structure demonstrated that the reasons for the catch per effort growth, according to the research and commercial vessels' data in early 1980s were not identical.

Research vessels' data showed that the catch per effort growth took place principally due to emerging of new abundant year-classes of 1973 - 1976 (after abundant year-classes of late 1960s). At the same time, commercial vessels' data demonstrated that the catch per effort growth took place due to the commercial harvesting specialization (shifting to the large-size flatfish of 1967 - 1970 abundant year-classes). In 1984 - 1985 those year-classes were considerably out of commercial exploitation due to natural reasons, so the catch per effort considerably decreased at the U.S. commercial vessels (Bakkala, Wespestad, 1988). The harvesting specialization primarily at large-sized fish in early 1980s was positive for the population's biomass growth, as the junior year-classes of 1973 - 1976 did not suffer the exploitation pressure. In the second half of 1980s such a specialization of commercial operations at senior flatfish groups led to the population's biomass decrease, as the year-classes of 1973 - 1976 became dominant in the population's commercial part both by biomass and abundance.

The year-classes which appeared in the second half of 1970s were not abundant. The standard trawl surveys' data does not demonstrate the presence of abundant year-classes in 1980s neither. If in 1981 the 1973 - 1976 year-classes were dominant in the population, in 1988 such age-groups corresponding to 5-8-year-olds are almost absent in the population. During 1980s the aging of the population is taking place.

Small increase of the catch per effort in 1986 - 1987 is due to the fact that in that period primarily the abundant year-classes of 1973 - 1976 were commercially exploited. As even the most abundant year-classes of yellowfin sole as a rule are out of exploitation by the age of 15 - 16 years, in 1990 - 1991 only two abundant year-classes of senior fish (1975 - 1976) will be dominant in the population's commercial part, them being in such an age when the leaving of population due to natural reasons sharply increases. Under those conditions the preservation of catch volume at the level of late 1980s can not be taken for granted. In accordance with actual decrease of the population's biomass, the leaving of the population's commercial part by at least two abundant year-classes of 1973 - 1974, the harvest should be correspondigly decreased, taking into consideration the latest estimates of the population's biomass (1.5 - 1,53 million tons), down to 150 - 160 thousand tons.

Similar decrease in the catch per effort both in Unimak and Pribyloff areas testifies to the clear tendency towards decreasing of the yellowfin sole recruitment in all areas of the Eastern Bering Sea.

The stabilizing of the yellowfin sole stocks is possible only if the averagely abundant year-classes start to regularly appear.

The analysis of reproduction, recruitment rates and population's biomass inter-annual variance demonstrated that in the yellowfin sole population the most abundant year-classes appeared in relatively cool years (1972 - 1976). Due to the fact that the periodical character of cool and warm hydrological conditions occurrence corresponds to the 11-year solar cycle, we can positively state that the appearing of the yellowfin sole abundant year-classes correlated to the period of solar activity decreasing and the water low temperature.

In early 1980s in period of relatively low water temperatures in demersal layer of the Eastern Bering Sea in the flatfish population there was noted the appearing of relatively large number of 1980 - 1981 year-classes' junior groups, as compared to adjacent years. But in subsequent years it became clear that even though those year-classes are more abundant than the adjacent ones, their abundance can not be compared to the abundant year-classes of 1973 - 1976. Anyway, those relatively abundant year-classes appeared in the cold water period (Fig. 2).

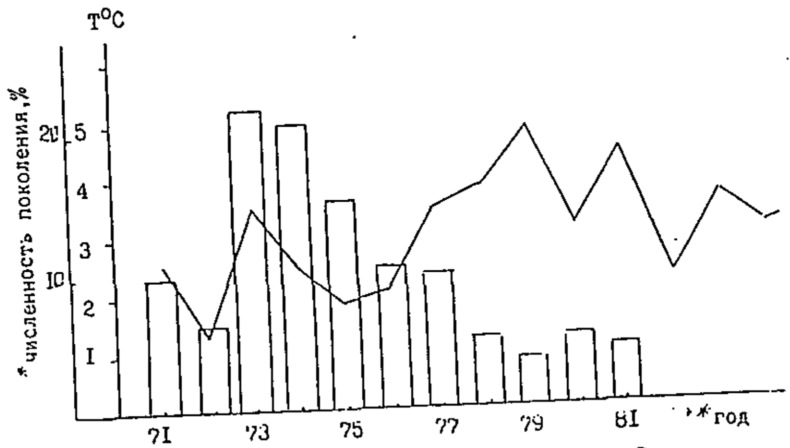

Fig. 2. Average temperature of the South-Eastern Bering Sea demersal layer in 1971 - 1985 (after Walters et al., 1988) and the relative abundance of the 1972 - 1981 yellowfin sole year-classes (by the 7-year-olds' abundance) in 1979 - 1988 (* - year-class abundance, %; ** - year).

Appearing of relatively large number of juveniles in the flatfish population corresponding to the 1984 - 1985 year-classes was noted in 1987 - 1988.

In the years subsequent to the abnormally warm period, influenced by El Nino (1982 - 1983), there appeared abundant year-classes of several North-Eastern Pacific species (cod, walleye pollock, hake). But, judging from the contents of those age-groups in the yellowfin sole population (from the trawl survey data), those abundance is much lower than the one of the 1973 - 1976 abundant year-classes.

As in 1987 the new period in water warming started (it will at least continue till 1991 - 1992), the probability of appearing of abundant year-classes in that period is not large. The population biomass will decrease considerably by early 1990s due to the 1970s abundant year-classes' leaving.

The yellowfin sole year-classes start to be intensively exploited when reaching 8 - 9 years of age (23 - 24 cm in length). So in early 1990s the 1981 - 1983 year-classes enter the population's commercial part, them being relatively non-abundant. In accordance with the cited changes in the population's commercial part age structure, it can be expected that the yellowfin sole biomass tendency towards decreasing will grow, as well as the catch per effort decreasing. By mid-1990s, when the relatively abundant 1984 - 1985 year-classes enter the commercial part of the population, the stabilization of its stocks is probable at the mid-level. In that period the probability of abundant year-classes appearing will be increased due to the starting of the relatively cool period. Those year-classes will enter the population's commercial part at the beginning of the third millenuium.

The biomass of rock sole, Alaska plaice and Bering flounder in 1980s, unlike the yellowfin sole, tends to increase. Those flatfish species' stocks are lesser exploited, mainly as bycatch when harvesting for yellowfin sole. The main part of the catch is constituted by rock sole, even though inter-annually its share in the overall flatfish catch is not equivalent, as well as the other species' catch volume inter-annual variance does not have a distinct tendency.

The rock sole is one of the most common species in the Eastern Bering Sea. The inter-annual variance analysis of the catch per effort, according to the standard summer bottom surveys' data, demonstrated the existence of the constant tendency towards growth in the course of 1980s. The catch per effort increased most significantly after 1985. The catch per effort growth was most seen in Unimak area where the main population recruitment was coming from. In 1987 the considerable growth of the catch per effort occurred in Pribyloff area as well.

The existence of such a tendency during the last decade testifies to the regular appearing of abundant year-classes. It is known that the rock sole abundant year-class can be registered after the standard trawl surveys' data when the fish reaches the age of as little as 3 years. So the sharp increase in the catch per effort in 1985 - 1988 testifies to the appearing of the abundant year-classes in the first half of 1980s. Before that, the U.S. specialists noted the appearing of abundant year-classes in late 1970s (Walters, Haliday, 1987). The rock sole population's commercial part consists as a rule of 5 - 6 year-classes.

The flatfish catches' size composition varies considerably during the whole period of 1980s, depending upon the year-classes' abundance. In 1983 the individuals of 1978 - 1980 year-classes sized 22 - 28 cm were dominant in the population. In 1985 the same year-classes aged 5 - 7 years were dominant as well, and in the meantime the abundant junior groups were noted. By 1988 the abundant year-classes of the second half of 1970s were practically out of the population, and at the same time the abundance of both the year-classes appeared in early 1980s and the junior groups corresponding to the 1985 - 1986 year-classes, was evident. Due to the regular appearing of the abundant year-classes in the course of 1980s, the tendency towards the rock sole biomass growth will remain present in early 1990s. Abundant year-classes,appeared in the second half of 1980s and already registered according to the trawl surveys' data, will become the basis of the population's commercial part in the mid- and late 1990s. In that period the stabilization of the rock sole stocks is possible at the high level.

On the basis of the population's biomass latest estimates (1.5 million tons), the balanced catch is determined as 150 thousand tons. Under the conditions of the stabilized highly abundant recruitment and the existence of the constant tendency of the population's biomass growth, this value can amount to the annual catch since late 1980s.

The Alaska plaice species is the third in biomass among the Eastern Bering Sea species (yellowfin sole and rock sole being the first two ones correspondingly). The Alaska plaice biomass has started to increase since mid-1970s (Walters, Wilderbuer, 1988).

In early 1980s the Alaska plaice catch per effort increased rapidly up until 1983, then it decreased, and after 1985 its slow growth began again. In 1988 considerable increase in the catch per effort was noted in Unimak area. The differences in the catch per effort dynamics in Unimak and Pribyloff areas are probably connected to the interannual change in the behaviour and distribution of Alaska plaice.

The Alaska plaice stocks stabilized in the second half of 1980s at the level of 450 - 550 thousand tons. Taking this into consideration, the Alaska plaice balanced catch amounts to 50 - 55 thousand tons.

Alaska plaice first appears in the trawl catches upon reaching the age of 3 years (20 cm), and is out of the population's commercial part at 14 - 15 years of age (43 - 45 cm). Before 1987 two groups of abundant year-classes could be distinguished in the flatfish population, and in 1986 senior individuals of the 1973 - 1974 year-classes (responcible for the population's biomass increase in 1980s) was practically out of the population. In 1988 the individuals sized 32 - 38 cm became dominant in the population, probably belonging to the abundant year-classes of 1977 - 1978. According to the trawl survey results of 1988, the considerable quantity of the junior individuals sized 24 - 28 cm was noted as well.

The 1977 - 1978 abundant year-classes will be dominant in the population's commercial part up until 1992 - 1993; this will provide the stability of commercial harvesting . In future, the early 1980s abundant year-classes' entering the population's commercial part is possible.

The trawl survey data testifies to the Alaska plaice stocks' stabilization and the regular appearing of abundant year-classes, which can provide constant annual withdrawal at the level of balanced catch (50 - 55 thousand tons).

Bering flounder is less abundant than rock sole and Alaska plaice, but its biomass amounts to 0.5 million tons according to the latest trawl surveys' data. The Bering flounder biomass started to increase at a considerable rate after 1981, which was evident from the catch per effort data both in Unimak and Pribyloff areas.

Normally, the commercial part of this species' population is constituted by 6 - 7 year-classes, and the individuals aged 10 - 12 years is quickly out of the population due to natural reasons. Before 1984 the 1973 - 1974 year-classes were dominant in the Bering flounder population. In 1985 the appearing of new abundant junior group (18 - 22 cm) of the late 1970s year-classes was noted. In the subsequent years those year-classes were dominant up until 1980s, the result of which being the biomass stabilization at high level.

The balanced catch of Bering flounder under the conditions of the biomass stabilization at the level of 0.5 million tons is determined as 50 thousand tons.

Thus, the overall volume of the possible catch of four flatfish species in the Eastern Bering Sea (yellowfin sole, Alaska plaice, rock sole and Bering flounder) amounts to 400 - 415 thousand tons, including the yellowfin sole - 150 - 160 thousand tons, rock sole - 150 thousand tons, Alaska plaice - 50 - 55 thousand tons, and Bering flounder - 50 thousand tons.

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Biological Information on Pelagic Pollock in the Aleutian Basin during the Summer of 1988

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ABSTRACT

The Japan-U.S. joint survey was conducted using the chartered research vessel Seiju maru No. 28 from August to October, 1988 with the purpose of determining the biomass and ecology of pelagic and midwater pollock distributed in the Aleutian Basin. The survey was conducted jointly using a midwater trawl and the quantitative echo sounder system which was newly developed by the National Research Institute of Fisheries Engineering, FAJ. The biological information on mature and juvenile fish obtained by the midwater trawl are reported here.

1. Mature fish

A total of 37 tows for mature fish were conducted with the midwater trawl. In late August, the weight of the catch was most abundant in waters near 55°N and 171°W, and in early October, the weight of the catch was most abundant in waters near 56.5°N and 174°E, and in these areas, the average weight of catch from four tows was 3,540 kg/h. The average weight of the catch in the other 33 stations was small (550 kg/h) (Fig. 2).

In early October, a concentration of pollock was observed in the western tip of the international waters (Fig. 3). The distribution of pollock was observed in depths between about 150 m and 200 m at night, whereas pollock concentrated in depths of near 200 m in daytime, and the thickness of the concentration was about 10 m. Pollock were mainly distributed in water temperature layers of 2°C and 3°C levels.

The fork length composition of pollock (Fig. 7) was unimodal for both male and female, the modes for males and females were observed at 48 cm and 50 cm, respectively. As for the sex ratio males were more abundant than females to one degree or another.

2. Juvenile fish

The number of successful tows made with the juvenile fish net was 37.

A total of 571 individuals of juvenile pollock was collected at 19 stations, but they were mainly collected in the eastern Aleutian Basin along the continental shelf area (Fig. 8). In addition, there was a tendency for the numbers of pollock to decrease as the distance from the continental shelf increased. Only four individuals were collected in waters west of 180° centering the international waters which were surveyed from late September to mid-October.

The fork lengths of juvenile pollock collected ranged from 21.0 mm to 101.0 mm. The fork length of pollock which were distributed at a far distance from the continental shelf were somewhat smaller than those nearer to the continental shelf. There was also a tendency that the condition factor of pollock in the Basin was rather less than that in the continental shelf.

1. Introduction

The Bering Sea was generally divided into the continental shelf at depths of about 200 m and shallower, the Basin area at depths of 3,000 m and deeper, and the slope area which lies between the two areas. Although pollock were widely distributed throughout the Bering Sea in the past, it has been assumed that the main distribution of pollock was from the continental area to the upper continental slope area. However, in the surface and midwater layers of the Aleutian Basin which accounted for most of the Basin area, it was shown that pollock formed a concentration of high density during the winter. Since a part of this concentration is also distributed in international waters, they are caught by countries such as Poland, Korea, and Japan, etc. Although there were some instances that juvenile pollock were collected in the Aleutian Basin, it is known that juvenile fish of body lengths of 35 cm and smaller are not abundant in this area, and that during this period they remain in the surrounding continental shelf area and after which they are recruited to the Basin. However, there are still many unknown aspects of the concrete life histories such as where they were spawned and what route they follow when recruited to the Basin.

The North Pacific Groundfish Section, Far Seas Fisheries Research Laboratory initiated new research on pollock jointly with the National Research Institute of Fisheries Engineering, FAJ and the U.S. Northwest and Alaska Fisheries Centre, since 1988. This research was conducted jointly using the comprehensive quantitative echo sounder system developed by the National Research Institute of Fisheries Engineering and midwater trawl. Here, considered the ecology of pollock from a part of information obtained by the research during the first year.

Method and Materials

The survey was conducted using the chartered landbased dragnet trawler Seiju maru No. 26 (349.42 GT) from July 10 to October 23, 1988. From July 10 to August 13, coordination of the comprehensive quantitative echo sounder system and collection of basic data were conducted, and from August 14 to October 12, field surveys were conducted in the Bering Sea. Fig. 1 shows the areas surveyed and transects of the surveys. The surveys were conducted by the following procedures: while the vessel was cruising for 24 hours along the survey transects, data were collected by the quantitative echo sounder and when some definite responses from fish were obtained, sampling with the midwater trawl was conducted. After, the pollock were collected, the body weights were measured, and a total or some of the pollock were measured for fork length (hereafter referred to as length). Furthermore, after a net of 3 mm in mesh size was attached to the inside of cod end of the same midwater trawl, sampling for juvenile fish was generally conducted within several hours after sunset. The horizontal and vertical opening of the net and water depth were measured by the net monitor (manufactured by Scanmar Co. Ltd.). In addition to this, in the Hakushin Bay (about 100 m in depth) sampling for juvenile fish was conducted by lamplight using a spoon net. Water temperatures were measured periodically using XBT. Juvenile fish collected were preserved in formalin of about 10%, and then, lengths and weights were measured. When the weight of pollock was measured, water on the surface was wiped away as much as possible using paper towels. Although a part of juvenile fish collected was brought back to the U.S., those data are also included in this report.

In addition, to make the Figure on distribution of pollock, Ishizuka's program (1988) was used which was described in the "Collection of Programs for the Stock Analysis by the Personal Computer".

Results

Distribution of mature fish

A total of 37 samplings by midwater trawl for mature pollock was conducted. Fig. 12 shows the relationship between water depth and horizontal and vertical openings of the midwater trawl net. The vertical and horizontal opening of the net averaged 43.0 m and 34.2 m, respectively, and depth of upper edge of net mouth averaged 184 m. Towing speed was 3.9 knots in average.

Fig. 2 illustrates the weight (per hour) of samples at respective stations. The abundance of pollock in the samples was high in waters near 55°N and 171°W in late August, and the abundance was also high in waters of 56.5°N and 174°E in early October, and the average weight from four tows which were conducted in these areas was 3,540 kg/h. Of those, the area where the abundance was greatest is indicated as X in the Figure and 1,526 kg for 15 minutes (6,104 kg/hour) were collected. At thirty-three stations other than the above areas, the abundance during the respective survey period was low, and it averaged 550 kg/hr. In the surrounding area X, although belt-shaped responses were observed consecutively in the monitors of the colored fish finder, the belt-shaped responses were scarce in waters other than area X.

Fig. 3 shows some pictures of the belt-shaped responses observed by the colored fish finder in early October. The left Figure shows the belt-shaped responses at daytime, and the right Figure shows the belt-shaped responses at night. Furthermore, sunrise on October 9th was about 10:30 a.m. (Alaskan time). Pollock was observed to be distributed in depths between about 150 m and 200 m at night, and were concentrated in depths of 200 m or so at daytime and the thickness of layer was about 10 m. The estimated vertical water temperature structure in waters where the belt-shaped responses were observed is shown in Fig. 4. It is known that pollock were mainly distributed in water temperature layers of 2°C and 3°C level, from Figs. 3 and 4.

Fig. 5 shows the estimated water temperature structure at certain stations and at depths of 175 m which the belt-shaped responses were observed by the colored fish finder. From this Figure, it is estimated that pollock inhabited the western international waters in early October were mainly distributed in waters of 3°C level. Dates of observation were from October 5 to 12 (the last survey day). In addition, the belt-shaped responses which were observed in the southeastern Basin in August are also recognized to be mainly distributed in waters of 3°C level.

Length composition and sex ratio of mature fish

Fig. 7 shows the respective length composition of the results obtained by collecting during the similar survey periods and similar survey stations of seven groups from A to G, as shown in Fig. 6. There is no great difference in the groups, except A and E, and the mode was observed at 48 cm for males and 50 cm for females. In contrast, in group A, each mode was 1 cm smaller for both males and females, and in group E, only females had a mode which was 1 cm greater than that in the other groups. In the variance and mean, significant differences were not recognized in any groups.

Table 1 shows the sex ratio of respective groups. In all groups, there were more males than females. Although some differences were recognized in the sex ratio of respective groups, in the international waters, the number of males and females in group A was almost the same while the number of females in groups B to D was almost half of that of males.

Results of juvenile fish sampling

Although a total of 42 tows with the juvenile fish net were conducted, the successful number of samples was 37, because there were some problems such as knots in the nets becoming untied. The water depth of the upper edge of the net mouth was 25 m on the average. The horizontal and vertical net opening were not measured because the sensor did not work properly. The towing speed was 4.0 knots on the average.

A total of 571 individuals of juvenile pollock were collected at 19 stations. Because the towing time varied by the sampling position, Fig. 8 illustrated the standardized number of juvenile pollock collected as converted to the number per hour. Although the total number, converted to respective station per hour, was 819 individuals, of those, 64% of the total were obtained from just three stations near the continental shelf. The station where the abundance was greatest was Station X in the figure, and 195 individuals were collected per hour on September 18 (Japan time). According to the Figure, it is known that relative abundance of juvenile pollock was distributed in the eastern Aleutian Basin along the continental shelf area during August and September. Furthermore, there was a tendency for the abundance to decreased as the distance of the stations from the continental shelf increased. Only four individuals were collected in waters west of 180° centering around the international waters surveyed from late September to mid-October.

In a lamplight sampling which was conducted in the Hakushin Bay, 38 individuals of juvenile pollock were collected. It was presumed that the number of juvenile pollock which was actually gathered at the lamplight were quite numerous, and appeared to be swimming against the current while forming schools. In addition, it was observed that several individuals of mature pollock appeared and occasionally attacked juvenile pollock.

Length composition of juvenile pollock

The lengths of 104 individuals which were brought back by the U.S. were measured by the U.S. scientists rather than by Japanese scientists, but on the assumption that there was no difference in measuring technique they were simply summed up here. The body measurements used by both was fork length. For body weight, the measurement was conducted by only the Japanese side.

The length of juvenile pollock collected ranged from 21.0 mm to 101.0 mm. The results of respective length composition obtained by grouping stations into 5 groups of J-A to J-E during similar periods and at similar stations together is shown in Fig. 9 and the length composition of juvenile pollock in the Hakushin Bay were shown in Fig. 10.

Although there were a maximum of 5 day differences in the sampling day between J-C and J-D, the small individuals such as those of 40 mm appeared in J-D when the sampling date was late. In addition, as compared with 2 stations at which a certain number of juvenile pollock was collected within group D, the average body length in Station D1 which is near the continental shelf was 66.7 mm (N=88), and was 59.7 mm (N=34) in station D2 which is in offshore waters. The length composition in J-E which is close to the continental shelf showed almost the same as that in the Hakushin Bay.

Table 2 shows the condition factor by length of juvenile pollock in the Hakushin Bay and in A to E which are located in the Basin. According to Table 2, as compared with juvenile pollock in the Basin and Hakushin Bay, it is known that the condition factor of juvenile pollock in the Basin was low at lengths between 40 mm and 100 mm.

Fig. 11 shows the relationship between the length and body weight of juvenile pollock in the Basin area. The most appropriate regression curve equation is as follows:

$$\text{Log } Y = 5.55586 + 3.17103 \times \text{Log } X$$

where, Y : body weight (g) and X : length (mm)
Coefficient of correlation was 0.97.

Discussion

Sasaki (1988) reviewed the past reports and reported that pollock were widely distributed in the Basin during the summer and formed schools of high density in the winter for spawning. In addition, he estimated according to the information obtained from the commercial vessels that the schools are formed in the western international waters around October, and move gradually toward the east along the southern edge of the international waters by March. According to the survey, it was confirmed that the density of pollock was generally low in waters east of the central Basin from August to September, but the schools were formed in the western edge area of the international waters in early October. These schools showed the belt-type response on the monitors of the fish finder, and their thickness was about 10 m. As compared with the thickness of belt-type responses in the surveys conducted in the winter of 1983 was 38 m on the average (Fisheries Agency of Japan 1984) and the thickness was about 100 m (maximum 200 m) obtained from the observation conducted in the winter of 1987 (Sasaki and Yoshimura 1987), it was fairly low and it was estimated to be formed in the early stage of schooling. Since the schools are scattered in depths between about 150 m and 200 m at night, it becomes a low density such as the level at which a single echo is scattered. Therefore, the fishing vessels conducted fishing in the surrounding areas only at daytime, and they seemed to conduct search fishing grounds in the surrounding areas at night.

The length composition of the pollock population in the Basin were not related to seasons, and it was known from the recent surveys to be unimodal with a mode of about 45 cm (Sasaki and Yoshimura, 1987; Naganobu and Goto, 1988; Fisheries Agency of Japan, unpublished). In the survey conducted in 1988, a unimodal composition was obtained in all areas of the Basin. In addition, in the surveys conducted in the summer of 1975, 1977 and 1978, the unimodal composition was also obtained (Suzuki, 1976; Okada, 1980; Yamaguchi, 1980). In contrast, in the surveys conducted in the winter of 1983, two modes, 38 cm to 40 cm and 40 cm to 48 cm occurred (Fisheries Agency of Japan, 1984). The stations surveyed where only fish with the mode between 38 cm and 40 cm appeared were 9 out of 46 stations. It implies that the small-sized pollock recruited from somewhere surrounding the Basin before that time and there was a possibility that they did not intermingle completely with pollock recruited earlier. According to the results of age determination by otolith conducted by the U.S., it indicates that about 40% of pollock which inhabited the Basin area in 1988 are from the 1978 year class (Traynor, personal communication). It was known that this 1978 year class is an extremely strong, dominant year-class in the eastern Bering Sea (Bailey et al., 1988). Therefore, it is hypothesized that most populations which presently inhabit the Basin are regarded as a part of pollock which are from this dominant year-class. If we follow this hypothesis, it is suggested that the small-sized pollock with a mode of 38 cm to 40 cm which were observed in the winter of 1983 belonged to the 1978 year-class which were recruited recently to the Basin. Yamaguchi (1984) conducted age determination of the samples obtained in the winter of 1983 and reported the average length by age. According to this, pollock with lengths of about 40 cm are estimated to be ages 4 to 5 fish. In due consideration of ambiguities which are observed in the age determination (Agriculture, Forestry and Fishery Technical Conference Secretariat, 1979), it is assumed that they are generally supposed to be of the 1978 year-class.

As the modes of both males and females of group A were 1 cm smaller than those of other groups in the surveys which were conducted at this time, it might be possible to assume that young pollock were recruited from the western Basin area. Sasaki (1988) reported that the schools of pollock are also distributed in the U.S.S.R. waters of the Aleutian Basin from information on the Japan-U.S.S.R. joint venture fishery in 1987. In early October, 1988, the information that scores of the U.S.S.R. vessels conducted fishing in the western offshore areas of the international waters were obtained from the fishing vessels which were engaged in fishing. If this was true, it is suggested that the schools of pollock are also distributed in the Basin areas west of the international waters. Whether it is true or not, further surveys are necessary, because information on the U.S.S.R. areas west of the international waters are still insufficient.

There is much information on pollock which inhabit the surface and midwater layers of the Basin (Suzuki, 1976; Maeda and Hirakawa, 1977; Okada, 1980; Sasaki and Yoshimura, 1988) and its presence has been frequently confirmed from a long time ago. Also, in the age determination by scale or otolith (Yamaguchi, 1980; Traynor, personal communication), it is known that those pollock consist of more than one year-class. From this, the distribution pattern of the pelagic and midwater pollock is not a temporary phenomenon that only occurred when a dominant year-class was present, although there are annual quantitative differences which are caused by the size of year-class, it can be said that it is a part of the general ecology of the pollock population. Maeda, Takahashi and Nakatani (1988) report that pollock are distributed in depths between 160 m and 260 m of waters that depth reaches to 1,000 m off Hiyama of Hokkaido. From such instances, it is determined that pollock individuals which are distributed in the open sea are not scarce. If so, despite the fact that they are the same species, when they reach a certain time in their life history it is not known why some individuals go out to the Basin area and some individuals stay on the continental shelf area. In the surveys conducted this time, pollock of high density were mainly observed in waters with water temperatures between 3.0°C and 4.0°C. In addition, pollock formed their schools in water temperature that was between 3.5°C and 4.0°C during February to March (Fisheries Agency of Japan, 1984). According to the surveys on water temperatures in the Aleutian Basin this time and in the past (Fisheries Agency of Japan, 1984; Naganobu and Goto, 1988; Sasaki and Yoshimura, unpublished), water temperatures in depths of 50 m and deeper ranged from 2.0°C to 4.0°C, and it was estimated that the seasonal changes were small. On the basis of these observations, it was suggested that pollock which inhabited the Basin could maintain a fairly stable temperature condition. This would be one of the advantages of pollock migrating to offshore waters. Although other environmental factors need to be studied in the future, either way, the fact that pollock not only can live on the continental shelf but also in the open sea may be an advantageous strategy to expand the extent of their distribution.

Although several instances of sampling of juvenile pollock on the Aleutian Basin have been reported in the past (Kobayashi, 1963; Maeda and Hirakawa, 1977; Haryu, 1980), they were all reports on the instances in which the lengths were 40 mm and under, except one instance which Haryu (1980) collected one individual of 97.1 mm. According to the results obtained from the surveys conducted this time, the distribution of individuals between 21 mm and 101 mm in length in the Basin was confirmed. This was considered to be caused by the net used this time was larger (for mature fish) and the towing speed was faster, such as 4 knots. Kobayashi (1963) and Haryu (1980) collected mainly individuals of 40 mm and under during June to August, and in the survey conducted this time, the individuals between 25 mm and 40 mm in length were also collected in August. However, Kendall et al. (1987) reported that the individuals of 15 mm and under in length were distributed in depths between 10 m and 15 m at night, and taking account that the average towing depth in this survey was 25 m, juvenile pollock may not have been collected in this survey.

The distribution area of juvenile fish obtained from the survey conducted this time was limited mainly to the edge of the continental shelf in the Basin. In the surveys conducted by the U.S. and U.S.S.R. jointly in the same period of 1987 using the trawl net in height (48 m) and width (55 m) of net mouth, 0.1 kg/hr of juvenile pollock in lengths between 30 mm and 120 mm in the Basin and 54.6 kg to 361.4 kg/hr on the continental shelf of the eastern Bering Sea were collected (Traynor, personal communication). In addition, the catch in the station where the highest number of fish obtained was 0.3 kg/hr. According to these instances, it was considered that although juvenile pollock distributed in the Basin during August to October, the numbers were fairly few, as compared with the number of individuals on the continental shelf, and it was considered that the main distribution area was the continental shelf area. Also, although we can not determine it, because the number of fish sampled on the continental shelf was few, juvenile pollock in the Basin have a tendency to be of low condition factor, as compared with that of juvenile fish on the continental shelf and poor growth was suggested. Because of this, it was difficult to consider that juvenile pollock distributed in the Basin in this period contribute largely for reproduction of the pollock populations on the Basin or continental shelf.

In J-B and D in Fig. 9, more than one mode was observed. Pollock in the Bering Sea spawn in the Basin during January to March, in the southeastern Bering Sea during March to June and in the northwestern Pribilof Islands during June to August (Hinckley 1987). Therefore, it is considered that there was a possibility that pollock spawned in different locations intermingle. It is necessary to clarify the dispersion process of eggs and larvae from respective spawning grounds by conducting the surveys on the continental shelf and Basin areas particularly from the spring to summer seasons in particular using a more appropriate net for surface towing in the future to determine the origin and route of recruitment of pollock.

<u>Acknowledgement</u>

The author truly thanks the following people for this research; the Seiju Fishery Co. Ltd. and the crews of the *Seiju maru No. 28* for their cooperation of the field surveys, Mr. Yoshimi Takao of the National Research Institute of Fisheries Engineering, FAJ for providing data from the quantitative echo sounder system, and Dr. William Carp, the Northwest and Alaska Fisheries Centre, U.S. for his provision of data on juvenile fish on the U.S. side, Dr. Keisuke Mizuno, the Far Seas Fisheries Research Laboratory for his advice on data of water temperature, and Drs. Takashi Sasaki and Kei-ichi Mito for reviewing this report.

Additional note

Age Composition

U.S. scientists collected random age samples of about 15 males and females from 32 trawl hauls. Otoliths were collected from 888 walleye pollock, 437 males and 451 females, and read. The descriptions below were based on age reading data presented by U.S. In advance of reporting, the author truly thanks Mr. Neal Williamson of the U.S. NMFS, who provided these data and much useful advice.

Age compositions by sex were shown in Fig. 13(a). Pollock ranged from age 3 to 16, but the total number of age 3 and 4 fish is only 3. The 10 year old group was dominant for both sexes and the major portion (37.1%) of the all samples came from fish of this group (Tab. 3).

Fig. 14 shows age compositions by sex and station groups (Fig. 6). The 10 year old males and females are dominant at all station groups. In group A, 6 year olds (1982 year class) are the second most dominant. In contrast, for all other groups, the 9 or 11 year old fish are second most dominant. Age composition from 3 trawl hauls in group A, where the pollock belt-shaped response was observed on the monitor in early October at the west side of the international waters, is shown in Fig. 13(b). The 10 year old group is dominant, but the age 6 group is more abundant than in group A and made up nearly 24%. Males contributed a higher percentage (30% to all male) than females (19% to all female).

Fig. 15 shows the relationship between mean fork length and age. The mean length at age was substantially larger for females than males. The average fork length difference between age 5 and age 15, where sample number are sufficiently high, are 33.2mm for males and 52.2mm for females.

Discussion

It was described also in the main report that the 1978 year class was dominant in the Basin, and the concrete percentage of 37.1% was presented here. The results of age reading from 32 trawl hauls indicated that the 1978 year class is dominant in the entire survey area.

Age composition in group A was considerably different. Age 6 group (1982 year class) was a secondary contributer to the group A population. The FL mode both of male and female age 6 pollock in this group was 470mm (from 465mm to 475mm). This was one reason the FL mode of group A is smaller than that of the other groups. The high contribution (over 20%) of age 6 pollock to the samples were observed at all 3 trawl locations where the belt-shaped response was observed. In contrast, in only 2 other trawl locations was the contribution by age 6 fish over 20%. Thus this may indicate that the 1982 year class specimens came mainly from the area west of the convention line in the Basin.

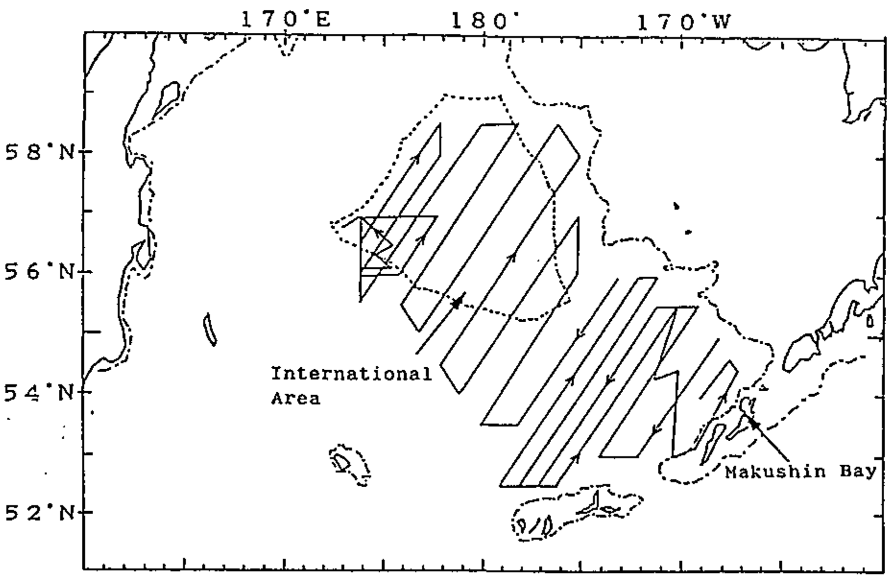

Fig. 1. Map of study area in the Aleutian Basin, showing the transects of Seiju Maru No.28 during the 1988 Japan-U.S. cooperative survey.

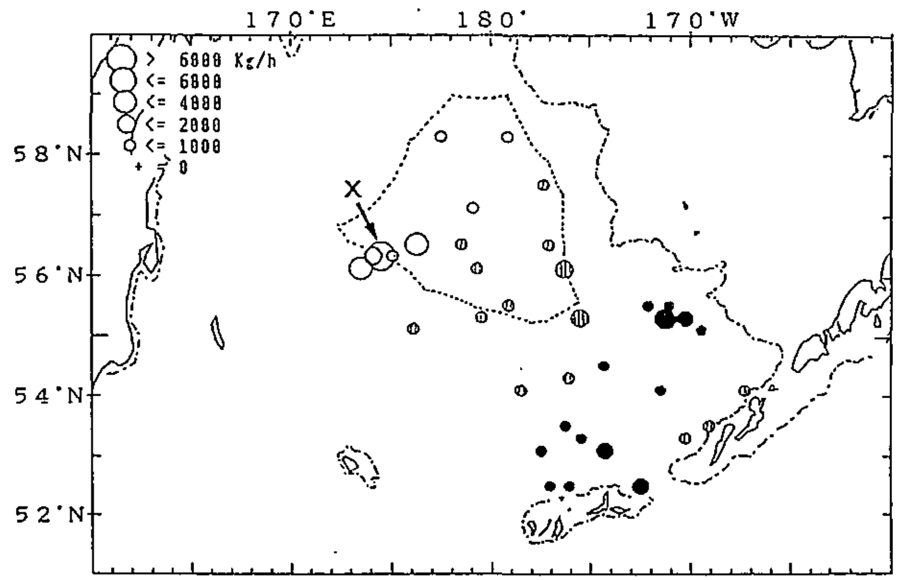

Fig. 2. Distribution and relative abundance (kg/hour) of adult walleye pollock in the Aleutian Basin during Aug. to Oct. in 1988.

● : Aug. ⦶ : Sep. ○ : Oct. X: Maximum catch station

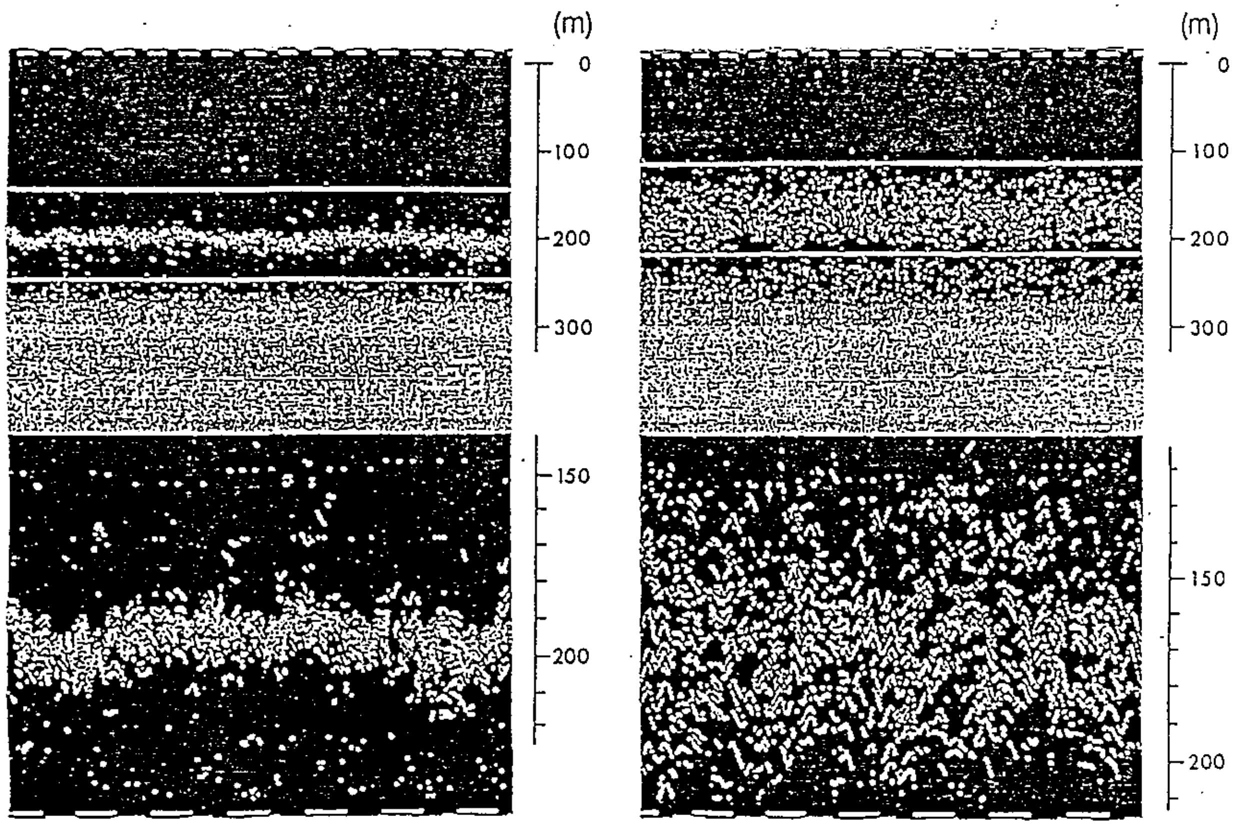

Fig. 3. Echogram sections displaying day-night vertical distribution of adult pollock at the western area of the international area during the 1988 survey. Sunrise

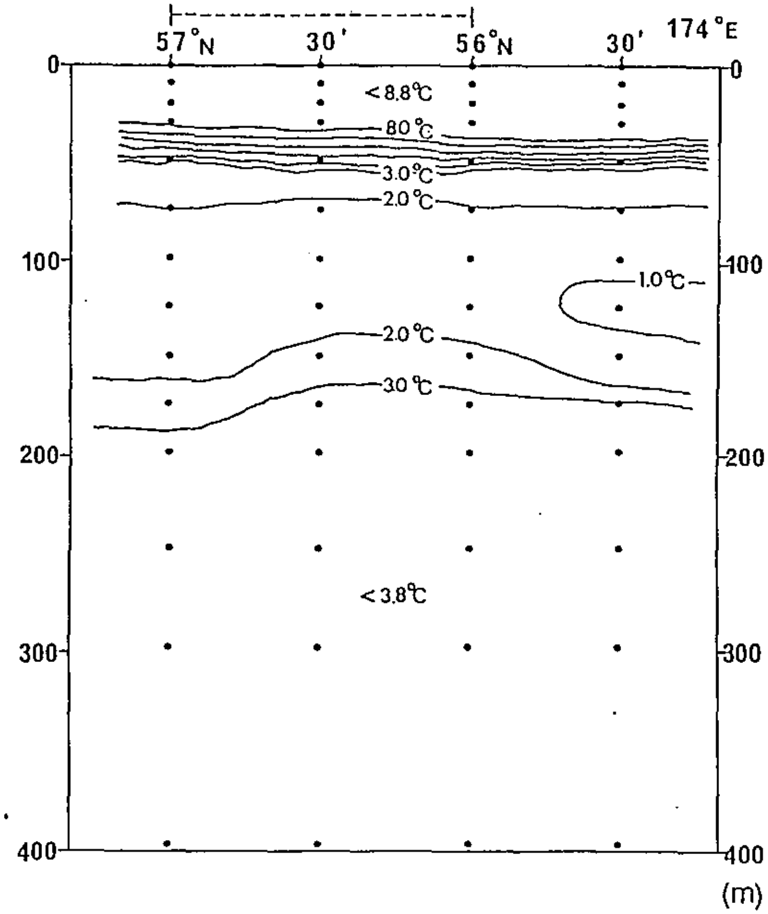

Fig. 4. Vertical distribution of water temperature between 55°30'N and 57°N along the longitude of 174° E.

|----| : Extent of pollock concentration.

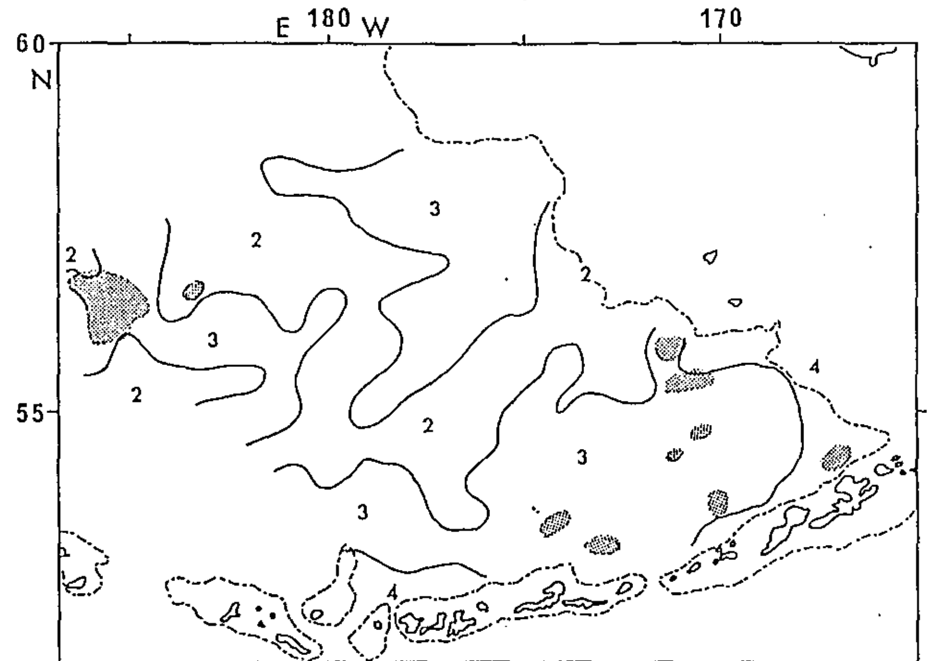

Fig. 5. Water temperature (°C) at a depth of 175m from Aug. to Oct. in 1988.

▒: Distribution of concentrations of pollock estimated from the echogram.

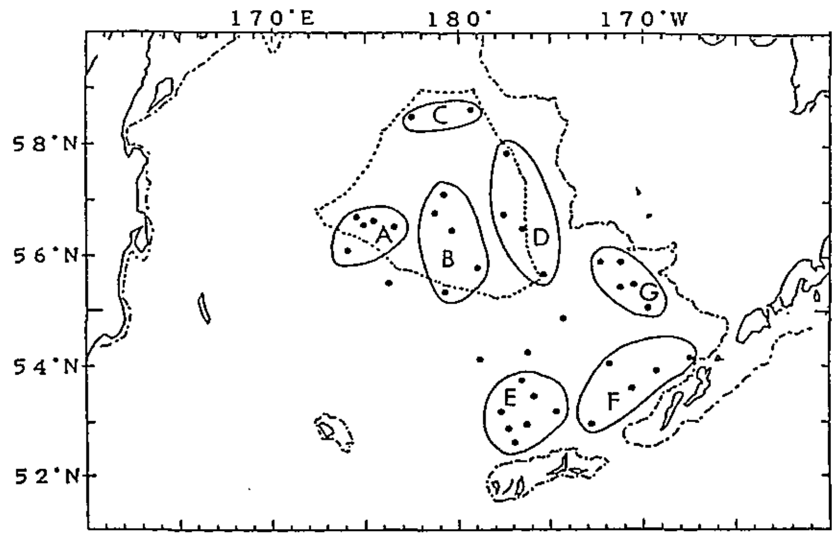

Fig. 6. Station groups for comparison of size composition of adult pollock.

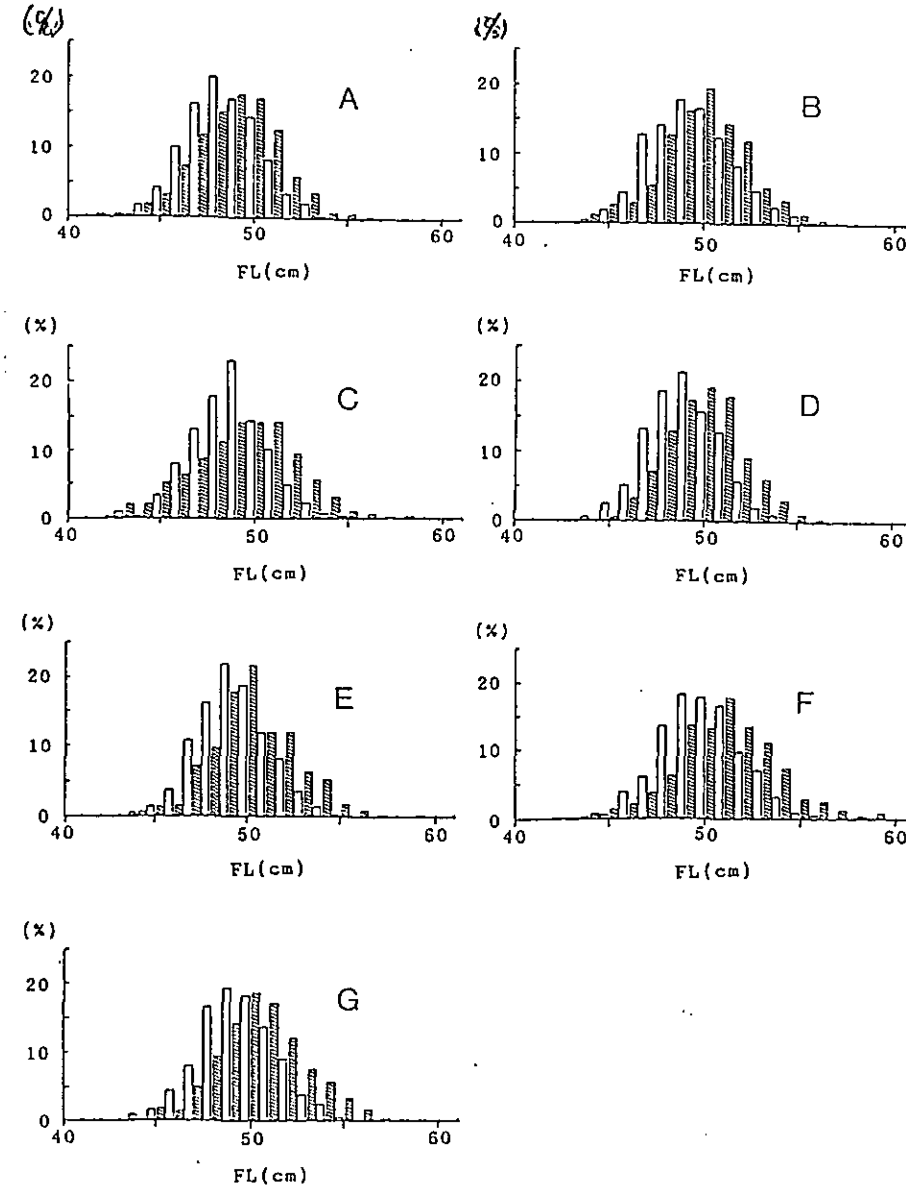

Fig. 7. Folk length distributions of walleye pollock by station groups showed in Fig.6 during Aug. to Oct. in 1988.

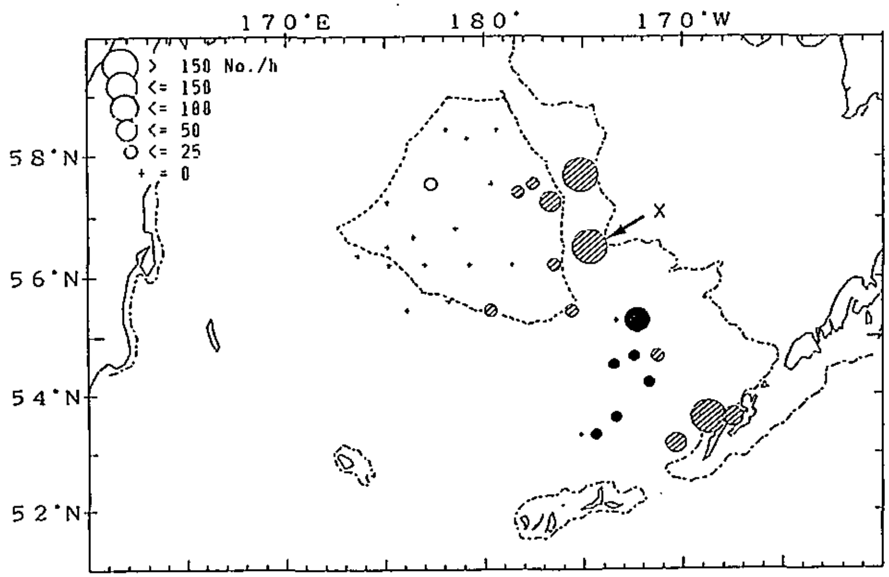

Fig. 8. Distribution and relative abundance (number /hour) of juvenile walleye pollock in the Bering sea during Aug. to Oct. in 1988.

• ● : Aug. ⊘ : Sept. ○ : Oct.
+ : no catch x : maximum catch

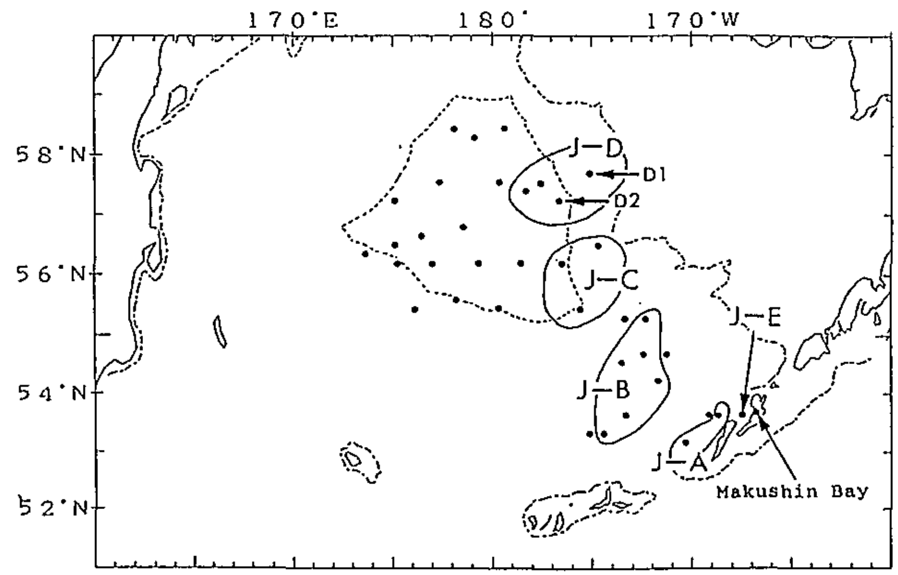

Fig. 9. Station groups for comparison of size composition of juvenile pollock in 1988.

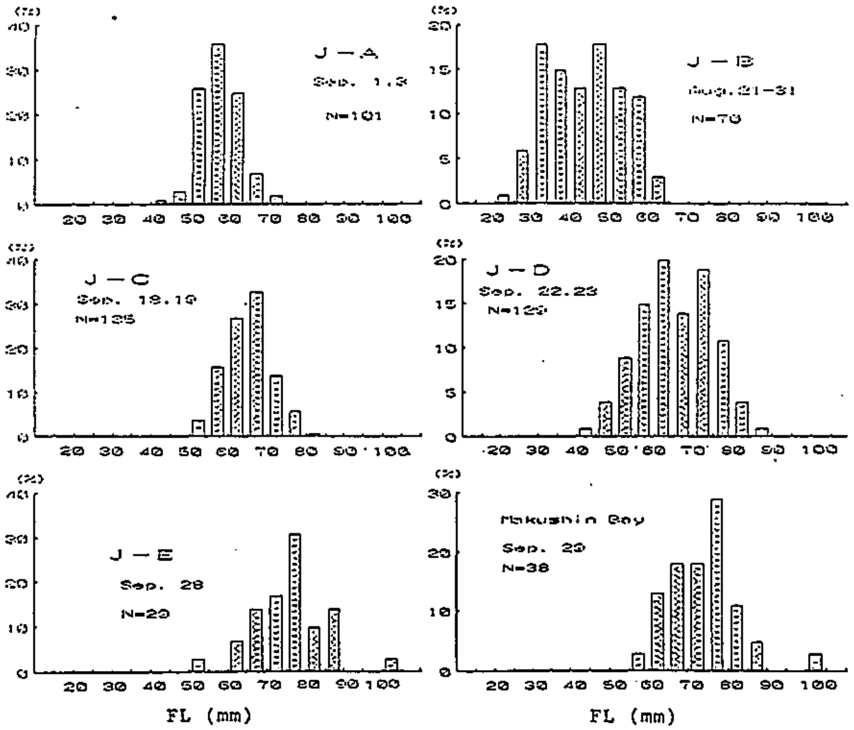

Fig. 10. Folk length distributions of juvenile pollock by station groups showed in Fig. 9 during Aug. to Oct. in 1988.

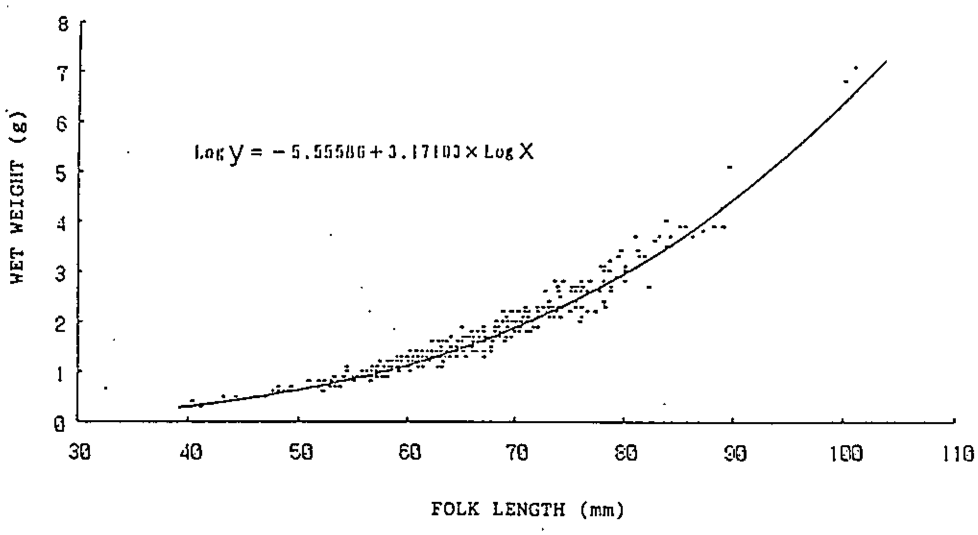

Fig. 11. Relationship between folk length and wet weight of juvenile pollock sampled in the Aleutian Basin during Aug. to Oct. in 1988.

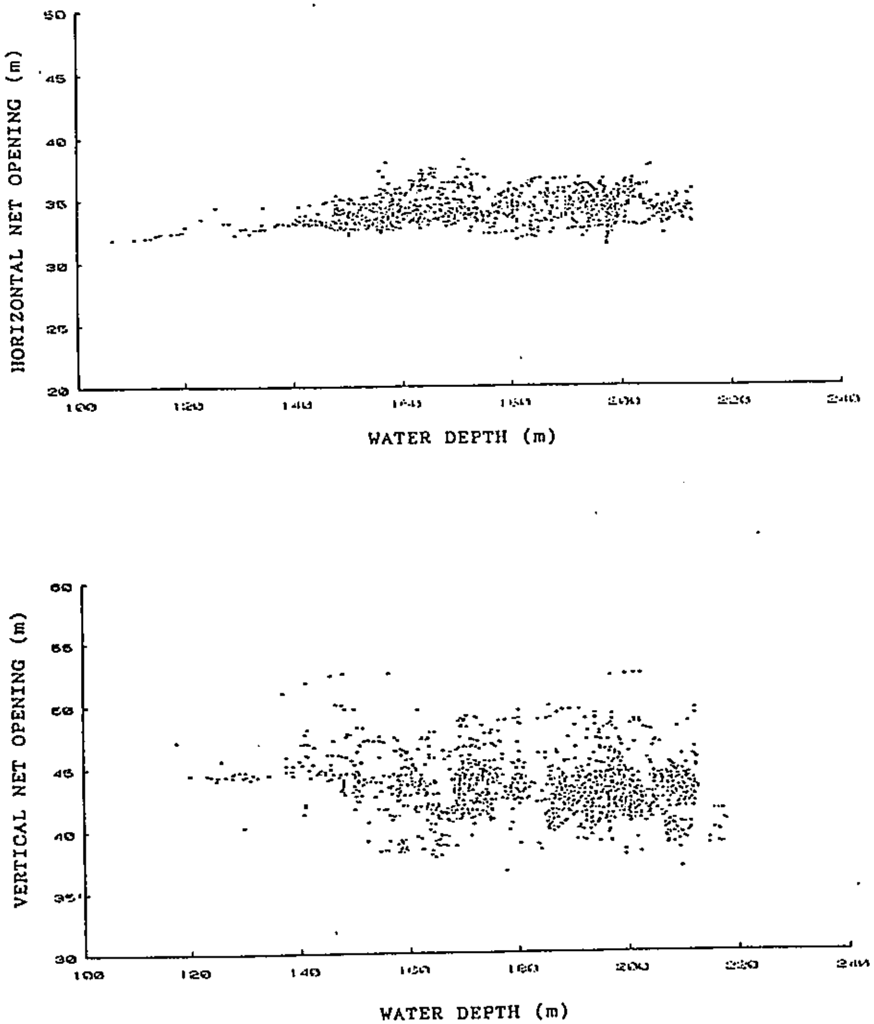

Fig. 12. Relationships between water depth and horizontal and vertical opening of midwater trawl for Seiju Maru No.28

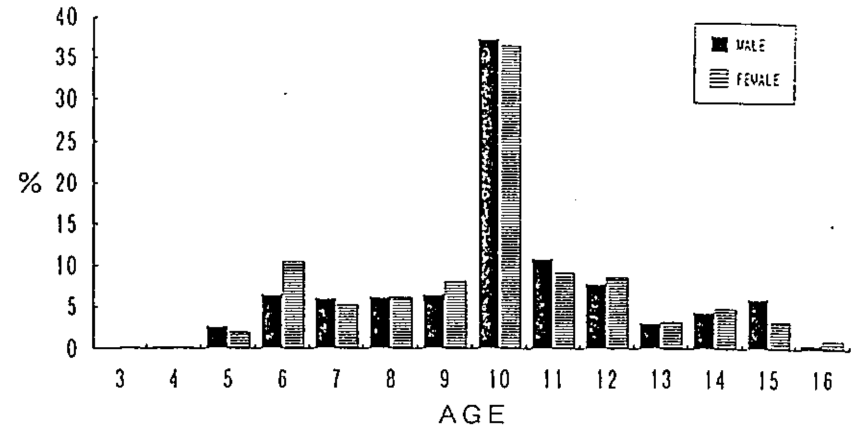

Fig. 13(a). Age composition (percentage) of pollock in the Basin during the 1988 Japan-U.S. cooperative survey.

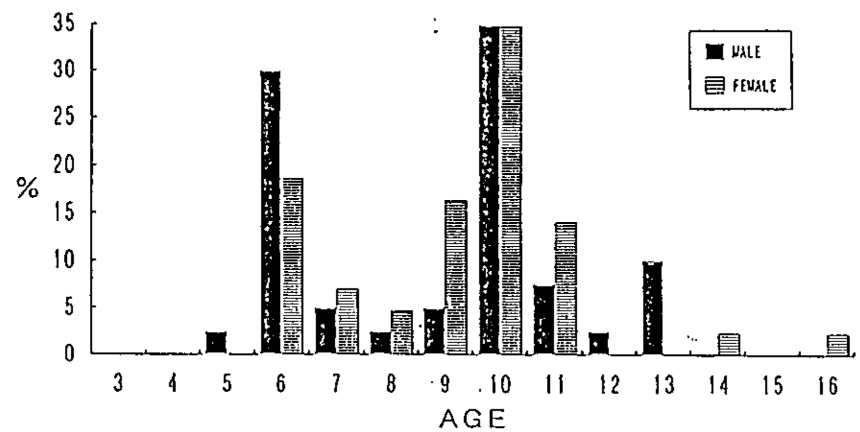

Fig. 13(b). Age composition (percentage) of pollock from 3 trawl hauls (No. 34, 36, 37) in the western area of the high seas where pollock concentrations were observed during the 1988 Japan-U.S. cooperative survey.

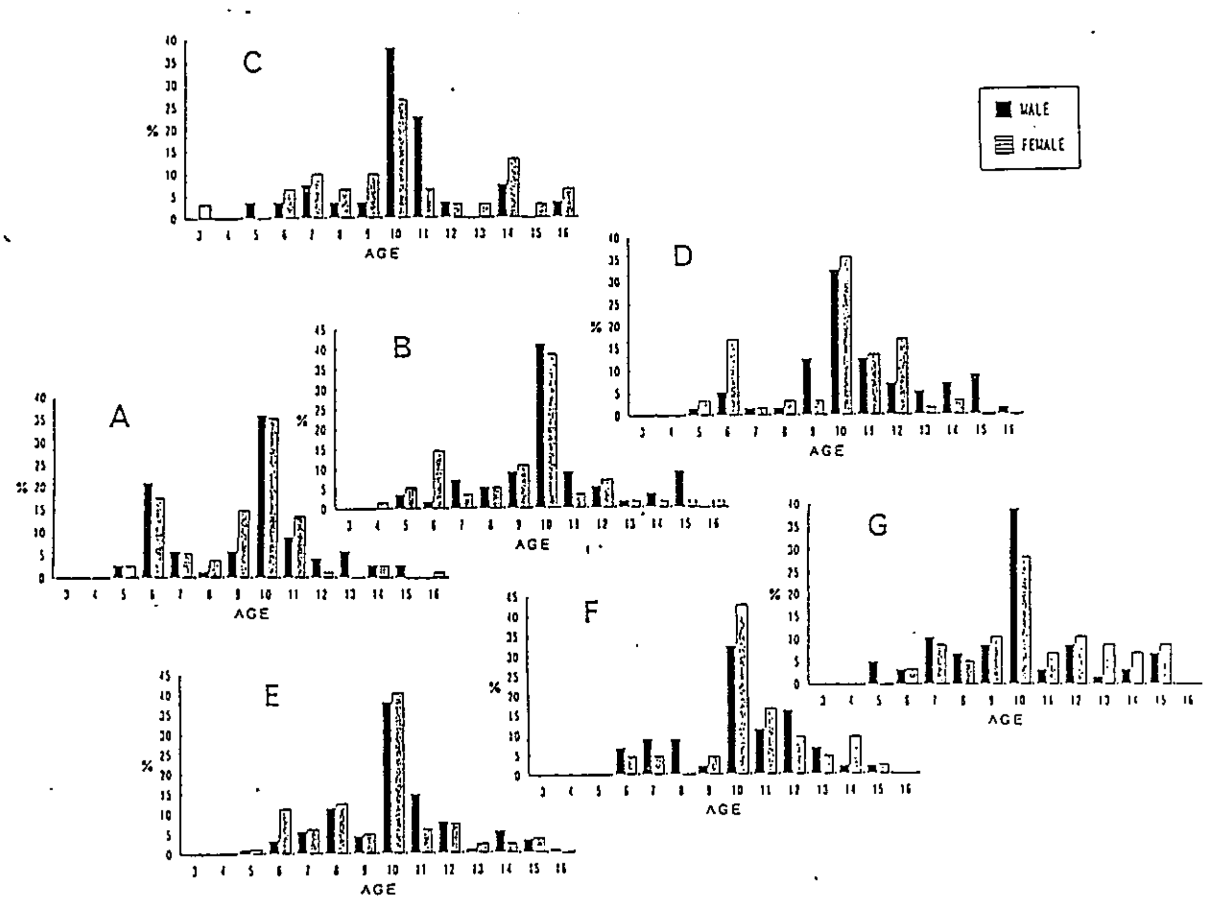

Fig. 14. Age compositions by station groups (Fig. 6) and sex

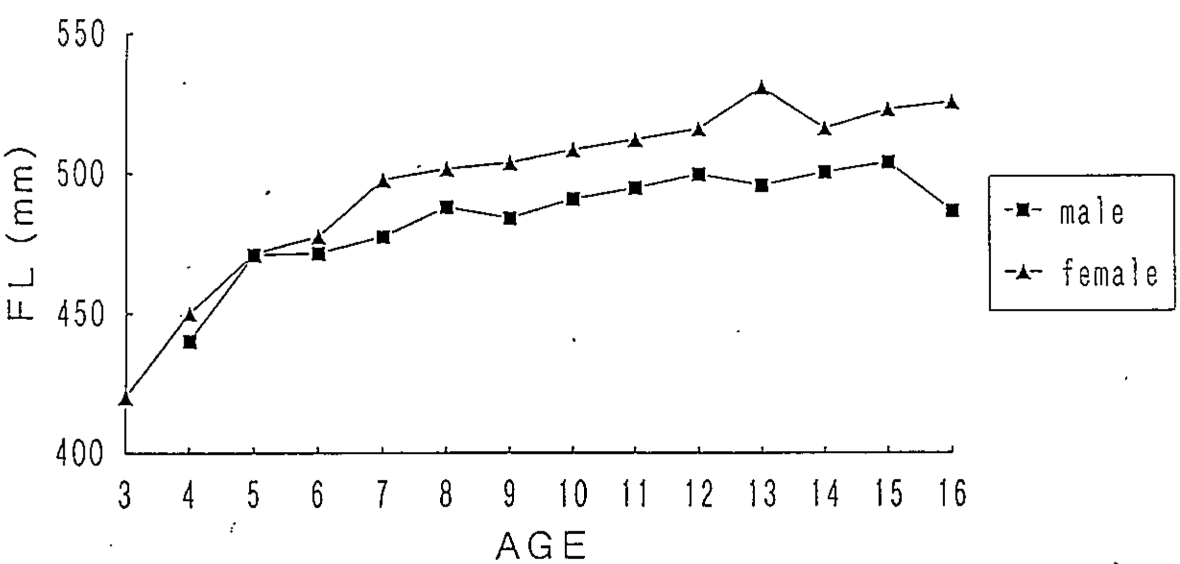

Fig. 15. Relationship between mean fork length and age for walleye pollock in the study area during the 1988 cooperative Japan-U.S. survey.

Table 1. Catch numbers and sex ratios of adult pollock by station groups showed in Fig. 6

Area	Male	Female	Total	Area	Male	Female	Total
A	1511 (1 :	1324 0.88)	2835	E	550 (1 :	428 0.78)	978
B	1156 (1 :	687 0.59)	1843	F	15 (1 :	473 0.66)	1188
C	471 (1 :	282 0.60)	753	G	709 (1 :	468 0.66)	1177
D	971 (1 :	469 0.48)	1440				

Table 2. Average ponderal index (X= Wet Weight/Folk Length x1000) of juvenile pollock by station groups showed in Fig. 9.

	J - A			J - B			J - C			J - D			J - E			HAKUSIN		
FL(mm)	$\bar{X}$	N	SD	$\bar{X}$	N	SD	$\bar{X}$	N	SD	$\bar{X}$	N	SD	$\bar{X}$	N	SD	$\bar{X}$	N	SD
40				5.00	6	0.81				6.11	1	--						
45				5.14	9	0.20				5.71	6	0.43						
50	5.73	3	0.05	5.02	5	0.53	5.25	4	0.34	5.65	14	0.64	5.72	1	--			
55	5.61	12	0.38	5.07	6	0.46	5.23	16	0.38	5.72	19	0.49	4.80	2	0.59	6.05	1	--
60	5.70	14	0.56	5.13	2	0.47	5.60	38	0.40	5.63	26	0.51	5.76	4	0.49	5.88	5	0.56
65	5.50	5	0.55				5.61	45	0.54	5.71	17	0.56	5.66	5	0.47	6.16	7	0.30
70	5.47	1	--				5.67	21	0.55	5.90	23	0.36	5.17	9	0.47	6.13	7	0.40
75.							5.75	8	0.52	6.05	13	0.53	6.12	3	1.11	6.06	11	0.48
80							6.39	1	--	5.98	5	0.36	5.68	4	0.10	6.36	4	0.35
85										5.80	1	--				6.68	2	0.62
90																		
95																		
100													6.89	1	--	6.80	1	--
40-100	5.64	35	0.45	5.07	28	0.47	5.57	133	0.50	5.77	125	0.50	5.56	29	0.65	6.15	38	0.45

Table 3. Age composition of pollock in the Basin during the 1988 Japan-U.S. cooperative survey.

	Age	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Number	Male	0	1	12	29	27	28	29	164	48	35	14	20	27	3	437
	Female	1	1	9	48	24	28	37	165	42	39	15	22	15	5	451
	Total	1	2	21	77	51	56	66	329	90	74	29	42	42	8	888
%	Male	0.00	0.23	2.75	6.64	6.18	6.41	6.64	37.53	10.98	8.01	3.20	4.58	6.18	0.69	100
	Female	0.22	0.22	2.00	10.64	5.32	6.21	8.20	36.59	9.31	8.65	3.33	4.88	3.33	1.11	100
	Total	0.11	0.23	2.36	8.67	5.74	6.31	7.43	37.05	10.14	8.33	3.27	4.73	4.73	0.90	100

Preliminary Report of Acoustic Survey of Aleutian Pollock conducted in 1988/89 Winter

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1. Introduction

For the purpose of scientific management of walleye pollock (Theragra chalcogramma) resources in the Aleutian Basin area, the Japan-US cooperative survey programs are being conducted. As one of the programs a midwater trawl / acoustic survey on pollock was conducted in 1988/1990 winter. The Japanese survey was planned and conducted by two institutions of the Fisheries Agency of Japan -- National Research Institute of Far Seas Fisheries (NRIFSF) and National Research Institute of Fisheries Engineering (NRIFE), with cooperation of the Alaska Fisheries Science Center (AFSC, NOAA, USA). Other than US scientists, scientists from Canada, Poland and China attended in this survey.

This preliminary report describes mainly acoustic items of the survey which have been able to be analysed till now.

2. Outline of the Survey

2.1 Survey Items and Methods

The survey items are as follows:

(1) Acoustic system calibration to ensure and maintain accuracy of the system. (This item includes sensitivity calibrations using a standard sphere, noise measurements, and intership calibration with the US vessel.)

(2) In situ target strength (TS) measurements by the dual-beam method to examine characteristics of pollock TS.

(3) Measurements of volume backscattering strength (SV) by the echo integration method to describe abundance distribution of pollock in the survey area and to estimate the total biomass.

(4) Midwater trawls to obtain biological information.

A research vessel of the Fisheries Agency, Kaiyo-maru (2644tons), was used for this survey. Survey operations were divided into four legs. The survey tracks in each leg are shown in the maps in Fig.1.

The echo sounding system used is the one developed by NRIFE and called the versatile quantitative echo sounding system (VESS)[1)2)]. Acoustic system operations (echo integration and in situ TS measurement) were conducted 24 hours a day. Vessel speed was usually seven to eight knots. It was sometimes slowed down to decrease noise. We tried to made mid-water trawls to collect biological samples when we observed relatively dense fish sign, but sometimes bad weather prevented to do so and only 24 trawlings were done. The average trawling speed was between three and four knots.

2.2 Cruise Itinerary and Survey Area

After the pre-survey to check the acoustic system and trawl gear, November 14～17 (Japanese standard time), the research vessel Kaiyo-maru departed Harumi-port, Tokyo, on December 1, 1988. On the way to the survey area, an intership calibration was conducted between Kaiyo-maru and Soyo-maru, which is a research vessel of National Research Institute of Fisheries Science and is equipped with a similar quantitative echo sounder as VESS, off the coast of Choshi in Japan. Leg 1 began December 8, 1988 (US time) in the west Bering sea. The survey completed on March 1, 1989.

The vessel's itinerary was as follows:

Pre-Survey	
(JAPAN TIME)	
Nov. 14	Standard target calibration #1 in Tateyama Bay
15～17	System check, Noise measurement
18	Standard target calibration in Tateyama Bay
Leg 1	
(JAPAN TIME)	
Dec. 1	Leave Harumi. U.S. scientist on board.
(U.S. TIME)	
Dec. 2～7	Cruise to the start point of survey.
Dec. 8～12	Survey operations Leg 1.
Dec. 13	Transit to Makushin Bay.
Dec. 14,15	Standard target calibration #2 in Makushin Bay.
Dec. 16～18	Cruise break in Dutch Harbor.
Leg 2	
Dec. 19,20	Transit to survey area.
Dec. 21～Jan. 2	Survey operations Leg 2.
Jan. 3～6	Transit to Seward.
Jan. 7～11	Cruise break in Seward. Canadian scientist and Polish scientist on board.
Leg 3	
Jan. 12～15	Transit to Makushin Bay.
Jan. 16～19	Standard target calibration #3 in Makushin Bay.
Jan. 20	Transit to near Bogoslof Island.
Jan. 21	Intership calibration with US vessel Miller Freeman.
Jan. 22～Feb. 7	Survey operations Aleutian Basin including International Zone (often break due to low pressures).

Feb. 8	Transit to Dutch Harbor.
Feb. 9～10	Cruise break in Dutch Harbor. Exchange US scientist. Chinese scientist on board. Canadian scientist get off.
Leg 4	
Feb. 11	Transit to Bogoslof Island
Feb. 12	Intership calibration with US vessel Miller Freeman.
Feb. 13	Transit to the survey area.
Feb. 14	Begin Leg 4. Transducer #1 broken.
Feb. 15	Change transducer (#1 to #2).
Feb. 16～26	Continue survey Leg 4.
Feb. 27～Mar. 1	Standard target calibration #4 in Makushin Bay.
Mar. 2,3	End survey in Dutch Harbor.
(Japan Time)	
Mar. 4～16	Cruise.
Mar. 17	Arrive at Harumi.

2.3 Scientific Personnel

Leg 1 12/8/88～12/12/88
Leg 2 12/21/88～1/2/89
Leg 3 1/22/89～2/7/89
Leg 4 2/14/89～2/26/89

Japan	Kazuyuki Teshima*1	Chief scientist	NRIFSF	Leg 1～4
	Yoshimi Takao	Fishery engineer	NRIFE	Leg 1～2
	Koichi Sawada	Fishery engineer	NRIFE	Leg 1～4
U.S.	Dennis Benjamin	Fishery biologist	AFSC	Leg 1～3
	Edmund Nunnallee	Fishery biologist	AFSC	Leg 4
Canada	William Show	Fishery biologist	PBS*2	Leg 3
Poland	Edward Jackowski	Fishery biologist	SFI*3	Leg 3～4
China	Ren Sheng-min	Fishery biologist	CAFS*4	Leg 4

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*2 Pacific Biological Station, Nanaimo, Canada
*3 Sea Fisheries Institute, Gdynia, Poland
*4 Chinese Academy of Fisheries Science, Shan Dong, China

3. Acoustic System and Calibration

3.1 Acoustic System Calibration

Standard sphere calibrations were conducted during the presurvey and three times during the survey by the same way as in 1988 summer[2]. We calibrated the transmitting and receiving factor (KT_R, see Ref.2) and the equivalent pulse width. The vessel was anchored fore and aft at 50～80 m of water depth. Two transducers were used. The transducer #1 was used in almost all surveys, but the transducer #2 was used at the latter part of Leg 4 because of a malfunction of #1.

Figure 2 shows the depth dependence of KT_R factors in all the calibrations. For the transducer #1 KT_R was from 97.4 to 99.0 dB at 10 m and this variation might come from the difference of water temperature. Since our towed body was at about 10 m depth in the survey, we adopted the values measured at 10 m before each leg.

On February 14 the transducer #1 was broken by a leak of sea water. After Feb.15 we had to use another transducer #2 which was made by the same specification as the broken one. The fourth calibration on February 27～March 1 was conducted on this new transducer in very good condition. The KT_R values of this transducer were less than those of transducer #1 by 6～7 dB.

In Table 2 of the last summer survey report[2], we summarized the calibration results with the results of other surveys for the purpose of comparison.

3.2 Noise and Threshold

Since the noise received by the echo sounding system degrades the acoustic results, we sometimes measured the noise level and, by referencing to the results, we made counterplans such as adjusting the threshold and changing the ship speed.

We measured the noise by the same way as in the last summer survey[2]. That is, we stopped transmitting, integrated noise signal with 1 min interval, and transformed thus obtained "noise SV" into the noise power spectrum level (NP).

Figure 3 is a result obtained at around 300 m depth water off Tateyama, Japan, on 15 November 1988 in presurvey. The SV values at 250 - 300 m layer were converted to NP and the results are shown against the ship speed. The depth of the towed body was 30 m when the ship was stopping and decreased up to about 10 m in accordance with increasing speed. Although the variation of the data is large, we can see the trends that the noise increases with the speed and that the wide channel is more sensitive to noise by about 5 dB.

This noise level is almost 10 dB greater than the level measured in

1988 summer survey on board Seijyu-maru. This made the survey and analysis difficult, especially for TS measurements. Since the echo sounding system was the same for both surveys, the difference in noise level must be caused by the difference in the towing methods and ships. The towed body was deployed by a crane installed on the front deck, the horizontal distance of the towed body and broadside was only about 4 m, and the towed body was located at near the side wall of the engine room and the propeller. Kaiyo-maru is 2644 tons and greater than Seijyu-maru by a factor of 7.6. From Ross's equation[3] to estimate ship noise, we might suffer 15 log 7.6 = 13 dB greater noise.

Thus, we often measured noise level (about one time a day) and by using the results we carefully set the threshold. The threshold function[2] were ordinarily "FLAT and SV at 100 m = -99 dB" or "20 log r and -90 dB."

3.3 Intership Calibration

The intership calibration (ISC) was performed between US R/V Miller Freeman and Japanese R/V Kaiyo-maru in order to check the both side acoustic systems. We attempted ISC three times.

The first one was tried together with the third sphere calibration on January 17,18 and 19. Both vessels were moored at anchor side by side and systems' triggers were synchronized. However, since there appeared few fish even in the night time, we could not get available results.

The second ISC was attempted in Bering Sea shelf waters on January 21. but bad weather halted operations.

Only the third intership calibration was successfully done and the details are decribed below.

The ISC took place 25 nmi southeast of Bogoslof Island on Feb.12 (local time). Transect lines in the calibration area are shown in Fig.4.

The two vessels steamed almost side by side with repeated transect over a large dense aggregation of pollock which was about 4 nmi long and at 320 - 480 m deep. An example of color echogram of this aggregation is shown in Fig.5. We collected echo integration data from the 15 passes above the school. Kaiyo-maru sailed about 0.3 nmi to port and 45° astern of Miller Freeman. Vessel speed varied between 4 and 8 knots depending upon weather condition, but it was kept same on the each line.

The Japanese system operated at 800 m range mode. We measured noise level before and during the intership calibration. According to the result, we used the threshold function of "20 log r" with SV value of -90dB at 100m.

There appeared two problems in analyzing the ISC data: The depths of both side towed bodies were about 10 m, but not measured exactly; US system could not measure the aggregation below 400 m where the dense aggregation still existed. Therefore, strict comparison could not be done and we compared the results selecting some plausible ranges of analysis.

The comparison of the estimated fish densities (kg/m^2) averaged over each pass are shown in Fig.6 where we assumed TSkg of -30 dB/kg as the transformation factor from the areal backscattering strength (SA) to the fish density. Assuming the towed body depths of 10 m, US calculation was done for SV in three different depth layers from the surface and Japanese from 26 to 410 mas shown in Fig.6.

We see the similar trends in both side results, but with slight changes of the anlysis range US results shift considerably. Since the results of this experiment show no large difference and since independent analyses of standard sphere calibration data confirmed the accuracy of both acoustic systems, we assume an intership calibration factor of unity.

4. Target Strength Measurements

4.1 Method and Results

We measured TS <u>in situ</u> 24 hours a day along with the echo integration. The results were shown on a CRT and a printer online as a matrix form showing distribution density in each depth layer and TS class.[1,2] Rawer data were memorized in files on floppy disks. In these files times of single eches measured from trigger, pulse width at half level, echo levels for narrow and wide channels etc. were recorded. In the following analyses we used these filed data.

In this winter survey the TS estimation was somewhat difficult compared with the last summer survey from the following reasons: Fish ditributed at depth (summer aroud 200 m and winter sometimes deeper than 400 m); The distribution density was generally high; Noise level was about 10 dB higher than in summer survey. Thus, we analysed the data considering these points.

From many data we selected the portion as to be able to examine the effect of distribution density (Table 1). First, we selected one or some data sets from each leg (positions are shown by black circles in Fig.1) considering as to include high, medium, and low densities, and patchy distributions. Next, in order to compare the results in the condition as same as possible, we selected data at high and low densities in the same day (25 Dec. and 23 Jan.). Noise level was observed on the 40 log r echogram basis. The criterion was that if we observe almost the same level of noise as fish echo we call the noise is "high." In order to eliminate the fish which locate largely out of the main groupe, we computed the average and standard deviation of fish depth, and selected the echo in the average ± one standard deviation (we call this process "depth restriction").

Table 1 shows the data and results. The asterisks in the table mean the depth restriction. TScm is the normalyzed TS which is defined by

$$TS[dB] = 20 \log L[cm] + TScm[dB] \quad (1)$$

where L is the folk length in cm. We used the average body length of 48.8 cm obtained from trawl samples. Figures 7 - 9 show echograms coresponding to the data No.3, 7, and 10. Figures 10 and 11 show TS against depth and TS frequency as a histogram for the data set No.3, respectively.

4.2 Discussion

The obtained value of TScm is about -64 to -60 dB and is considerably high compared with the value of -66.0 dB which has been obtained for pollock by several methods[2)-4)]. We can imagine some causes for this: (1) There might be differences in the body or bladder shape and the orientation distribution of fish due to the differences of season and maturity; (2) There might be difference in the body length sampled by trawl because of the difference of the ship and net; (3) The high distribution density and the deep fish location might cause erroneous TS; (4) Noise contribution might make observed TS high.

Although we could not diretly check the first two possibilities, we can compare body shape and size with past data and estimate the difference. We compare the relationships between folk length and body weight obtained in this survey and in the last summer survey. Since the body weight was not measured in the summer survey, we use the data obtained by angling in Makushin Bay, Unalaska Island. The relations are regressed to the formula

$$W = a L^3 \quad (2)$$

and get the coefficient a of 6.9×10^{-3} g/m^3 (correlation coefficient 0.87) for summer and 7.0×10^{-3} g/m^3 (0.77) for winter. Since the coefficients a may be thought as an index of body shape, these results reveal that there was no large discrepancy in body shape.

Reviewing the past results[5)] of the survey in these area, the average body lengths of the pollock in the Bering Sea have been estimated from 46 cm to 48 cm in both summer and witer seasons. Therefore, the average folk length of 48.8 cm may be thought as a representative value.

We next consider about above reasons of (3) and (4). We see tendency of increasing measured TS with increasing densities and depths. These phenomena must be come from the fact that increasing number of fish echoes or increasing depth produces more multiple echoes and their echo peaks may be classified as "single echoes" giving large false TS. The depth restriction results in a little increase in measured TS. This tendency can be also explained by the above reason, because this procedure might select dense portion of school.

From Table 1 we also see a tendency that measured TS is large when the noise is high. The reason for this may be that noise added single echoes gave large TS.

The present pulse width comparison method for single echo discrimination is pointed out that the discrimination sometimes fails when the echoes contain multiple echoes[6)].

As we have original and raw data in MT and disks, we will reanalyze by using other discriminatin method such as wave form comparison. Our method presently adopted is simultaneous operation of the echo integrator and dual beam processor. This method succeeded in the last summer survey, but this would be problematical for the winter distribution of pollock. In this connection, in 1989 summer survey we again obtained TScm value of near -66.0 dB. Therefore, we can conclude that if there are a few fish in the effective beam width, we can measure exact TS. The effective method for dense aggregation should be to lower a transducer down near to fish distribution as was done by AFSC.

Above mentioned problems suggest us that as for this winter survey we must not use measured TS value for scaling the echo integrator output. Then we calculated TS value of -32.2dB for the scale factor by substituting TScm of -66.0 dB and the average folk length of 48.8 cm obtained by trawl samples into Eq.(1). This TS value happened to be exactly the same as the one in the last summer survey.

5. Fish Distribution and Abundance Estimation

5.1 Method

We operated the echo integrator on 24 hour basis. The ship speed was 7 - 8 kt according to the weather conditions. The integration period was set in time mode and was ordinarily three minutes.

The analyzing method is almost the same as 1988 summer survey. We read small mesh integrated data (SV) from disks and, by referencing echogram, classified them to leave the objective fish echoes. According to the classification we restrict depth range and compute the areal backscattering strength (SA) for each three minute period. In this survey as the noise level was high and the fish distribution was rather deep, noise and fish echoes were often superimposed. Many efforts were made to discriminate noise from fish echoes by seeing echograms and the field note. The data collected when special operations such as trawling and CTD cast were performed were abandoned in SA calculations. The ISC data were also omitted in abundance estimation process because of many repeated passes over one large school.

5.2 Distribution of Pollock

Figures 5, 7, 8, and 9 show some examples of echograms exhibiting distributions of pollock. The density was generally high and the depth was deep than in the last summer survey.

Figure 12 shows SA values averaged over 40 integration period (about two hours) along track lines.

In order to see the distributions more clearly, we conbine data from all legs and averaged SA in each block of 30 min latitude by one degree longitude. Since there are variations in sample numbers in blocks, we omit the blocks which contain less than 20 integration period (approximately 20 × 7 kt × 3 min = 7 nmi). The result is shown in Table 2. In the table minus symbols mean no-data and asterisks less than 20 integration periods.

From these figure and table, in the west part of the surveyed area there were a few pollock and in the east part pollock were abundant especially near Aleutian Islands. This distribution pattern coincides well with the CPUE distribution obtained by trawl sampling.[7]

5.3 Population Size Estimation

In this survey it was very difficult to follow the originally planed grids because of the bad weather of this winter and the resultant track lines became much irregular as shown in Fig.1. Therefore, computation of abundance is not straightforward. We tried two methods to estimate abundance.

One trial is to compute abundance for the main part of each leg. Average SA are calculated for each leg excluding cruising tracks and multiplied by the area shown by bold lines in Fig.1. To convert SA into fish number and abundance we used the TS value of -32.2 dB and the weight for one fish of 801.9 g which was computed by substituting average length of 48.8 cm into Eq.(2). The results are shown in Table 3, No.1 - 4. As an index of abundance in the International Zone (IZ), SA values obtained only in IZ in Leg 2 are averaged and multiplied by the surveyed area (33.5 % of the total IZ area) as shown in Table 3, No.5. These abundances for each leg reflect differences both in time (leg interval were about two to four weeks) and surveyed area. The estimated abundance is large for Leg 4 which included abundant coastal area along Aleutian Islands.

The second trial is to use block based data and compute abundance per block and all area surveyed. Table 4 shows the abundance in each block obtained by using the SA values of Table 2. The total biomass is shown in Table 3, No.6. Comparing this results with No.4, it seems that the latter is too large. This may come from the fact that there were very dense aggregation at the small area near Aleutian Islands (see Fig.12) and the data obtained for the aggregation made the average SA too large.

We, with cooperation of AFSC, USA, will father analyse these winter data and estimate not only abundance but also sampling error.

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Table 3 Estimated abundance by several methods.

NO	METHOD	AREA [km²]	AVE.SA [dB]	POPULATION [fish × 10^6]	ABUNDANCE [k ton]
1	1ST LEG	95,453	-66.5	35.45	28
2	2ND LEG	86,394	-57.8	241.95	194
3	3RD LEG	196,818	-63.3	153.20	123
4	4TH LEG	228,243	-45.7	3484.47	2794
5	2ND LEG, IZ	68,804*	-58.1	177.23	142
6	TOTAL(BLOCKS)	326,621			1746

* This area is 33.5% of total IZ area (205,311km²).

Table 4 Estimated abundance (k tons) in each block.

	171-172E	172-173E	173-174E	174-175E	175-176E	176-177E	177-178E	178-179E	179-180E	180-179W	179-178W	178-177W
58.0 - 58.5	-	-	-	-	-	-	-	-	-	-	1.67	-
57.5 - 58.0	-	-	-	-	-	-	-	-	-	-	0.54	0.40
57.0 - 57.5	-	-	-	-	-	23.63	14.31	15.59	-	-	0.67	-
56.5 - 57.0	-	-	-	-	-	6.54	10.46	3.34	1.01	-	0.65	-
56.0 - 56.5	-	-	-	-	-	8.50	12.69	6.86	9.13	0.78	0.77	-
55.5 - 56.0	-	-	-	-	-	16.59	6.07	4.71	2.38	4.93	2.97	11.91
55.0 - 55.5	-	-	-	-	-	16.01	5.76	3.07	-	-	0.85	-
54.5 - 55.0	-	-	-	1.08	-	-	-	5.57	4.58	-	-	-
54.0 - 54.5	-	0.68	-	-	0.57	-	-	-	-	-	-	3.73
53.5 - 54.0	0.51	-	-	-	1.50	-	-	5.35	7.22	6.58	16.38	11.87
53.0 - 53.5	-	-	-	-	-	0.35	0.55	0.51	0.78	0.36	-	3.04
52.5 - 53.0	-	-	-	-	-	0.55	0.54	-	-	0.81	1.15	1.61
52.0 - 52.5	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.51	0.58	0.00	1.02	2.07	77.16	50.38	46.52	25.05	13.45	25.55	32.55
area (km²)	3550	3606	0	3562	7255	24574	24574	28050	21193	17982	31072	21453

	177-175W	176-175W	175-174W	174-173W	173-172W	172-171W	171-170W	170-169W	169-168W	168-167W	167-166W	166-165W
58.0 - 58.5	-	-	-	-	-	-	-	-	-	-	-	-
57.5 - 58.0	-	-	-	-	-	-	-	-	-	-	-	-
57.0 - 57.5	-	-	-	-	31.82	-	-	-	-	-	-	-
56.5 - 57.0	-	-	-	20.45	4.52	-	-	-	-	-	-	-
56.0 - 56.5	-	-	-	8.72	21.65	-	-	-	-	-	-	-
55.5 - 56.0	6.04	-	-	-	-	-	30.33	55.45	41.01	-	-	-
55.0 - 55.5	3.86	-	-	-	-	-	25.67	17.40	42.02	-	-	25.67
54.5 - 55.0	7.24	-	-	-	-	-	-	26.42	-	4.07	14.92	7.94
54.0 - 54.5	4.15	-	-	-	-	-	-	-	17.03	41.23	41.42	-
53.5 - 54.0	8.25	9.41	21.60	33.07	22.86	-	25.08	61.25	-	44.40	-	-
53.0 - 53.5	2.67	-	-	-	-	7.75	39.86	517.02	-	-	-	-
52.5 - 53.0	-	-	1.99	10.70	23.91	-	-	-	-	-	-	-
52.0 - 52.5	-	-	131.67	-	-	-	-	-	-	-	-	-
Total	32.21	9.41	155.26	72.93	105.42	7.75	120.95	687.55	100.06	89.70	56.34	33.61
area (km²)	21504	3650	11165	14199	17539	3693	14335	17858	10598	10818	7169	7081

Table 1 Reslts of target strength analysis.

No.	1	2	3	4	5	6
DATE	12/11/88	12/25/88			12/27/88	12/30/88
TIME	16:45〜17:30	09:09〜09:40	09:49〜10:16	11:24〜11:55	13:26〜13:56	03:31〜03:46
LEG #	1	2			2	2
POSITION	N53° 22′ E179° 29.2′	N55° 48.33′ E179° 6.99′	N55° 52.59′ E179° 8.80′	N56° 4.19′ E179° 12.84′	N56° 11.5′ E178° 2.4′	N57° 16.71′ E176° 59.20′
PING #	1325	857	701	857	857	467
ECHO #	187	453	697	1544	1602	453
ECHO #*	132	368	569	1051	1087	323
TS [dB]	-29.71	-30.16	-28.99	-27.22	-28.47	-28.89
TScm [dB]	-63.48	-63.93	-62.76	-60.99	-62.24	-62.66
TS* [dB]	-29.62	-30.12	-28.93	-26.93	-28.35	-28.59
TScm* [dB]	-63.39	-63.89	-62.70	-60.70	-62.12	-62.36
DEPTH [m]	197.49	213.17	216.75	256.54	270.49	263.49
σ [m]	13.67	14.87	11.04	20.13	20.75	27.06
DENSITY	LOW	LOW	MEDIUM	HIGH	M, H	PATCH
NOISE	LOW	LOW	LOW	LOW	LOW	LOW

No.	7	8	9	10
DATE	1/23/89			2/25/89
TIME	05:16〜05:31	11:27〜11:50	13:32〜14:03	21:07〜21:32
LEG #	3			4
POSITION	N53° 48.45′ W176° 45.38′	N53° 28.21′ W176° 9.09′	N53° 21.7′ W176° 39.92′	N54° 42.1′ W166° 8.6′
PING #	494	701	831	1274
ECHO #	642	563	1227	398
ECHO #*	486	383	1036	236
TS [dB]	-26.34	-27.33	-26.96	-26.9
TScm [dB]	-60.11	-61.10	-60.73	-60.67
TS* [dB]	-26.3	-27.29	-26.9	-25.92
TScm* [dB]	-60.07	-61.06	-60.67	-59.69
DEPTH [m]	301.45	304.92	288.64	233.5
σ [m]	21.44	20.89	16.54	23.59
DENSITY	HIGH	LOW	MEDIUM	PATCH
NOISE	HIGH	HIGH	HIGH	L, M

* Depth restricted

Table 2 Average SA in each block. (- : no data, * : too small sample)

	171-172E	172-173E	173-174E	174-175E	175-176E	176-177E	177-178E	178-179E	179-180E	180-179W	179-178W	178-177W
58.0 - 58.5	-	-	-	-	-	-	-	-	-	-	-54.13	*
57.5 - 58.0	-	-	-	-	-	-	-	-	-	-	-69.10	-70.36
57.0 - 57.5	-	-	-	-	-	-51.91	-54.92	-54.49	-	-	-68.20	*
56.5 - 57.0	-	-	-	-	-	-58.38	-55.34	-50.58	-66.51	-	-68.39	-
56.0 - 56.5	-	-	-	-	-	-57.30	-55.56	-58.23	-56.99	-67.70	-67.75	-
55.5 - 56.0	-	-	-	-	-	-54.45	-58.82	-59.92	-62.88	-59.72	-61.92	-55.89
55.0 - 55.5	-	-	-	-	-	-54.66	-59.10	-61.83	*	-	-67.42	-
54.5 - 55.0	-	-	-	-66.43	-	-	-	-59.22	-60.15	-	-	-
54.0 - 54.5	*	-68.48	*	*	-69.27	-	-	-	-	-	-	-61.10
53.5 - 54.0	-59.78	-	-	-	-65.09	-	-	-59.19	-58.28	-58.68	-54.72	-56.12
53.0 - 53.5	-	-	-	-	*	-71.49	-69.51	-69.05	-67.99	-71.38	-	-62.09
52.5 - 53.0	-	-	-	-	-	-69.60	-69.62	-	-	-67.89	-66.37	-64.91
52.0 - 52.5	-	-	-	-	-	-	-	-	-	-	-	-

	177-176W	176-175W	175-174W	174-173W	173-172W	172-171W	171-170W	170-169W	169-168W	168-167W	167-166W	166-165W
58.0 - 58.5	-	-	-	-	-	-	-	-	-	-	-	-
57.5 - 58.0	-	-	-	-	-	*	-	-	-	-	-	-
57.0 - 57.5	-	-	-	-	-51.45	*	-	-	-	-	-	-
56.5 - 57.0	-	-	-	-53.43	-59.62	-	-	-	-	-	-	-
56.0 - 56.5	-	-	-	-57.19	-53.19	*	-	-	-	-	-	-
55.5 - 56.0	-58.84	-	-	*	-	-	-51.83	-48.49	-50.52	-	-	-
55.0 - 55.5	-50.84	-	-	-	-	-	-52.61	-54.30	-50.47	-	*	-52.61
54.5 - 55.0	-58.16	-	-	-	-	-	-	-52.54	-	-60.66	-55.02	-57.76
54.0 - 54.5	-60.63	-	-	-	-	-	-	-	-54.50	-50.66	-50.64	-
53.5 - 54.0	-57.70	-57.13	-53.52	-51.67	-53.27	*	-52.87	-48.99	*	-50.39	-	-
53.0 - 53.5	-62.65	*	-	*	*	-58.02	-50.91	-39.78	-	-	-	-
52.5 - 53.0	-	-	-63.97	-56.67	-53.18	-	-	-	-	-	-	-
52.0 - 52.5	-	-	-45.82	-	-	-	-	-	-	-	-	-

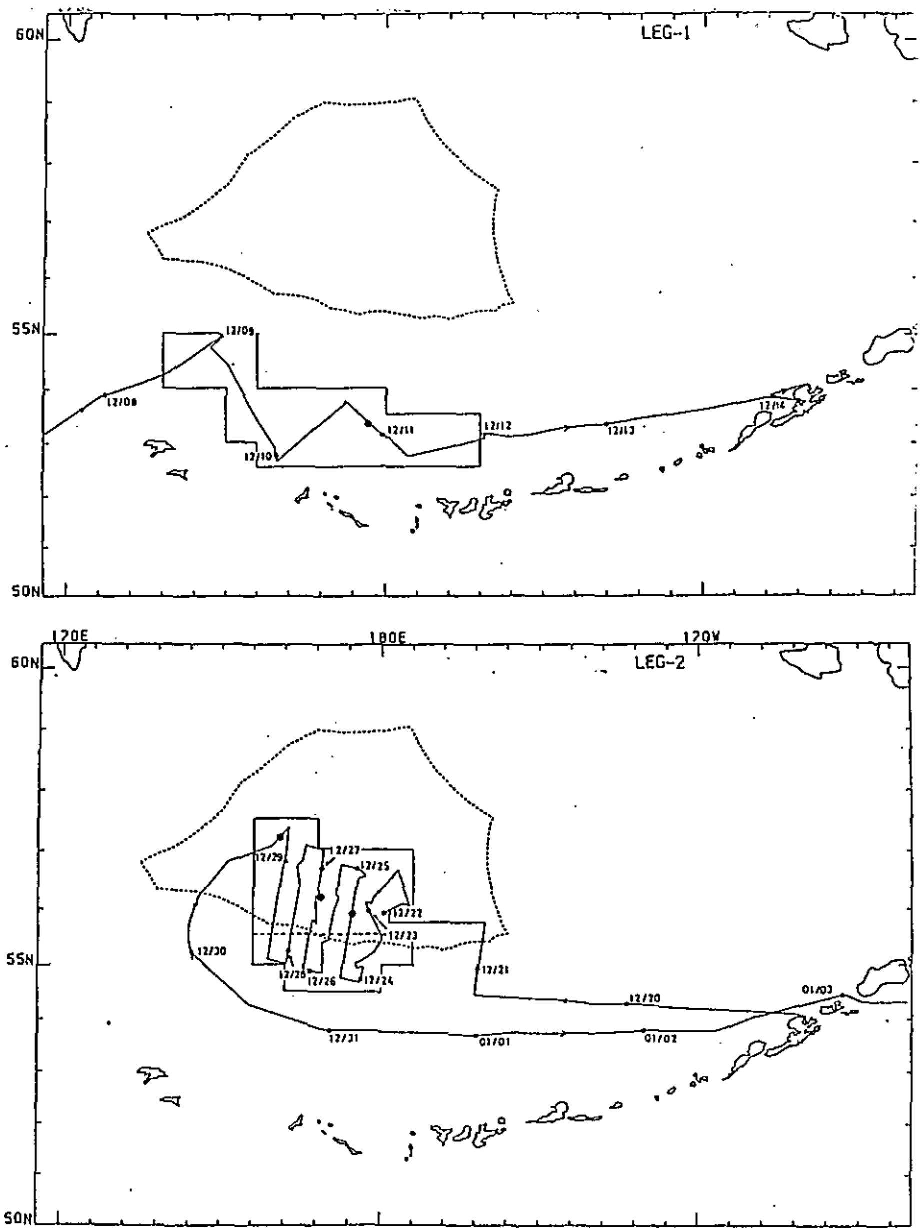


Fig.1 Survey tracks. Bold lines are borders of area for abundance calculations. Open circles are noon positions and black circles TS analysis positions.

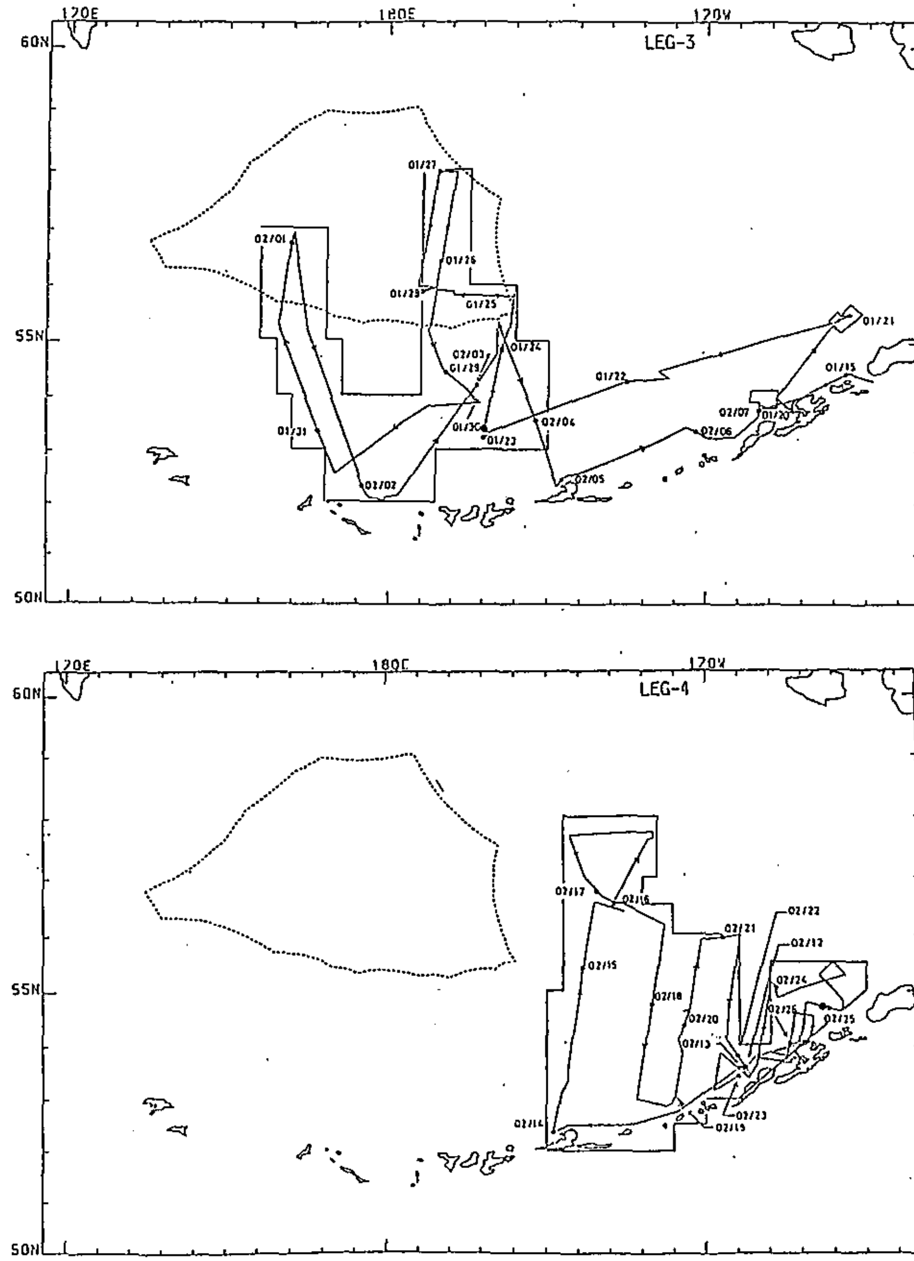
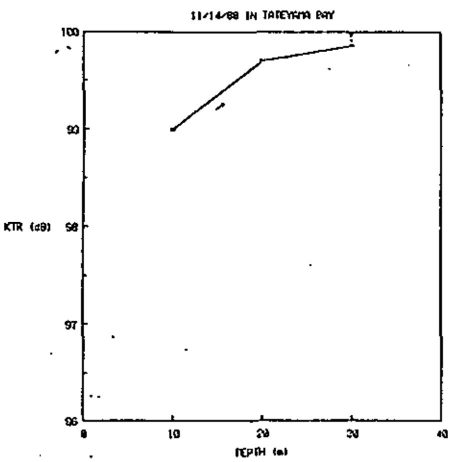
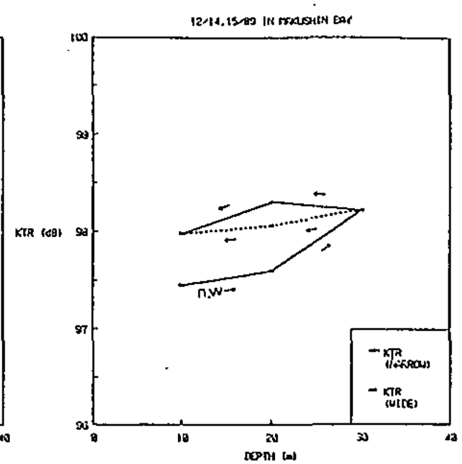


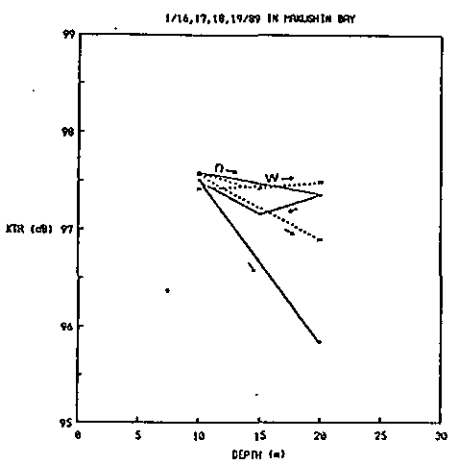
Fig.1 Continued



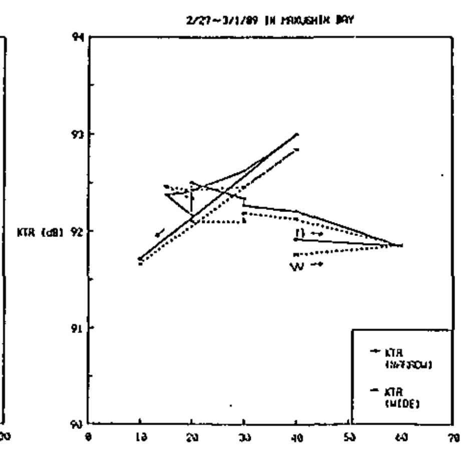
(a) Calibration in pre-survey.



(b) Calibration after the 1st Leg.



(c) Calibration before the 3rd Leg.



(d) Calibration after the 4th Leg.

Fig.2 Depth dependences of the transducer sensitivity. Only (d) is for transducer #2 and others for #1.

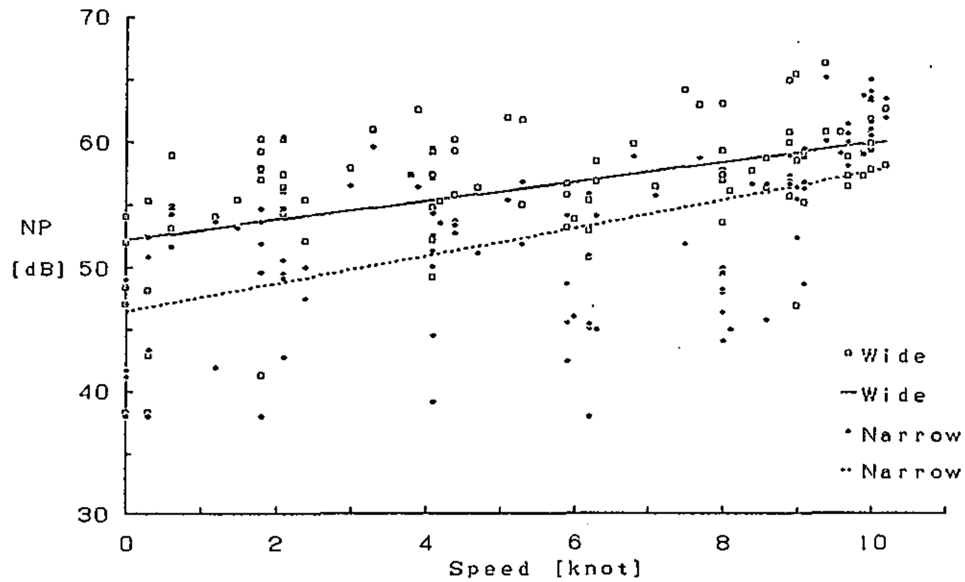


Fig.3 Noise spectrum level (NP) plotted against ship speed.

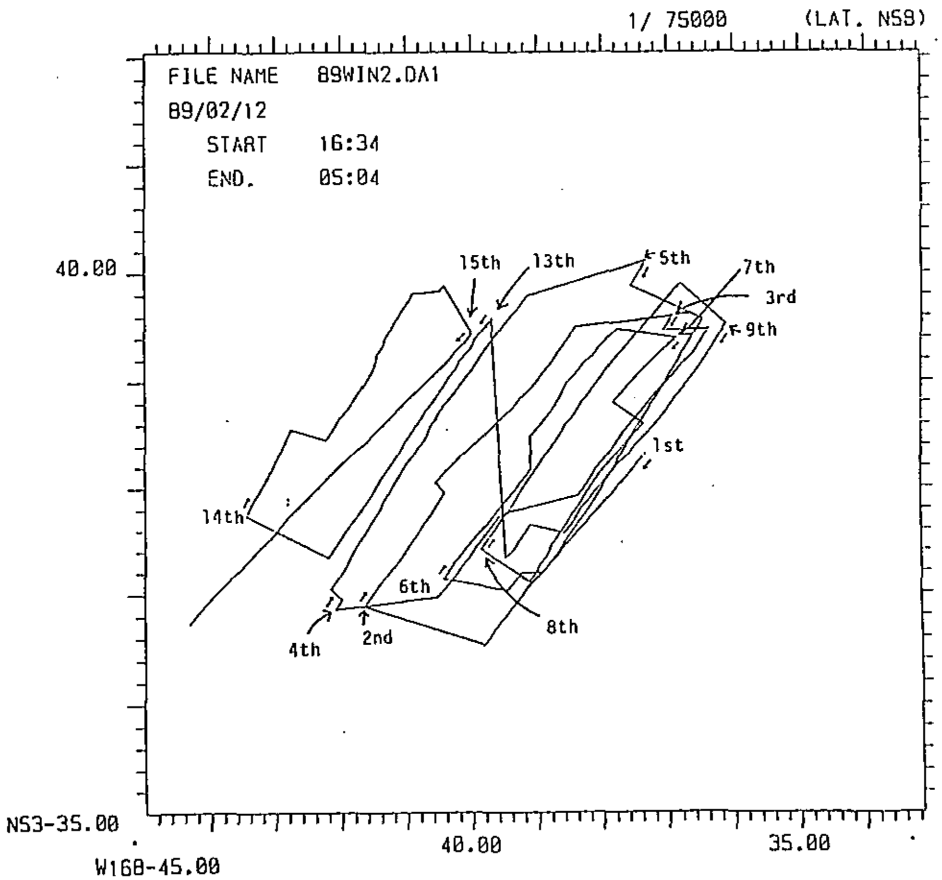


Fig.4 Passes of two vessels in intership calibration.

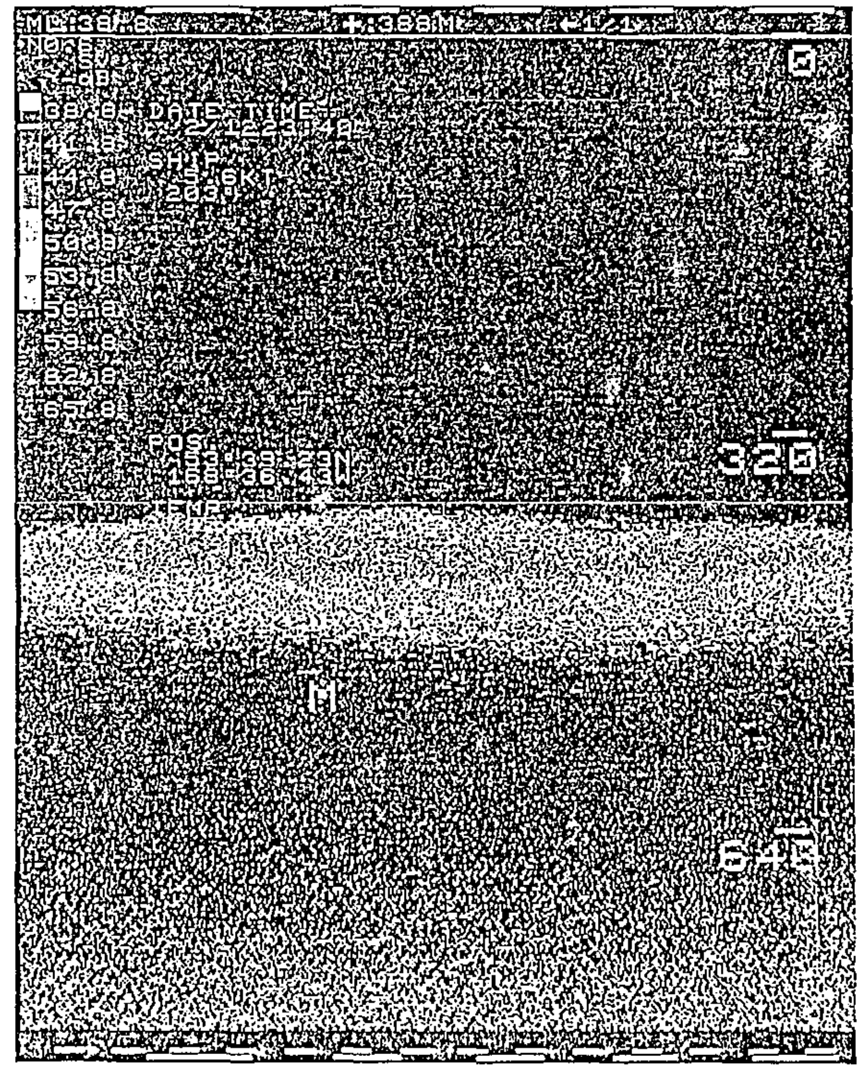


Fig.5 A typical echogram obtained in intership calibration.

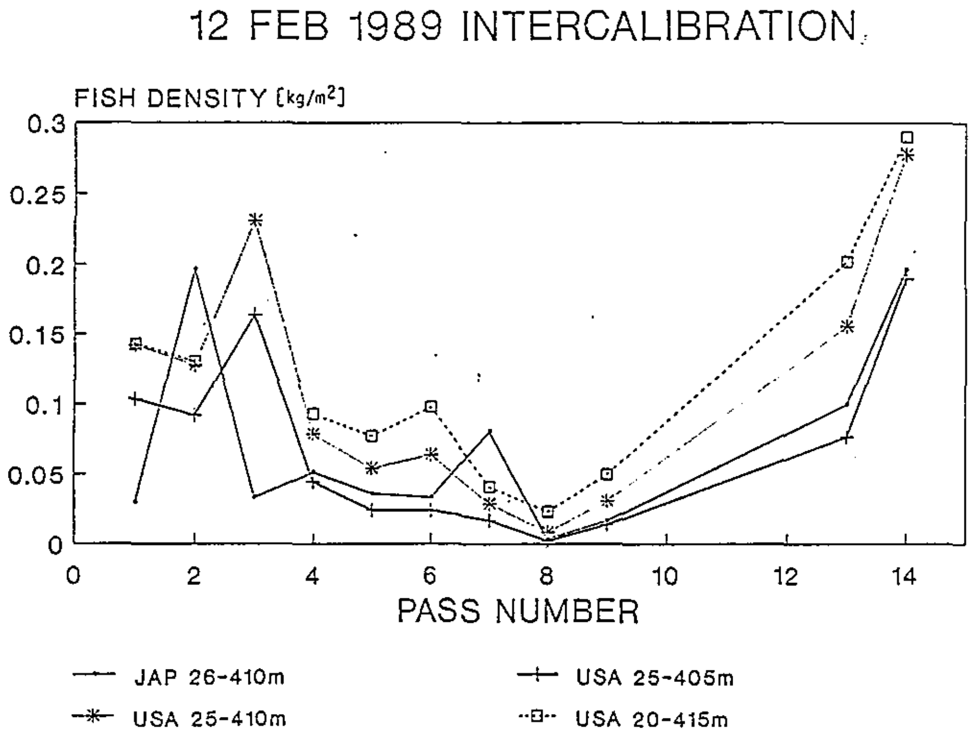


Fig.6 Comparison of US - JAPAN intership calibration results

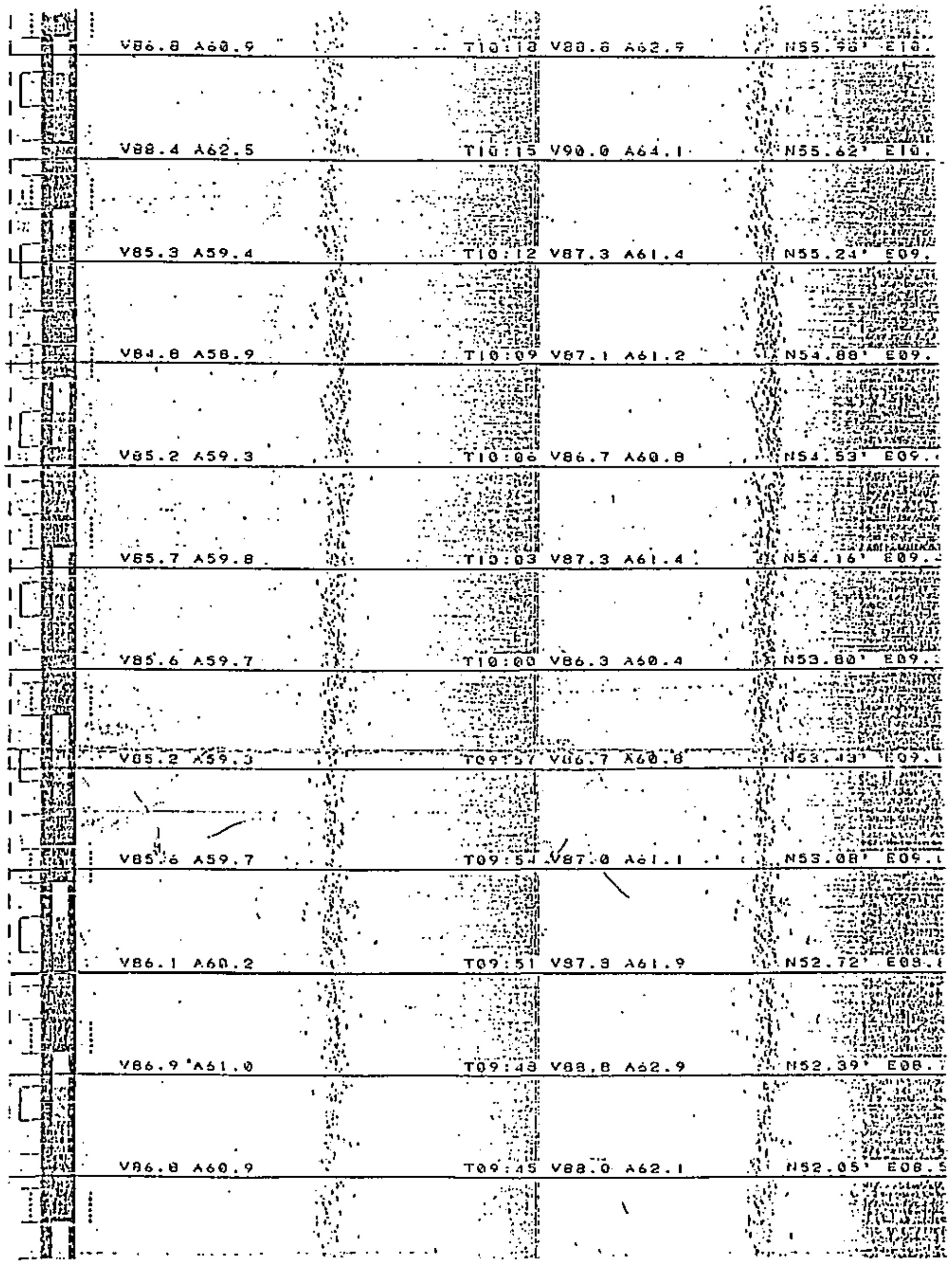


Fig.7 An example of echogram.
Leg 2, No.3, Rnage: 400 m, 40 log r, Left: Narrow, Right: Wide

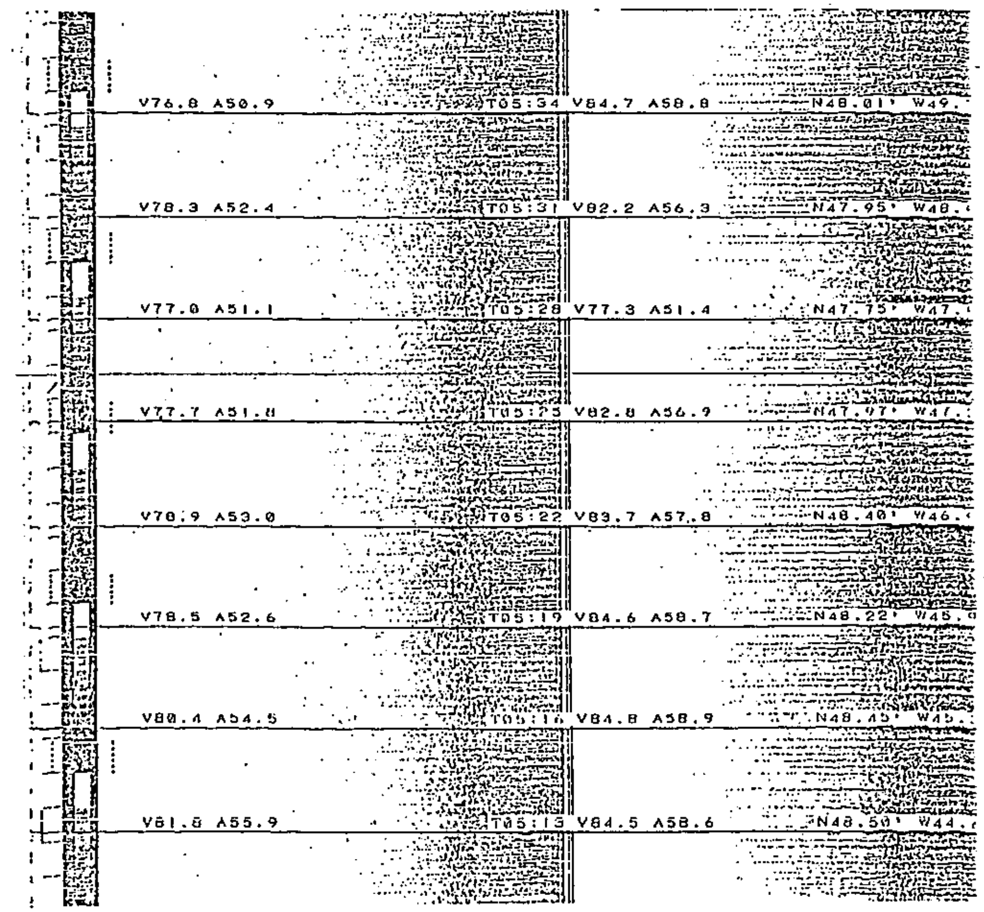


Fig.8 An example of echogram (Leg 3).
Leg 3, No.7, Rnage: 400 m, 40 log r, Left: Narrow, Right: Wide

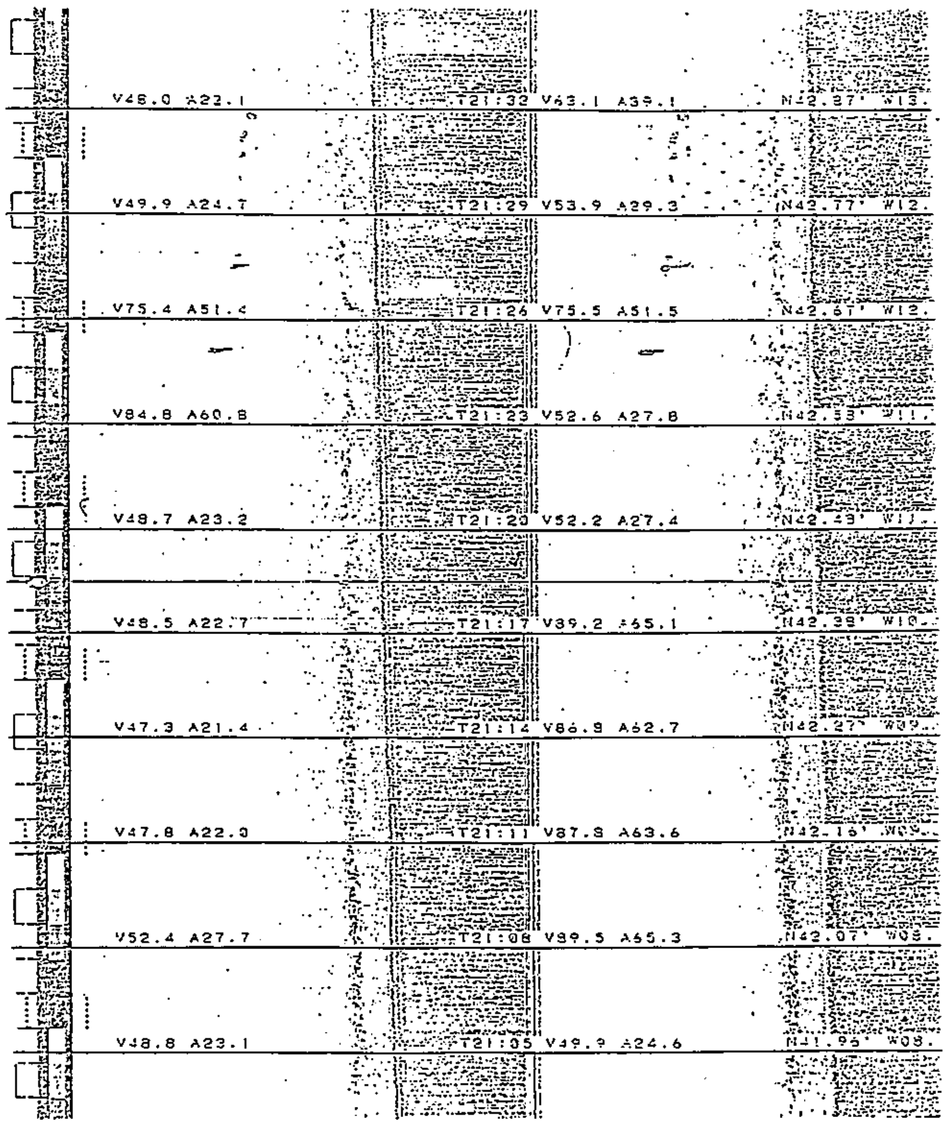


Fig.9 An example of echogram (Leg 4).
Leg 4, No.10, Rnage: 400 m, 40 log r. Left: Narrow, Right: Wide

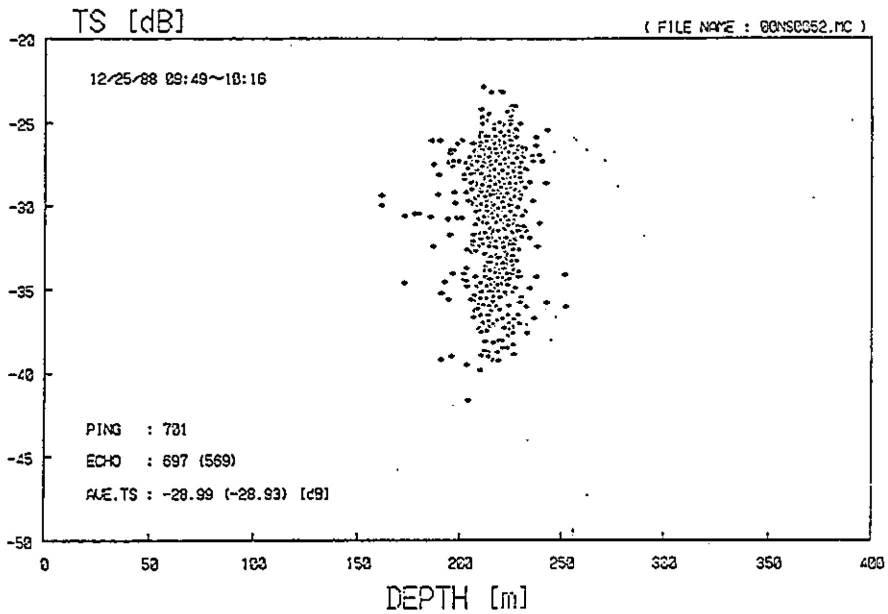


Fig.10 Measured TS values plotted against depths of fish. Data is No.3 of Table 1.

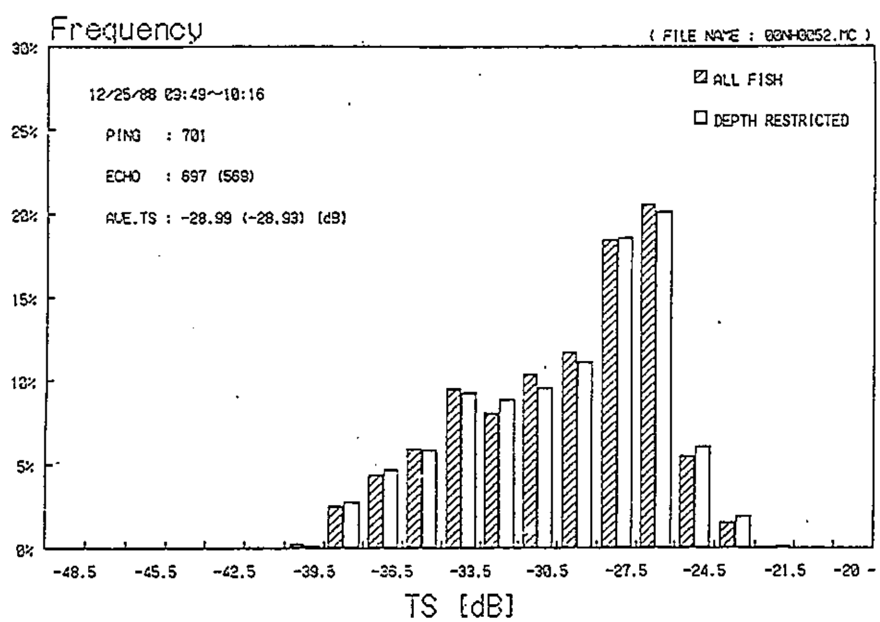


Fig.11 An example of TS histogram. Data are corresponding to Fig.10.

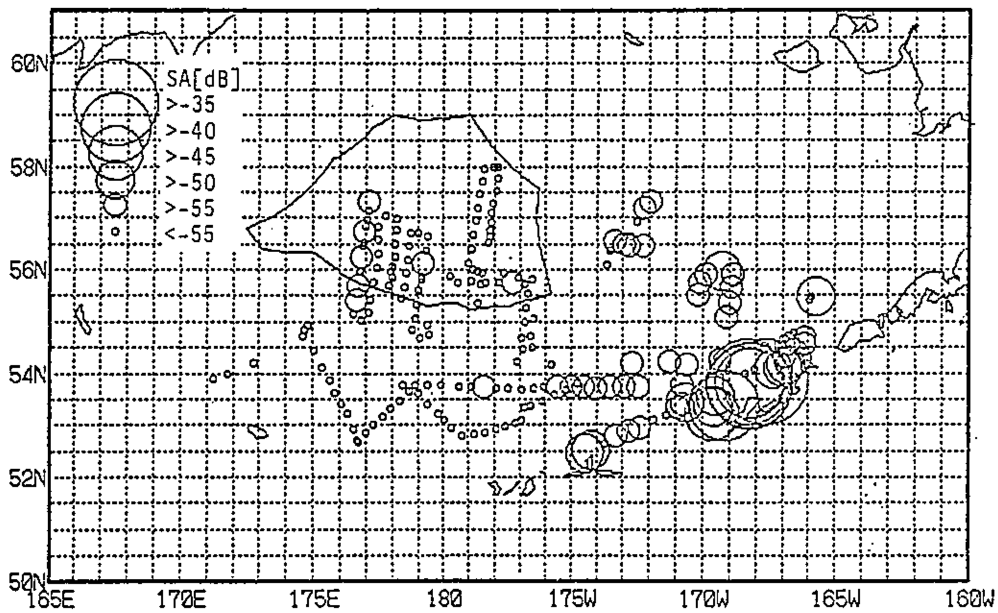


Fig.12 SA distribution along track lines.

Report of Acoustic Survey of Aleutian Pollock Conducted in 1988 Summer

Document for the Working Group on U.S. - Japan Joint Survey of Aleutian Pollock (6 - 11 November 1989, Seattle) (Revised January 1990)

National Research Institute of Fisheries Engineering
Tokyo, Japan

CONTENTS

1. Introduction

A midwater trawl / acoustic survey on walleye pollock (Theragra chalcogramma) in Aleutian area was conducted in 1988 summer as one of the programs of Japan-U.S. cosurveys for the purpose of scientific management of pollock resources in that area. Japanese survey was planed and performed by two institutions of Fisheries Agency of Japan, Far Seas Fisheries Research Laboratory (FSFRL) and National Research Institute of Fisheries Engineering (NRIFE), with cooperation of Northwest and Alaska Fisheries Center (now renamed Alaska Fisheries Science Center (AFSC), NOAA, USA).

In this report we describe mainly on acoustic items of the survey. A more comprehensive report will be published near future.

2. Outline of the Survey

2.1 Survey Items and Methods

The survey items are as follows:

(1) Acoustic system check and calibration for ensuring and maintaining accuracy of the system. (This item includes the operational check of our system, sensitivity calibrations using a standard sphere, noise measurements, and intership calibration with U.S. vessel.)

(2) In situ target strength (TS) measurements by the dual-beam method for obtaining a reliable scale factor for abundance estimation and for examining characteristics of pollock TS.

(3) Measurements of volume backscattering strength (SV) by the echo integration method for knowing abundance distribution of pollock in the survey area and estimating the total biomass.

(4) Midwater trawls for obtaining biological samples.

A fisheries vessel, Seiju-maru #28 (Hokuten trawler, 349tons), was chartered for this survey. Survey operations were divided into for legs, commenced on August 10, and were completed on October 12. The survey tracks in each leg are shown in the maps in Fig.1.

Acoustic system operations were conducted 24 hours a day. Vessel speed was usually eight knots. It was sometimes slowed down to 4 - 7 knots for TS data collection or for decreasing noise. When we observed somewhat dense fish signs, we made mid-water trawl to get biological samples. The average trawling speed was between 3 and 4 knots.

2.2 Cruise Itinerary

After initial tests and calibration of the acoustic system in Mutu Bay of Aomori prefecture, nothern Japan, Seiju-maru #28 departed Hachinohe on July 31, 1988. The vessel's itinerary was as follows:

Pre-Survey

(JAPAN TIME)

July 10 - 13	Acoustic system loaded on F/V Seiju maru #28 in Hachinohe.
July 14	Initial tests of acoustic system.
July 16-17	Standard sphere calibration (#1) in Mutu Bay.
July 18	Mid water trawl and Scanmer initial tests. Noise measurements.
July 21	Standard sphere calibration off Hachinohe.
July 24 ~ 25	Mini-survey for system check off Hachinohe.
July 31	Embark U.S. scientist. Depart Hachinohe.

(US TIME)

August 1 ~ 5	Transit to Aleutian Basin.

Leg 1

August 6	Check of acoustic system.
August 7	Transit to the east of Aleutian Basin.
August 8	Adjustment of towed body.
August 9	Transit to the area of intership calibration.
August 10 ~ 11	Intership calibration with U.S. F/V Pelagos.
August 12	Standard sphere calibration (#2) in Makushin Bay.
August 13	Intership calibration with Pelagos in Makushin Bay.
August 14 ~ 15	Research, transect 1.
August 15 ~ 17	In port, Dutch Harbor; Exchange scientists.

Leg 2

August 18 ~ September 2	Research of the southeast Aleutian Basin. Transect 3 ~ 9.
September 3	Standard sphere calibration (#3) in Makushin Bay.
September 3 ~ 6	Transit to Kodiak.
September 6 ~ 12	In port, Kodiak; Exchange scientists.

Leg 3

September 12 ~ 14	Transit to start of transect 10.
September 14 ~ 26	Research of the central Aleutian Basin. Transect 10 ~ 20.
September 28	Standard sphere calibration (#4) in Makushin Bay.
September 29 ~ October 2	In port, Dutch Harbor; Exchange U.S. scientist.

Leg 4

October 2 ~ 3	Transit to start of transect 20.
October 3 ~ 12	Research of central Aleutian Basin. Transect 20 ~ 24.
October 12	Noise measurements.
October 13 ~ 18	Transit to Hachinohe.

(JAPAN TIME)

October 19	Arrive at Hachinohe.

2.3 Scientific Personnel

Leg 1

Kazuyuki Teshima	Chief scientist, FSFRL
Yoshimi Takao	Fishery engineer, NRIFE
Kikuro Nemoto	Electronics engineer, Kaijo Denki Co, Ltd.
Masahiro Tukuda	Assistant, Sibaura Institute of Technology (SIT)
Jim Traynor	Fishery scientist, NWAFC

Leg 2

Kazuyuki Teshima	Chief scientist, FSFRL
Yoshimi Takao	Fishery engineer, NRIFE
Masahiro Tukuda	Assistant, SIT
John Garrison	Electronics technician, NWAFC

Leg 3

Taku Yoshimura	Chief scientist, FSFRL
Yoshimi Takao	Fishery engineer, NRIFE
Masahiro Tukuda	Assistant, SIT
Douglas Smith	Fishery biologist

Leg 4

Taku Yoshimura	Chief scientist, FSFRL
Yoshimi Takao	Fishery engineer, NRIFE
Masahiro Tukuda	Assistant, SIT
William Karp	Fishery biologist, NWAFC

3. Acoustic System and Calibration

3.1 Acoustic System

For this survey program, NRIFE developed a new versatile echo sounding system, abbreviated VESS. The system is a modified and expanded version of the multipurpose echo sounding system[1] previously developed by NRIFE. Since the outline of VESS was described in the previouse report[2], here we briefly describe the system and necessary information for further explanations.

The echo integration and the dual-beam target strength (TS) measurement are the two important methods applicable by this system. The followings are the prominent features of the system:

(1) The transmitting and receiving system was designed according to the design procedure whose principle is minimum error[3];

(2) Recording and displaying absolute echo levels make easy to understanding and discriminating objective schools;

(3) We introduce an averaging procedure in the dual-beam method to get more accurate TS;

(4) Combining the measured in situ TS data and the distribution densities obtained by the echo counting method, the system can display TS distribution as a matrix form easy to understand;

(5) Two-step and multi-channel echo integration method enables both on-line checking and accurate post-processing of volume backscattering strengths (SV);

(6) By appling dual-beam echo integration method, fish avoidance to surveying vessel and effect of noise can be monitored, and variabilities of SV from smallness of sampling volume and errors by beam motion can be reduced.

Figure 2 shows the system block diagram of VESS and Table 1 lists the specification. In Appendix A1, the basic formulae for processing echoes are decribed with definitions of variables.

The towed body was suspended by a vessel boom through a snatch block with a shock absorber. By this arrangement the body was towed about 7m apart from the vessel side. In most occasions the cable length was driven 15m below the sea surface (when the vessel was stoped) and towed depth was about 10m below the surface at survey speed (about eight knots). Figure 3 is one of the towing chracteristics showing towed depth against the vessel speed.

Figure 4 is an example of paper records. From the markers in the left margine we can read the absolute echo levels and some parameters necessary for quantitative understandings. This example shows "40 log r" TVG output and the range is 400m. Echo integrator outputs are also printed at each integration period.

Figures 5 - 7 show typical color displays. The display mode of Fig.5 is TSS[2] and the decibel values of D^4T_3 (see Eq.A4 in Appenndix 1) can be read for single echoes by comparing their color with the color pattern. Figures 6 and 7 are the displays of SVS mode and directly show SV values if schools are large compared with beam width.

The single echo processor consits of a dual beam processor (DBP), a personal computer (PC, NEC, FC-9801X), and a printer. The DBP performes the extraction of single echoes by pulse width comparing method, measurements of the narrow and wide channel echo levels, directivity compensation, TS calculation, and eho counting under the commands and parameters given by PC. In order to lessen errors by noise inherent to dual-beam system, average echo levels are used, that is, specified number of samples prior to the echo peak are averaged. Since the echo counting is done only for the echoes within a specified cutoff beam angle, there is little bias caused by variability in TS. In Fig.8 an example of parameter settings of the dual-beam processor is shown.

The final results of DBP are transfered to PC and are displayed on CRT and on the printer as shown in Fig.9. Rawer data are memorized in floppy disks for further processing. In Fig.9 the vertical axis shows depth and the horizontal TS values. The numbers in the matrix are the distribution density in the unit specified by "EXP". For example, in the layer of 80-90m and TS range of -53 to -50dB the distribution density of fish is $\dot{9} \times 10^{-6} m^{-3}$. The marginal distribution of TS is shown as average distribution densities in "TOTAL" row and marginal distribution of density in "Na" column. The row of "TSa" is averaged TS by depth. In the column of "MULTI" indices of multiple echoes are shown in percent, and "BOTTOM" column counted number of bottom echoes or maximum range specified by the sounder.

The upper part of Fig.10 is diplay of TSS mode[2] and the lower part is TSD mode which shows true TS processed by the dual-beam processor.

The echo integrator is designed to perform the echo integration in several groups of integration meshes (period x layer width) and in independent two channels simultaneously. This structure enables to apply the two-step echo integration and dual-beam echo integration methods.

Figure 11 is a typical example of echo integrator parameters used in this survey. In the figure, "INT.PERIOD" specifies a basic integration period in time (second) or sailed distance (nautical mile) selected by "INT.MODE." This period is for the "small mesh" integration and the resultant SV are memorized on floppy disks. For the "large mesh" integration multiples for the above basic period are specified in "INT.PERIOD-1" for the built-in printer, "-2" for the paper recorder (Fig.4), and "-3" for the abundance map and the results are printed on the respective devices. Ten layers for large mesh are set by "INT.LAYER." Fifty layers for the small mesh are set automatically and the width is the sounder range divided by 50. The threshold can be set by a SV value at 100m range ("THR.SV") and selecting one of the range functions of ± 10 log r, ± 20 log r, and flat ("THR.MODE").

Figure 12 is examples of the threshold function of + 20 log r and threshold SV of -75 - -95dB.

3.2 Acoustic System Calibration

The standard sphere calibration was conducted once during pre-survey and three times during the survey (see 2.2) with the vessel anchored fore and aft at water depths of 100 ~ 150 m.

We calibrated the transmitting and receiving factor (TR-factor, KT_R) and the equivalent pulse width (τ) by using a copper sphere (ϕ 60.0 [mm], TS=-33.7 [dB]). (The definitions of variables or parameters are shown in A1.) We calibrated TVG coefficients, GT_M and GT_F, at the same time. We computed KT_R by measuring echo voltages at the pre-amplifier output using a digital oscilloscope at the instant when narrow and wide beam levels were equal.

Table 2 is the summary of the calibration results (see also Fig.A1). The results of 1988-1989 winter survey and 1989 summer survey are also included as a reference.

In order to make sure the accuracy of the measured KT_R value and to check the performance of DBP, we measured TS of the sphere by DBP using the calibrated KT_R. Figure 13 shows thus measured TS against elapsed time from the instant of the transducer launching. The results well agreed with the sphere TS.

We made it a rule to adopt new KT_R value obtained in each calibration, because the sea conditions in Makushin Bay were better than that in Mutsu Bay and because the water temperatures were different in each calibration. Although we measured GT_F and GT_M, since there are no large change in the results, we never changed the parameter values. Also, the equivalent pulse width changed little and we used the values measured in the first calibration. (see Fig.A2).

In the followings we describe more details of each calibration, referencing the depth dependence of KT_R shown in Fig.14.

The first calibration was conducted in Mutsu Bay during the pre-survey. We adjusted the sensitivity of narrow and wide beam to be the same value and decided to use it in the 1st Leg.

The second calibration on August 12 was conducted with U.S. chartered vessel, Pelagos, moored together. There were rather large KT_R changes between narrow and wide channels and with depths under 30 m (Fig.14(a)). The difference between channels might be come from the fact that the suspended sphere was not at the center of the beams. The value of KT_R at 10m depth apparently decreased by more than 1 dB compared with the first calibration results (see Table 2). We think this difference was caused by the temperature characteristics of our transducer sensitivities. The water temperature was 15° C in Mutsu Bay and 11° C in Makushin Bay.

The third calibration on September 3 was conducted in good condition. We changed the fin depth such as 10 m, 40 m, 80 m, 40 m, and 10 m (Fig.14(b)). At 80 m the standard sphere was almost near the bottom, and the echo from the sphere might be overlapped with fish echoes. The result at the last 10 m is also unreliable because of fish interference.

The fourth calibration on September 28 was conducted also in good condition. The fin depth was changed in the sequence of 10 m, 30 m, 50 m, 70 m, 50 m, 30 m, and 10 m (Fig.14(c)). At 70 m, because of fish schooling near the sphere, the accuracy of the calibration was lower than the accuracy of the other depths. The tendency was such that the deeper the fin depth, the higher the sensitivity (Fig.14(c)). This was the general tendency as regards to the present transducer (#1). In this time we adopted the first values at 10 m.

3.3 Noise and Threshold

We measured noise level received by our system several time in order to know the characteristics of noise and to specify threshold parameters of the echo integrator.

The measuring method is as follows. We stopped transmitting, received only noise, and integrated noise signal by the ordinary echo integration procedure but with small integration widths. The integrator outputs can be converted to noise spectrum level N_0 [dB re μ Pa/Hz$^{1/2}$] by giving parameters such as the equivalent beam angle.

The engine speed dependence of noise was measured in the pre-survey and the end of Leg 4. Figure 15 shows the noise spectrum level as a function of engine speed. Since the engine speed was usually around 370rpm (8kt), the noise level was rather low as about 40dB.

Since the noise level was low, fish distributions were rather shallow (Figs.4-7), and our two-step echo integration method could select fish echoes aginst noise in post-processing, we used rather low threshold level; The function was "+ 20 log r" or "flat" and the threshold SV was -90 to -99dB (see Figs.11 and 12).

However, during the mid-water trawl, the engine speed was about 500 rpm and the noise level was high (see Fig.15). So that the echo integration data during the trawl had to be abandoned and those were interpolated by the neighbouring data.

3.4 Intership Calibration

The U.S. F/V Pelagos and the Japanese F/V Seiju-maru started intership calibration at 56° 11.4'N and 169° 01'W on August 10 (see Fig.1). The two vessels sailed side by side (about 0.3 nmi apart). We could find fish schools but we had to stop the calibration because of bad sea condition.

We restarted intership calibration at N53° 35' and W167° 21' on August 11, but we could not find fish school.

On August 12, Pelagos and Seiju-maru were at anchor side by side in Makushin Bay for the purpose of the sphere and intership calibrations. We collected echo integration data of walleye pollock distributing below the ships (Fig.10).

The Japanese system operated in 800 m range mode and the transmitting period was about 2.2 sec. By synchronizing the transmitting triggers, U.S. and Japanese systems transmitted pulses alternately. In order to examine interference between two systems and noise conditions of the calibration site, the Japanese system collected the noise integration data while the U.S. system was transmitting. The noise level was very low and almost all the data were -99.9dB which is the under-range indicator of the Japanese echo integrator. This experiment ensured the effectiveness of the alternate transmission and low ambient noise.

We operated each system in the condition as same as possible: Towed body depths were 15 m; The distance between both transducers were about 30m; Pulse width was 0.6ms; The integration period was 1 min; No thresholding was used.

After the Intership calibration, we performed the standard sphere calibration each other. This is our second calibration explained in 3.2. Since the echo integration was done using KT_R value calibrated in Mutu Bay, the Japanese echo integration data were corrected by newly obtained result (+ 1.6 dB).

Figure 16 compars U.S. and Japanese areal backscattering strengths (SA). The echo integration layer was taken as 10 - 95 m from the transducer. The average ratio of U.S. to Japanese is almost 4 (exactly 3.93). In the figure, four times of Japanese data are also drawn as a reference. The trends of SA with time sequence are similar between both data, but Japanese data are more variable.

We compared SA of each 10 m layer (see Fig.A3). The average ratio of U.S. to Japanese is about 1.5 near the bottom (90 - 95m layer), while the ratios of upper eight layers (10-80 m) are larger than 5. There might be a possibility that we measured the same school not active near the bottom and different active schools in midwater.

In order to check other possibilities of inconsistency, we checked our system by using electrically simulated echo signals and by echo integration of sphere echo, but found no problem. In addition, we checked our basic formulae and processing method, but we also did not find problem. Further, the intership calibration in 1988/89 winter survey using the same acoustic systems showed a very good agreement between both systems.

These facts suggest us that there might be differences of observed schools during the intership calibration. It seems that we should check other factors, such as ship lights and engine noise in the case of intership calibration with vessels anchored.

4. Target Strength Measurements

4.1 Method and Results

In order to get a scale factor for echo integration outputs, to elucidate the relationships between TS and body length of fish, and to know the distribution of TS values in the survey area, TS of pollock were measured by the dual-beam processor all through the survey simultaneously with SV measurements.

Since most of fish signs were observed upper 250m layer, the echo sounder range of 400m was usually used. The pulse width was 0.6ms throughout this survey.

The parameter settings of DBP are as follows (see also Fig.8):

Analyzing period: 100 pings (about 6 min)
Cutoff beam angle: 3°
Pulse width range for single echo extraction:
Half echo level: 0.54 - 0.76ms (for 0.6ms PW)
Basis echo level: 0.2 - 0.3 of peak level
< 0.96ms
Threshold level: 100 - 150mV at 10 and 200m
Averaging number: 3

The display of DBP as shown in Fig.9 were used for further analyses.

We refered to trawl samples to obtain the relationship between TS and body length. The trawlings were performed at 37 points, as shown by the dots with station number in Fig.17. Table 3 shows the conditions at the time of trawlings. The vessel speeds were in the range of 3.0 - 5.1kt.

As an example, the TS distribution and body length distribution at Station 04 is shown in Fig.18. The summary results comparing the trawl results and acoustic results at all trawl stations are also shown in Table 3. The trawling depth and depth range of TS measurements were nearly the same. The sampling volumes of trawling were computed roughly by multiplying the net openig area (simply the product of net width and height observed by Scamer net monitoring system), trawling speed, and trawling time.

The average TS is computed from the TS distribution ("TOTAL" of Fig.9) as weighted mean in which the representatives are derived from decibel range of class after Foote and Traynor (Ref.4, Eq.(6)). The estimated body length from TS are obtained by the following relationship:

$$TS = TS_{om} + 20 \log L[cm] \qquad (1)$$

where $TS_{om} = -66.0$dB. This value was derived by Foote and Traynor[4]. Our TS measurements of pollock by controlled method also gave nearly the same

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value[6]. The sampling volume for each ping is computed by

$$V = 2/3\ \pi\ (1-\cos\theta_c)\ (r_2^3-r_1^3) \qquad (2)$$

where r_1 and r_2 are depth range and θ_c is cutoff beam angle. The total sampling volume is the product of this sampling volume and ping numbers in an analyzing period. The echo number is obtained as the product of the total sampling volume and the average density. The normalized TS, TS_{om}, is reduced from Eq.(1) by substituting the average body length obtained by trawl samples.

We see from Table 3 that the average body lengths by trawl samples are concentrated in 47.8 - 50.6cm (σ = 2.0 - 2.8cm). While the estimated body lengths from average TS largely vary as 21.7 - 66.2cm. Therefore, the variavility of TS_{om} is also large and in the range of -73.2 - -63.2dB. However, the mean of TS_{om} for all 37 data is -66.3dB (95% confidence range is -67.2 - -65.5dB) and this very well agrees with the above mentioned general value of -66.0dB.

Figure 17 shows the average length by trawl samples and the estimated length from TS as a distribution map. This map suggests that although the estimated length is variable, there may be a somewhat systematic difference in TS by sea area. That is, we can see large TS in north-west and east parts in the map.

Similar anlyses of TS were performed for other data where trawl data was absent. The results are shown in Fig.19. The radius of the circle is proportional to estimated body length. The data base of this figure is about three times larger than that for Fig.17. From this figure we can see that there are pollock population with smaller TS in the eastern part of the international zone.

4.2 Consideration

As the origin of difference between body lengths obtained by trawl samples and estimated from TS data, we can imagine two reasons: (1) The trawl samples might be biased by vulunerability and mesh size; (2) There might be differences in factors affecting to acoustic scattering property of fish, such as orientation distribution of fish and situation of fish component, especially swimbladder, in each surveyed area.

With respect to the reason (1), we examined the past trawling data and did not find serious selectability by net (Sasaki and Yoshimura, personal communication). Therefore, the above reason of (2) will be more plausable. This suggests that we must more deeply examine morphological and behavioural properties of fish. Conversely, there may be a possibility to guess generic difference by acoutic means.

As mentioned above, although the variability of TS_{om} in each area was rather high, the total average of TS_{om} is very close to the generally accepted value. This shows the correctness of our measuring system and the previous TS data obtained by several different methods.[4]

Therefore, as the scale factor for conversion of echo integrated data to distribution density, we can use the TS value computed by Eq.(1) inserting TS_{om} = -66.0dB and total average body length by trawl samples (49.0cm). (This conclusion was agreed in the previous working group of Japan-U.S. cosurvey.) Thus, we get the fianl TS value as the scale factor for conversion of SV to distribution density by

$$TS = -66.0 + 20\log 49.0 = -32.2\ \text{dB}$$

Since the body length distribution by the trawl sample was uni-modal and the variance was very small (see Table 3 and Fig.18), we used the above value throughout for abundance estimation.

5. Fish Disribution and Abundance Estimation

5.1 Method

Relative and/or absolute distribution of pollock was observed by quantitative displays of the sounder and echo integrator outputs.

Typical echo integrator parameters are shown in Fig.11. In the body of the survey the echo integration period was set in "TIME" of "0240"sec and SV data were obtained at four minutes interval which was about 0.5nm at normal survey speed. (A period of 1 minute was used in the noise integration and in the intership calibration.) Since we usually used 400m range, the integration layer widths of 25 - 100m were selected to cover the whole echo sounder range. We sometimes drew on-line abundance maps on CRT or plotter. These results were used for the rough observation of abundance distribution.

Since we collected many output data files in this survey, we made a simple data base for management of the data files. It includes file name, start and end times, location, day or night, fish existent depth, depth range for the areal backscattering strength (SA), noise, and comment.

Comparing echograms with the small mesh SV data in each data file, we selected the meshes which contain fish echoes to compute SA (two-step echo integration). Since there were almost no contamination by other fish than pollock and by noise, the selection procedure was rather simple and directed to exclude the meshes where no fish was observed. But when trawlings were operated, the noise contribution became large and we had to omit the data. We examined the effect of excluding the data obtained when the trawling was operated and found little errors. Thus obtained SA values were averaged in each 0.5° latitude by 1° longitude mesh (Fig.20, Fig.A4), because most transect lines were designed to cut diagonally the above geographycal meshes.

Since both narrow and wide (strictly composite) beam echoes are independently integrated (dual-beam echo integration) in our echo integrator, we can compute the difference between narrow beam SA and composite beam SA to examine the avoidance effect and noise effect (Fig 21).

5.2 Distribution of Pollock

In the first place, we qualitatively see pollock distributions by legs (Fig.1) through the paper records and color displays.

Leg 2: Survey work began at 55° N, 168° W, we observed many fish signs between August 18 and 22. We saw comparatively high density distributions near Aleutian Islands. Pollock concentrated between 150 and 200m in daytime (Fig.5), while they rapidly dispersed in 100 to 200m layers at night. We could not see good fish signs on transects #7 and 9 after August 22. After we surveyed on transects #8 and #6, we surveyed again the area where we observed good fish signs in the first half of Leg 2.

Leg 3: Survey began at transect #10 on September 15. In the afternoon of the day we observed good fish signs continuously between 200 and 260m. After sunset, the fish distribution was dispersed between 150 and 250 m and the numbers of fish signs decreased. On September 17, we observed many single fish signs between 100 and 200 m at the eastern part of the International Zone (IZ), 55° 30'N, 176° W. Fish number increased after the sunrise and fish concentrated between 150 and 200 m. On September 18, fish signs started to increase at 56° 12'N, 176° 30'W in daytime. These signs distributed between 160 and 190m. They spread 130 - 230m in the evening (see Fig.22) and dispersed at 55° 30'N, 178° W. After this time, we did not observe dense fish schools in the middle of IZ. 298

Leg 4: We started our survey from transect #20 on October 4. In the middle of IZ, we observed pollock layers between 180 and 200m. But their densities were comparatively low and they spread in 100 - 200m depth at night. We could see more fish signs when sailing in the western part of IZ. We observed a dense pollock school at 170 - 200m depth at from 56° 10'N, 174° E to 56° 40'N, 174° 20'E.

We finished the survey on the designed transect lines on October 10. Then we started a exploratory survey at the end of Leg 4 (see Figs.1 and 4). Seiju-maru went to the western edge of IZ, because many commercial fishing vessels were fishing there and getting good catch at that time. On October 10 19:30 (early morning) at 56° 53'N and 174° W, we met a dense and continuous fish layer at 170 - 200 m depth (see Fig.6). Its thickness was about 15m. Fifteen fishing vessels were fishing near Seiju-maru. The number of schools decreased on October 11 at 4:30 (evening). We again observed dense fish layer between 180 and 200 m on October 12 at 1:06 (see Fig.7). The fish kept dense layer till 13:30 (night) at 56° 50'N, 173° 08'W. Its thickness was about 20 m, and its maximum SV was - 28.1dB and mean SV about - 35 dB. We stopped the research on October12 14:01.

Looking over all legs, pollock mostly distributed around 200m depth, but they occasionally distributed as deep as 400m depth.

Next, we inspect pollock distribution quantitatively, referencing to the echo integration results.

Figure 20 shows the distribution of the average SA values in geographical meshes of 30' latitude by 1° londitude and the results are divided into 3dB-step classes from -66dB to -54dB (see also Fig.A4). In the figure blank meshes means no data. The largest SA (-57 < SA < -54dB) are seen at near the Aleutian Islands (August data) and at the west end of the IZ (October data). The next class (-60 < SA < -57dB) distributes also along the Islands (August data) and at the western part of IZ (October data), and further at the east end of IZ (September data). At from the center of IZ to the southern part of the south of IZ where the survey was conducted from September to October, there were few distributions.

5.3 Population Size Estimation

Although there remains the problem of disagreement in the intership calibration results as shown in 3.4 and our survey took as long term as three months in which pollock might moved extensively and the distribution might changed, we try to estimate pollock population size by the present acoustic results.

In the first place, we calculate population from SA values obtained only on the parallel transects in IZ; Several exploratory transects data at the end of Leg 4 were excluded.

The total average of SA in IZ was calculated from SA of each geographycal mesh which was weighted by its area as follows:

$$SA = 10 \times \log \frac{\Sigma (A_i \times S_{ai})}{\Sigma A_i} = -60.8 \text{ dB}$$

where S_{ai} is arithmetic value of average SA for each mesh, A_i is area of each mesh in IZ, and ΣA_i is area of IZ (205,311 km^2). Using thus obtained average SA and TS value of -32.2dB (see 4.2), we get the average areal density of pollock, n[m^{-2}], and the population of pollock in IZ, N, as following:

$$n = 10 \hat{} [(SA-TS) / 10] = 0.0014 \text{ m}^{-2} ,$$

$$N = n \times \Sigma A_i = 2.84 \times 10^8 .$$

Using the regression curve between the fork length (L) and body weight (W) obtained by trawl samples in this survey, the average body weight is

$$W = 6.9 \times 10^{-3} L^3 = 6.9 \times 10^{-3} \times 49.0^3 = 811.8 \text{ g} .$$

From the above, biomass in IZ is estimated as

$$W \times N = 811.8 \times 2.84 \times 10^8 = 2.3 \times 10^5 \text{ ton} .$$

In Table 4 the results of abundance estimates are summarized.

In order to assure the order of the above acoustic estimate, we tried to estimate roughly the population size of pollock in IZ by using the mid-water trawl data. The following formula was used to get areal density:

(areal density) = (number of fish caught by trawl)

/ [(width of net mouth) x (trawled distance)]

The fish densities were calculated for each trawl. They were averaged and multiplied by area of IZ. Estimated biomass was 3.1×10^5 tons. This value is slightly (8×10^4 tons) larger than the acoustic estimate, but the order is the same.

In the western edge of IZ, we surveyed on the exploratory transects. In the above estimation these data were not included and only the data obtained on the regular transects were used. Since most of the pollock fisheries aim at winter schools one of which we happened to met on the exploratory transects, we try to estimate the abundance in these five meshes surveyed exploratory. This results 6.1×10^4 tons. And if we exchange the abundance in these five meshes with those obtained by the regular transects, the estimated biomass in the IZ becomes 2.5×10^5 tons.

In the same manner we estimated the biomass of the surveyed area except IZ and the result was 3.7×10^5 tons. Thus we get the biomass estimate of the whole surveyed area of 6.2×10^5 tons.

5.4 Consideration

Since the present survey was carried out through three months (from August to October), we must take the seasonal movement of pollock population with season into account in order to reasonably evaluate the distribution. Sasaki[6] reported that a large pollock stock are used to appear in the western end of IZ in October and move eastward by month and the above distribution can be thought to roughly fit to this tendency.

The estimated value from trawl data should be larger than acoustic value because we trawled at where fish sign appeared. Inversely, the trawl result may be under-estimate, because only the layer of net height were swept. Anyhow, the order of the abundance estimate by trawl data agreed with that by acoustic data.

Since our echo integrator can integrate both narrow and composite beam echoes independently, we can extract several information by comparing narrow and composite beam outputs: The composite beam has a wider directivity than narrow beam (see Table 1), so that it is affected more by noise than the narrow beam; If there is an avoidance of fish to a surveying vessel, the composite beam gives larger values because of larger obsrvation volume. The differences between narrow and composite beam SA are shown in Fig.21. The composite beam SA are slightly larger than narrow beam SA at many geographycal meshes. This fact demonstrates that there might be slight contribution of noise or avoidance effect, but the general smallness of the difference assures that our system operated properly and noise and avoidance effects were not serious.

6. Conclusion

Japan / U.S. cooperative hydoroacoustic / midwater trawl survey of Aleutian pollock was carried out successfully from July to October in 1988.

The results of the Japanese acoustic survey are as follows:

(1) Newly developed echo sounder system fulfilled its function. We could collect the echo integration data to estimate the distribution and biomass of the Aleutian pollock. We could also collect the target strength data as the scaling factor to estimate biomass.

(2) The calibrations of the system showed little changes in critical parameters such as the transmitting and receiving factor. The received noise in the survey cruise was low.

(3) The intership calibration between U.S. and Japanese acoustic systems conducted in Makushin Bay showed a large difference between two systems, and the average ratio of U.S. / Japanese SA is about four. We have checked our system hardwares, processing methods, and theories each other, but we have not found any problems. There might be a possibility that the objective fish of the two systems were different.

(4) As the results of the target strength measurements, we got the body length - normalized TS, TS_{om} = - 66.3 dB. This value agreed well with the result of the study by Foote and Traynor[4] and ours[5].

(5) The vertical distribution of pollock were seen to be from 150m to 250m depth. Dense schools were distributed along the Aletian Islands in August and at the western most part of IZ in October.

(6) A tentative estimate of the pollock biomass in IZ is 2.5 x 10^5 tons. It is estimated as 6.2 x 10^5 tons for the all surveyed area.

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Appendix

A1. Basic Formulae for Echo Processing

In this appendix, we show the basic formulae which we use in our system.

The echo pressure P_F of single fish is shown by

$$P_F^2 = P_0^2 D^4 r^{-4} \exp(-4 \alpha r) T_s , \qquad (A1)$$

where P_0 is source pressure level, (r, θ, ϕ) are spherical coordinates of fish position, D is pressure directivity function, α [Neper/m] is absorption attenuation coefficient, T_s is arithmetic value of TS. This signal is amplified by the pre-amplifier to give

$$E_R = P_F M G_R , \qquad (A2)$$

where M is the receiving sensitivity and G_R is the pre-amplifier gain. In order to compensate for range, we use a "40 log r" time-varied-gain (TVG) amplifier whose gain is

$$G_F(r) = G_{TF} r^2 \exp(2 \alpha r) , \qquad (A3)$$

where G_{TF} is TVG coefficient. The TVG output E_{TF} is then

$$E_{TF}^2 = K_F^2 D^4 T_s , \qquad (A4)$$

$$K_F = K_{TR} G_{TF} , \qquad (A5)$$

$$K_{TR} = P_0 M G_R . \qquad (A6)$$

We call K_{TR} "transmitting and receiving factor" or "TR-factor", and this factor is totally calibrated by a standard sphere. In the individual fish estimation procedures, we deal with this signal.

The echo pressure returned from a layer or large school of fish, P_M, is shown by

$$P_M^2 = P_0^2 c \tau /2 \ \Psi \ r^{-2} \exp(-4 \alpha r) n_M \langle T_s \rangle , \qquad (A7)$$

where c is the sound speed, τ is equivalent pulse width, Ψ is the equivalent beam angle, n_M is the average distribution density, and $\langle T_s \rangle$ is average TS. We can compute τ from the observed wave form w(t) obtained in the process of sphere calibration by

$$\tau = \int_0^{\tau_m} w^2(t)\, dt , \qquad (A8)$$

where w(t) has values at $t = 0 - \tau_m$ and is unity at the point where K_{TR} is observed. Ψ is computed from the observed directivity pattern by

$$\Psi = \int_\Omega D^4 \, d\Omega , \qquad (A9)$$

$$= \int_0^{2\pi} \int_0^{\pi/2} D^4(\theta, \phi) \sin\theta \, d\theta \, d\phi \qquad (A10)$$

where Ω is solid angle. This multiple echo is pre-amplified and compensated for range by "20 log r" TVG, whose gain is

$$G_M(r) = G_{TM} r \exp(2 \alpha r) , \qquad (A11)$$

where G_{TM} is TVG coefficient. The TVG output is

$$E_{TM}^2 = K_M^2 S_V , \qquad (A12)$$

$$K_M^2 = (K_{TR} G_{TM})^2 \ \Psi \ c \tau /2 , \qquad (A13)$$

$$S_V = n_M \langle T_s \rangle , \qquad (A14)$$

where S_V is the volume backscattering strength (SV) in layer or school.

In the echo integration method, we average all the echoes, single or multiple echoes, in the predefined layer ($r \sim r+r_w$) and ping sequence (m), and obtain the following average SV:

$$\langle S_V \rangle = \frac{1}{K_M^2} \frac{1}{r_w} \int_r^{r+r_w} \left(\frac{1}{m} \sum_{i=1}^{m} E_T^2 \right) dr = \langle n \rangle \langle T_s \rangle , \qquad (A15)$$

where $\langle n \rangle$ is average distribution density. E_T can be multiple echo (Eq.A12) or single echo through "20 log r" TVG:

$$E_{TMF}^2 = (K_{TR} G_{TM})^2 D^4 T_s / r^2 , \qquad (A16)$$

In this paper the decibel value of any arithmetic value is shown by making the first two letters of the arithmetic variable capital, for example,

$$KT_R = 20 \log K_{TR} , \qquad (A17)$$

$$TS = 10 \log T_s .$$

Table 1 Specifications of VESS.

Transducer (BioSonics)
- Frequency: 38kHz
- Element: PZT, 79 elements
- Size: 450mmϕ
- Beam width: Narrow 6.4° , Wide 15.6°
- Equivalent beam angle: Narrow 0.0072sr, Composite 0.012sr
- Transmitting sensitivity: 175.3dB re μPa/V at 1m
- Receiving sensitivity: -159.7dB re V/μPa

Towing system (Endeco/BioSonics)
- Towed body: V-fin, 1.3m
- Towing cable: 26.7mmϕ, 200m, Haired fairing (30m)
- Winch: 1500kg max, 10m/min

Transmitter
- Power: 2.8kW
- Source level: 228.3dB re μPa at 1m
- Nominal pulse width: 0.6, 1.2, 2.4ms
- Equivalent pulse width: see Fig.A2
- Range: 50, 100, 200, 400, 800m
- Pulse repetition period: 213.3, 346.6, 613.3, 1146.6, 2213.3ms for above range

Receiver
- Channels: Narrow, Wide (Composite)
- Sensitivity: 0, 10, 20, 30, 40dB (relative)
- Band width: 3kHz
- TVG: 20 log r + 2αr, 40 log r + 2αr, independent
  α = 10.0 dB/km (ROM)

Analogue data recorder
- Conponent: PCM data recorder (NF Elec.Instr. RP-880)
- Video deck (Sony SL-HF500)
- Signals: 4 TVG outputs, Sounder parameters, Navigation data

Paper recorder
- Paper: Dry, 300mm wide
- Record absolute echo levels by stepwise darkness and markers

Color display
- Display modes[2]: TSS, TSR, TSD, TSB, SVS, SVR, SVB
- Colors: 12 selectable from 4024 colors
- Continuous color hard copy (Mitsubishi G500A-10)

Single echo processor
- Component: Dual-beam processor (DBP),
  Personal computor (NEC FC-9801X)
  64 Mbytes floppy drive (Tokin Co. MDP-6400)
  Color printer (NEC NM-9700)
- Single echo extraction: Pulse width comparizon
- See text for more details

Echo integrator
- Component: Echo integrator (JRC NJZ-544)
  Personal computer (NEC FC-9801X)
  Plotter (EPSON HI-80)
- Channels: Narrow and wide (composite)
- Outputs: built-in printer, paper recorder,
  abundance map (CRT, plotter)
  floppy disk (1 Mbytes)
- See text for more details

Calibrator
- Sphere: Copper 60.0mmϕ, TS = - 33.7dB
  Tungsten carbide, 38.1mmϕ, TS= -42.3dB
- Oscilloscope: Digital (NATIONAL VP5720A)

Miscellaneous
- Interface between navigation aids and VESS (JRC)
- Power supply
- Container (Tokai Fruehauf): 2.8m x 2.3m x 2.4m
  4 racks, tables etc.

(Kaijyo Denki Co. arranged the total system and manufactured all the components except those with which maker's name are listed.)

Table 2 Summary results of standard sphere calibration. 1988-89 winter and 1989 summer results are also listed as reference.

START DATE	END DATE	POSITION	TR #	TR FACTOR (dB) KTRN	KTRW	TVG COEF. (20LOG) GTMN	GTMW	TVG COEF. (40LOG) GTFN	GTFW	EQUIVALENT PULSE WIDTH (msec) τs (N0.6)	τs (N1.2)	τs (N2.4)	τs (W0.6)	τs (W1.2)	τs (W2.4)
7/21/88	7/21/88	MUTSU	TR #1	99.90	100.20	5.70	3.69	-19.40	-19.40	0.57	1.17	2.38	0.55	1.11	2.40
8/12/88	8/12/88	MAKUSHIN	TR #1	98.10	98.30	*	*	-19.08	-19.49	*	*	*	*	*	*
9/3/88	9/3/88	MAKUSHIN	TR #1	98.90	99.10	5.74	3.58	-19.48	-19.43	*	*	*	*	*	*
9/28/88	9/28/88	MAKUSHIN	TR #1	98.50	98.50	5.79	3.77	-19.81	-19.73	0.55	*	*	0.55	*	*
11/14/88	11/14/88	TATEYAMA	TR #1	98.50	98.50	5.64	3.43	-19.32	-19.70	0.54	1.12	2.27	0.58	1.13	2.28
12/14/88	12/15/88	MAKUSHIN	TR #1	98.00	98.00	5.83	3.53	-19.37	-19.55	0.59	*	*	0.58	*	*
1/16/89	1/19/89	MAKUSHIN	TR #1	97.40	97.40	5.42	3.62	-19.23	-19.41	0.55	*	*	0.57	*	*
2/27/89	3/1/89	MAKUSHIN	TR #2	91.70	91.70	5.59	3.62	-19.65	-19.57	0.55	*	*	0.57	*	*
7/14/89	7/14/89	MUTSU	TR #2	92.00	92.00	5.81	3.61	-19.77	-20.30	0.55	1.18	2.42	0.57	1.19	2.33
7/29/89	7/31/89	MAKUSHIN	TR #2	92.60	92.00	5.10	3.30	-19.92	-19.52	0.53	*	*	0.55	*	*
8/11/89	8/12/89	MAKUSHIN	TR #2	99.70	99.00	5.37	3.34	-19.80	-19.45	0.55	*	*	0.55	*	*
8/25/89	8/26/89	MAKUSHIN	TR #2	99.50	98.90	*	*	-19.57	-19.53	0.57	1.16	2.29	0.58	*	2.32
9/9/09	9/10/89	MAKUSHIN	TR #2	99.30	98.90	5.50	3.39	-19.92	-19.37	0.58	1.16	2.42	0.57	1.15	2.44
9/27/59	9/29/89	MAKUSHIN	TR #2	99.40	99.00	5.34	3.62	-19.72	-19.66	0.57	1.11	2.32	0.54	1.16	2.40

Table 3 Comparison of trawl sampling data and *in situ* TS data.

ST	Time Japan	Alaska	GMT	N/D	Condition Speed	WT.	S. State
1	08/20 04:53	08/19 11:53	08/19 19:53	D	3.6	C	3
2	08/21 03:12	08/20 10:12	08/20 18:12	D	5.1	F	4
3	08/21 16:29	08/20 23:29	08/21 07:29	N	4.1	C	3
4	08/22 04:31	08/21 11:31	08/21 19:31	D	3.8	C	3
5	08/22 08:39	08/21 15:39	08/21 23:39	D	4.0	C	3
6	08/24 09:02	08/23 16:02	08/24 00:02	D	4.8	C	4
7	08/25 08:40	08/24 15:40	08/24 23:40	D	3.6	R	4
8	08/25 17:15	08/25 00:15	08/25 08:15	N	3.0	R	6
9	08/26 08:08	08/25 15:08	08/25 23:08	D	3.5	C	6
10	08/26 23:55	08/25 06:55	08/26 14:55	D	4.3	C	2
11	08/27 09:07	08/26 16:07	08/27 00:07	D	3.6	C	2
12	08/28 00:44	08/27 07:44	08/27 15:44	D	3.7	C	4
13	08/29 09:16	08/28 16:16	08/29 00:16	D	3.8	C	2
14	08/29 19:34	08/29 02:34	08/29 10:34	N	4.1	R	2
15	08/30 08:43	08/29 15:43	08/29 23:43	D	3.7	BC	3
16	09/01 14:54	08/31 21:54	09/01 05:54	N	4.8	BC	4
17	09/02 07:12	09/01 14:12	09/01 22:12	D	4.4	F	4
18	09/03 00:05	09/02 07:05	09/02 15:05	D	4.2	C	2
19	09/16 07:13	09/15 14:13	09/15 22:13	D	3.7	F	5
20	09/17 13:10	09/16 20:10	09/17 04:10	N	4.7	F	5
21	09/18 07:15	09/17 14:15	09/17 22:15	D	3.9	d	3
22	09/19 06:27	09/18 13:27	09/18 21:27	D	4.0	C	3
23	09/21 06:20	09/20 13:20	09/20 21:20	D	3.6	C	3
24	09/21 16:12	09/20 23:12	09/21 07:12	N	3.9	C	2
25	09/22 05:24	09/21 12:24	09/21 20:24	D	3.9	BC	3
26	09/23 09:01	09/22 16:01	09/23 00:01	D	3.9	F	3
27	09/24 05:24	09/23 12:24	09/23 20:24	D	3.9	d	6
28	09/25 07:01	09/24 14:01	09/24 22:01	D	3.9	BC	2
29	09/26 03:04	09/25 10:04	09/25 18:04	D	3.9	d	3
30	10/04 11:08	10/03 18:08	10/04 02:08	D	3.8	d	3
31	10/05 08:39	10/04 15:39	10/04 23:39	D	4.2	BC	2
32	10/06 08:57	10/05 15:57	10/05 23:57	D	3.8	BC	2
33	10/07 05:52	10/06 12:52	10/06 20:52	D	3.4	BC	1
34	10/07 11:38	10/06 18:38	10/07 02:38	D	3.6	BC	2
35	10/08 07:24	10/07 14:24	10/07 22:24	D	3.8	BC	4
36	10/09 07:09	10/08 14:09	10/08 22:09	D	3.6	O	1
37	10/12 11:07	10/11 18:07	10/12 02:07	D	3.6	C	6

ST:Station number. N/D:Night/Day. Speed:Ship speed in knots.
WT.:Weather(C:Cloudy. F:Fog. R:Rain. BC:Blue sky & Cloudy .
D:Dense fog. O:Overcast). S.State:Sea State

Table 3 Comparison of trawl sampling data and *in situ* TS data (continued).

ST	Trawling					Target strength						TScm
	Dep. [m]	Vol. [m³]	Num.	Ave. FL [cm]	σ [cm]	Dep. [m]	Ave. TS [dB]	σ [dB]	Est. FL [cm]	Vol. [m³]	Echo #	[dB]
1	170 ~ 200	10837904	142	48.8	2.0	-	-	-	-	-	-	-
2	120 ~ 170	15206771	210	49.2	2.4	-	-	-	-	-	-	-
3	160 ~ 160	11180894	161	50.6	2.4	120 ~ 220	-33.1	-32.8	44.2	2560303	384	-67.2
4	180 ~ 180	5193748	233	49.5	2.6	120 ~ 220	-31.9	-33.3	50.9	2560303	2740	-65.8
5	180 ~ 180	5574520	267	49.5	2.3	140 ~ 240	-31.3	-32.7	54.1	3180287	2767	-65.2
6	160 ~ 210	6347174	226	49.2	2.2	100 ~ 200	-32.0	-32.2	50.3	2009206	964	-65.8
7	140 ~ 160	9800784	178	49.2	2.4	100 ~ 200	-33.1	-33.7	44.0	2009206	1507	-67.0
8	140 ~ 160	7333920	87	49.3	2.5	100 ~ 200	-33.0	-32.3	44.5	2009206	1949	-66.9
9	160 ~ 180	9982280	288	48.6	2.1	100 ~ 200	-32.8	-32.6	45.9	2009206	1427	-66.5
10	180 ~ 180	12184308	317	48.4	2.2	140 ~ 240	-34.3	-33.6	38.4	3180287	8014	-68.0
11	180 ~ 180	4900392	199	49.1	2.3	140 ~ 240	-30.5	-32.1	59.6	3180287	1590	-64.3
12	160 ~ 180	10175814	122	49.2	2.2	-	-	-	-	-	-	-
13	180 ~ 200	9521872	90	49.9	2.6	120 ~ 220	-32.4	-33.5	47.7	2560303	1306	-66.4
14	120 ~ 160	10934207	-	-	-	120 ~ 220	-38.3	-37.9	24.2	2560303	1101	-
15	180 ~ 200	10018208	275	48.8	2.1	140 ~ 240	-33.9	-33.8	40.1	3180287	1431	-67.7
16	200 ~ 220	12445440	279	49.6	2.7	-	-	-	-	-	-	-
17	140 ~ 170	13689984	294	50.4	2.8	-	-	-	-	-	-	-
18	150 ~ 160	19543230	263	50.0	2.5	100 ~ 200	-30.8	-32.3	57.6	2009206	1889	-64.8
19	160 ~ 180	12334320	292	48.9	2.5	120 ~ 220	-35.0	-35.0	35.4	2560303	1024	-68.8
20	140 ~ 160	19526562	328	49.5	2.2	120 ~ 220	-30.6	-37.9	59.1	2560303	256	-64.5
21	160 ~ 200	17209710	421	48.4	2.2	100 ~ 200	-35.5	-34.4	33.6	2009206	1045	-69.2
22	180 ~ 200	6400512	518	48.3	2.0	100 ~ 200	-33.9	-33.5	40.3	2009206	2532	-67.6
23	180 ~ 200	11200896	245	49.5	2.4	120 ~ 220	-39.3	-41.0	21.7	2560303	435	-73.2
24	160 ~ 180	11375910	85	49.6	2.2	120 ~ 220	-38.7	-39.5	23.2	2560303	256	-72.6
25	180 ~ 180	10068583	256	48.9	2.4	100 ~ 200	-35.7	-35.9	32.7	2009206	1125	-69.5
26	190 ~ 210	10920873	245	49.3	2.3	120 ~ 220	-34.3	-33.9	38.6	2560303	1843	-68.1
27	160 ~ 170	15596803	497	50.0	2.3	-	-	-	-	-	-	-
28	170 ~ 190	15596803	300	49.9	2.4	60 ~ 160	-	-	-	1113674	-	-
29	150 ~ 160	11296459	464	48.0	2.1	80 ~ 180	-	-	-	1526997	-	-
30	180 ~ 190	5542110	378	48.2	2.1	120 ~ 220	-29.6	-29.5	66.2	2560303	973	-63.2
31	200 ~ 220	10889760	503	48.3	2.4	150 ~ 250	-31.9	-31.1	50.4	3516112	527	-65.6
32	190 ~ 210	5542110	599	47.8	2.2	130 ~ 230	-30.7	-32.1	58.5	2861684	687	-64.2
33	180 ~ 200	4958730	595	48.5	2.2	100 ~ 200	-32.5	-33.1	47.1	2009206	482	-66.3
34	180 ~ 200	3500280	574	48.4	2.4	100 ~ 200	-29.7	-32.9	65.6	2009206	904	-63.4
35	160 ~ 170	17365278	250	48.4	2.6	-	-	-	-	-	-	-
36	180 ~ 190	10034136	554	48.0	2.5	100 ~ 200	-32.1	-31.9	49.8	2009206	502	-65.7
37	180 ~ 180	2508534	513	48.0	2.2	-	-	-	-	-	-	-
											Ave.	-66.3

Table 4 Estimated pollock biomass

Item	IZ1	WIZ	AIA	IZ2	IZN	TTL
Area [km²]	205,311	17,010	260,076	205,311	205,311	448,377
Ave.SA [dB]	-60.8	-55.7	-59.8	-	-	-
Population [10⁶ fish]	284	75	457	313	-	770
Biomass [10³tons]	230.5	61.1	370.6	254.2	310	624.8

IZ1: International Zone (IZ), regular transects

WIZ: West end of IZ

AIA: Aleutian Island area (Toal surveyed area - IZ)

IZ2: IZ, exprolatory transects for west end

IZN: IZ, trawl sample

TTL: Total (IZ2 + AIA)

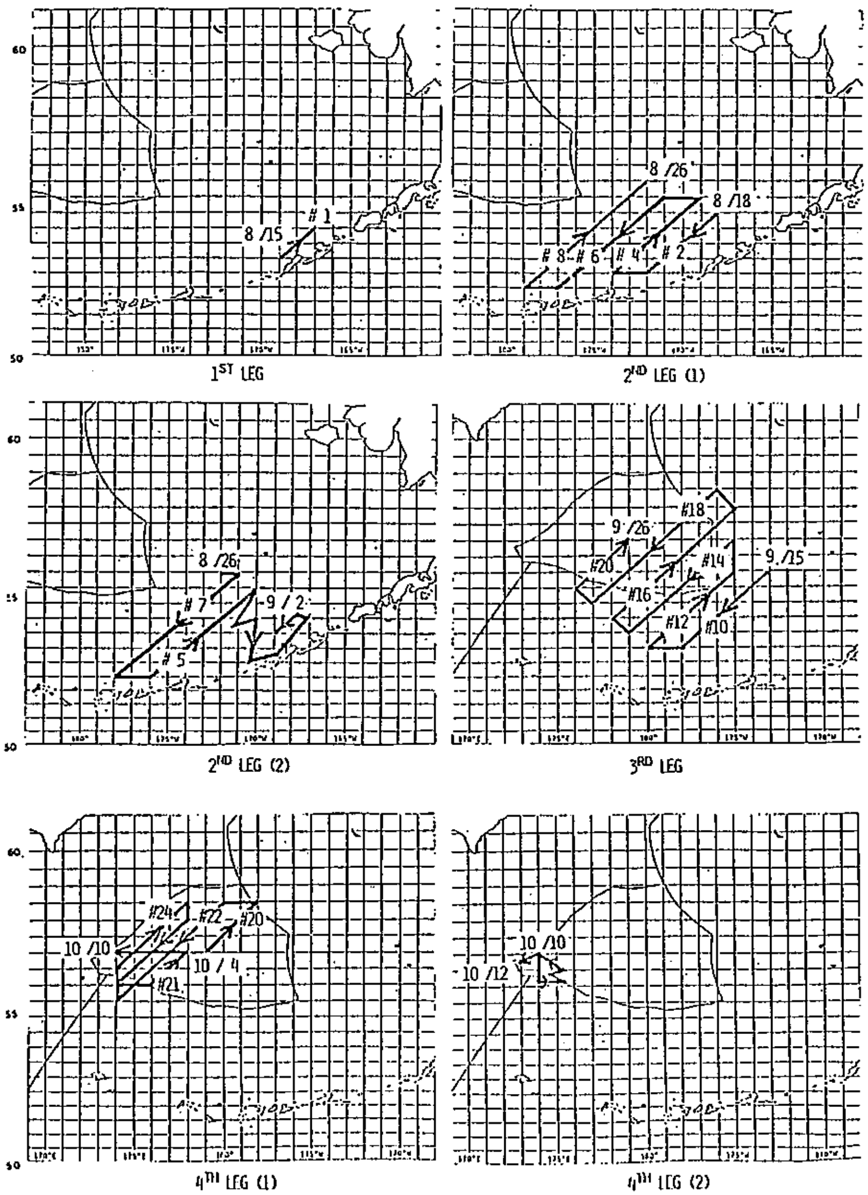


Fig.1 Tracks of 1988 summer survey.

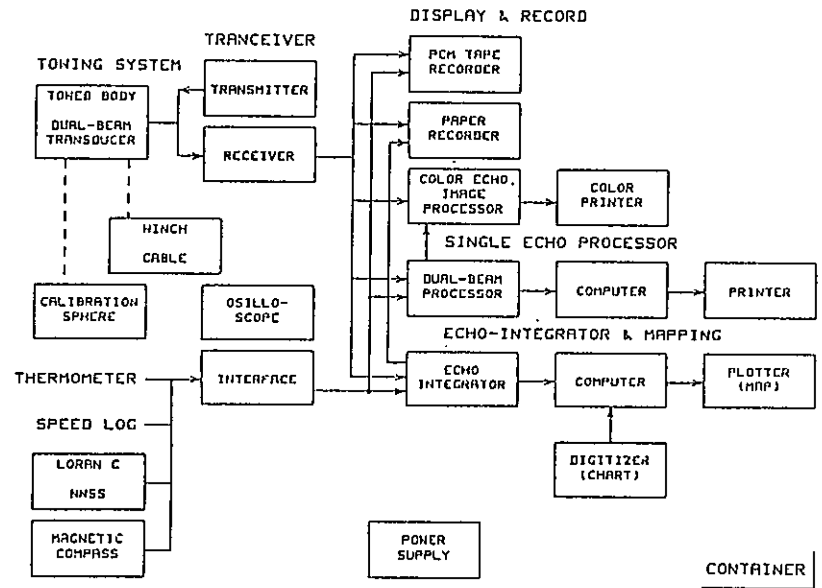


Fig.2 System block diagram of VESS

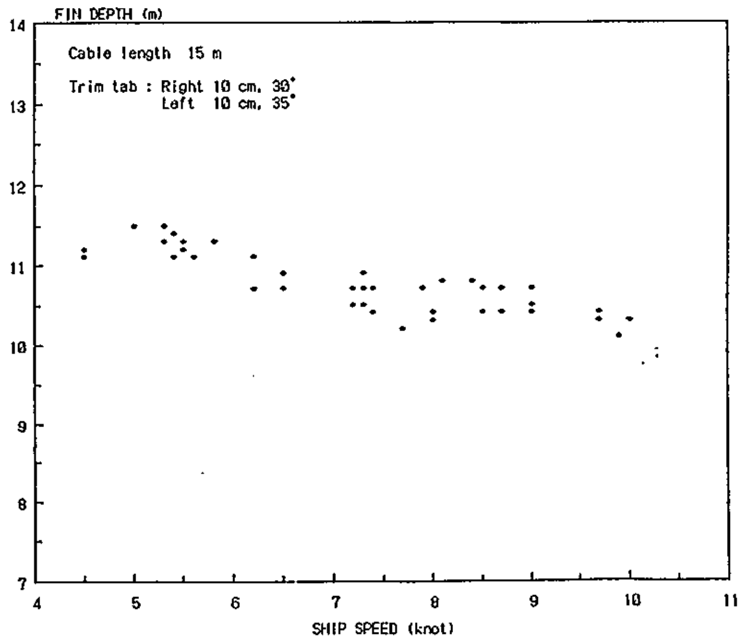
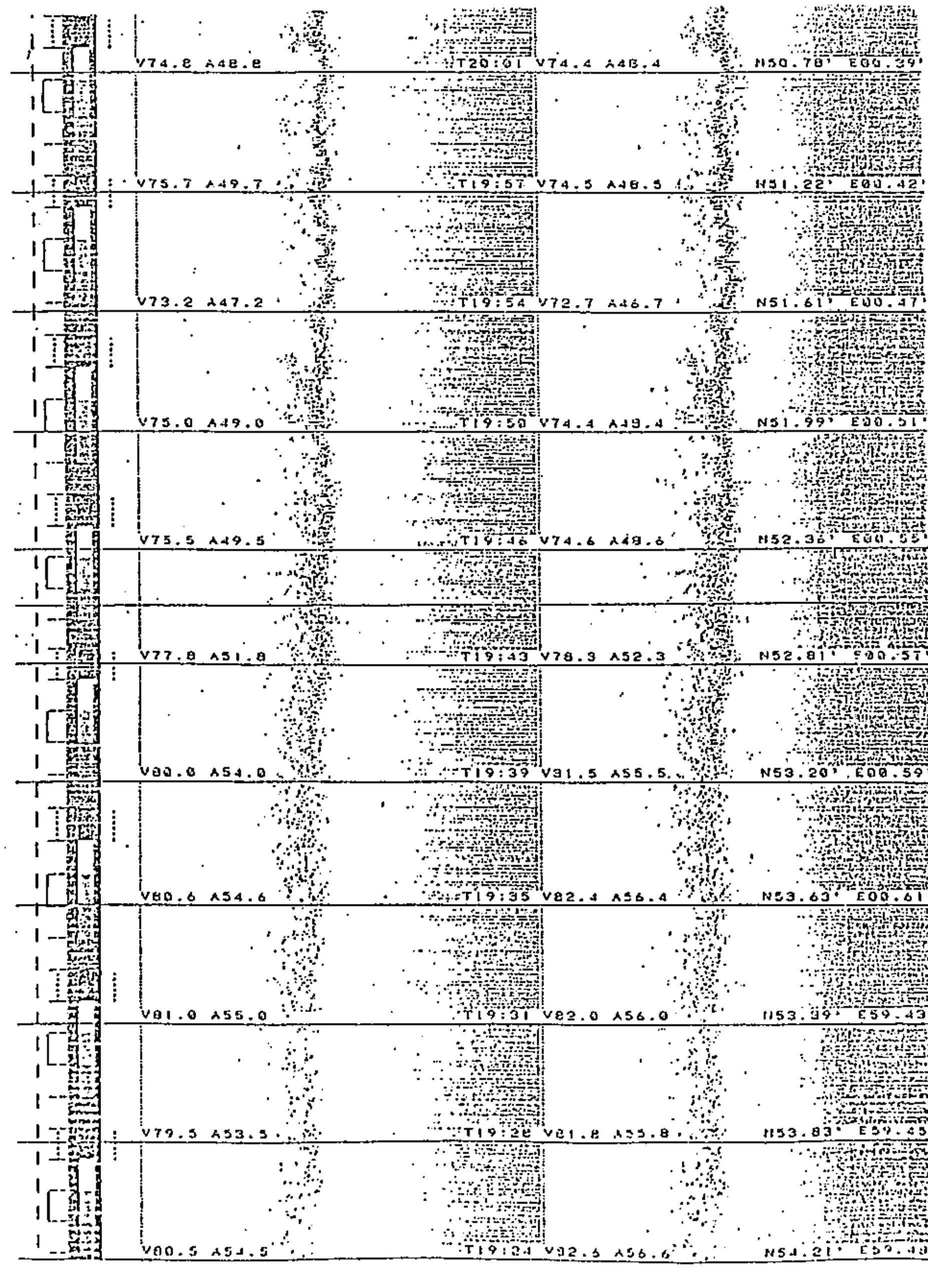


Fig. 3 Relation between measured fin depth and ship speed.



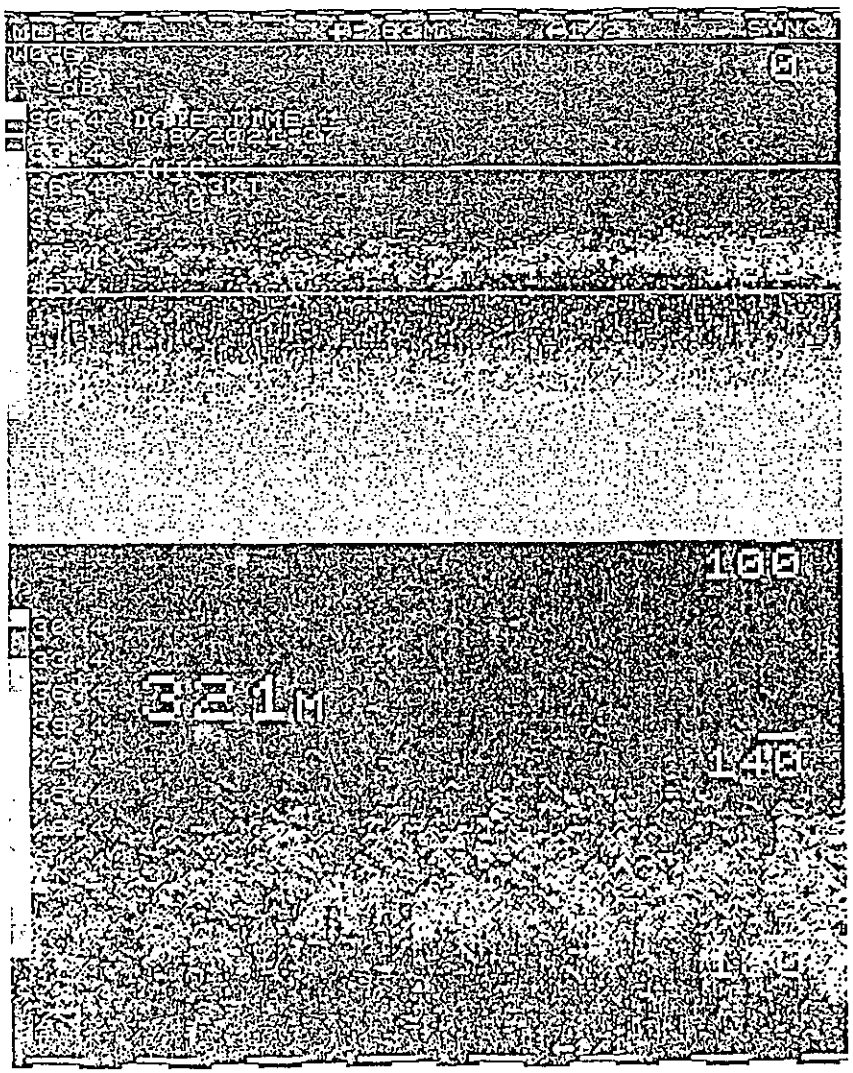


Fig.5 An example of color display (Day time,TSS mode).

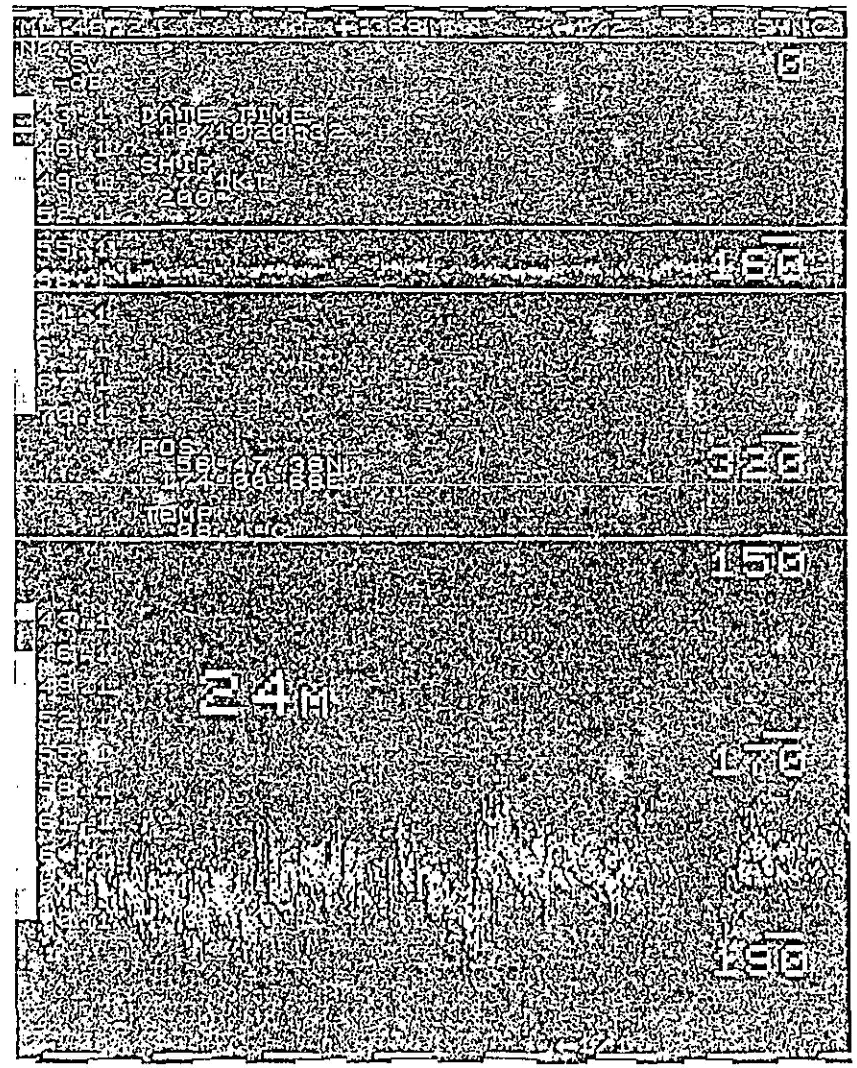


Fig.6 An example of color display showing dense layer (SVS mode).

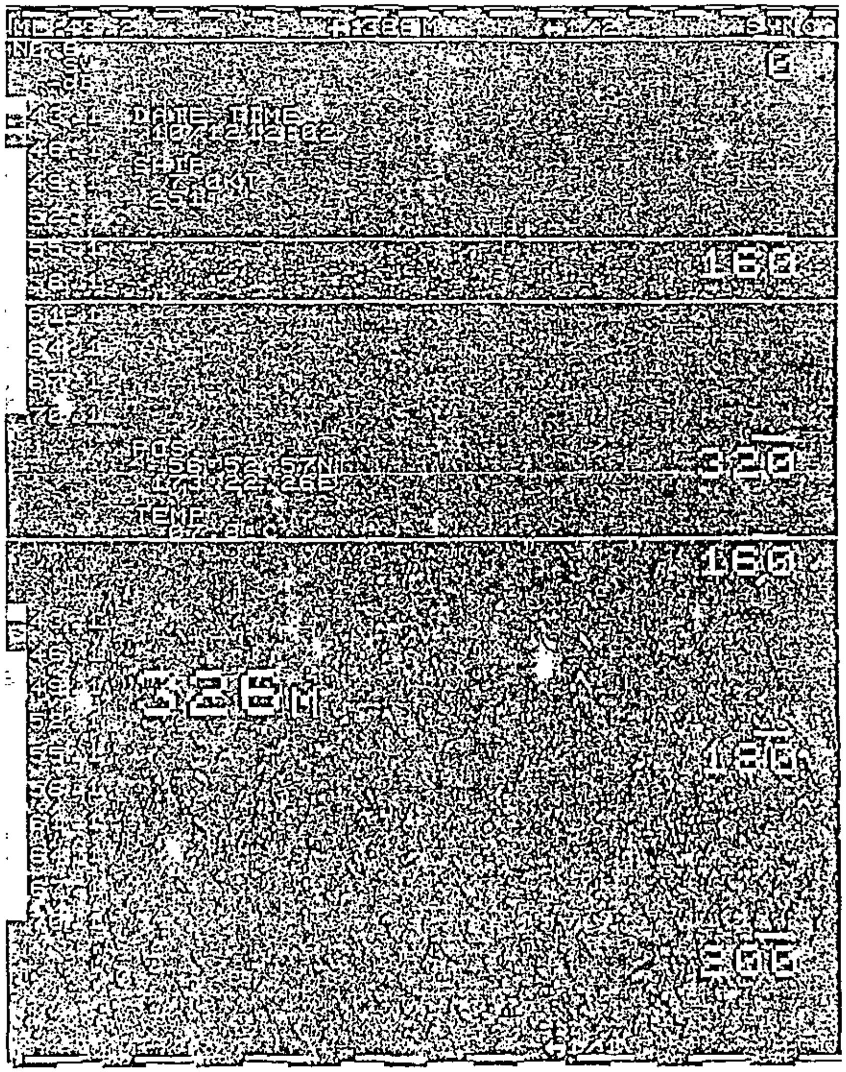


Fig.7 An example of color display showing scattered pollock (SVS mode).

PARAMETERS

[PRP PARAMETER]

1) PULSE WIDTH (0~ 9980 STEPS 20μ SEC.)

	τ 0.6	τ 1.2	τ 2.4
MIN. AT 1/2 LEVEL	540	400	400
MAX. AT 1/2 LEVEL	760	1600	3200
N. MAX. AT B. LEVEL	960	2000	4000
W. MAX. AT B. LEVEL	960	2000	4000

2) AMP. THRESHOLD LEVEL (0~ 9990 STEPS 10mV)

	10m	200m
NARROW BEAM	500	500
WIDE BEAM	500	500

3) BASE LEVEL (0,4~ 0.1) 0.2

4) START DEPTH (0~ 99) 10 m

5) AVERAGE NUMBER (1~ 10) 3

FILE P PERI P PRP P OLP P Dn TBL Dw TBL D MAX. FILE MENU PRP R

PARAMETERS

[OLP PARAMETER]

1) TOW DEPTH 0 m

2) KN 38.7 dB

3) KW 38.9 dB

4) θ CUT OFF 3.0 °

FILE P PERI P PRP P OLP P Dn TBL Dw TBL D MAX. FILE MENU PRP R

Fig.8 Parameters of dual-beam processor.

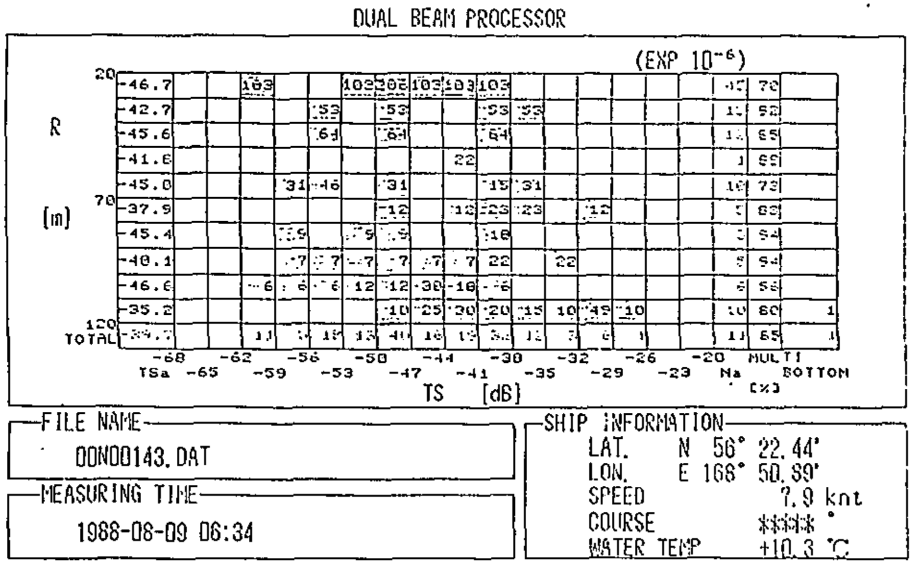


Fig.9 An example of online DBP output.

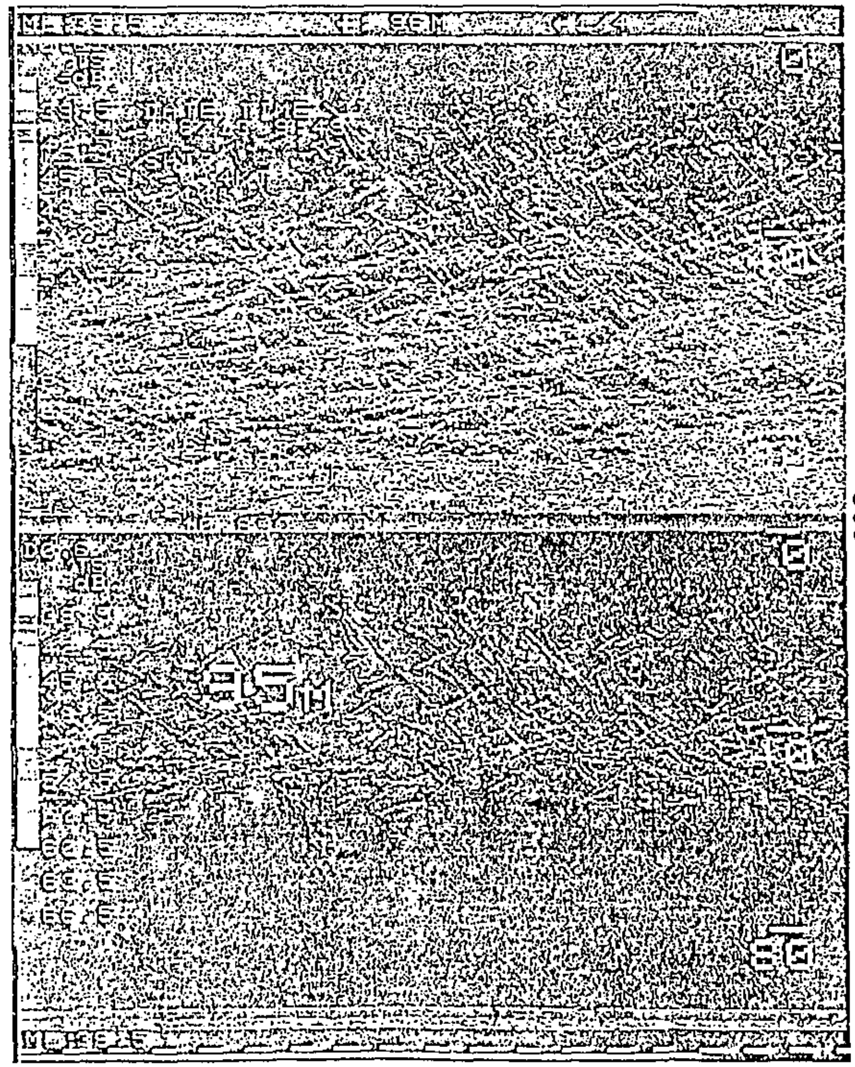


Fig.10 Color display obtained in Makushin Bay. Upper:TSS mode, Lower:TSD mode (output of DBP).

```
---------------------------------------MEMO
TITLE           GP-ECHO-INTEGRATOR
MEMO            VESSEL  SEIJU MARU
                SURVEY  BERING LEG4
                SOUNDER KJ-1000
                COMMENT 88 OCT.EXT
PERIPHERAL      LORAN-C ON
                TEMP    ON
                SOUNDER ON
                PLOTTER ON
                ANOTHER
---------------------------------------CONT.
CHANNEL         ALT
BOTTOM SIG.     INT
B.LEVEL(V)      8.0
B.OFFSET(meter) 5.0
B.WIDTH(meter)  25
DRAFT(meter)    06.0
THR. MODE       FLAT
THR. SV(dB)     -99(CH1)    -99(CH2)
INT. MODE       TIME
INT. PERIOD     0240
INT. PERIOD-1   01
INT. PERIOD-2   01
INT. PERIOD-3   01
LAYER MARKER    ON
---------------------------------------FACTORS
AUTO/KEY        AUTO
RANGE(meter) 1     2     3     4     5
           050   100   200   400   800
SENSITIV.(dB)1     2     3     4     5
     CH1  00.0  10.0  20.0  30.0  40.0
     CH2  00.0  10.0  20.0  30.0  40.0
P.WIDTH(ms)  1     2     3
     CH1  0.57  1.17  2.38
     CH2  0.55  1.11  2.40
                  CH1          CH2
TR-FACTOR(dB)   +93.5        +93.5
ANT-FACTOR(dB)  +05.7        +03.7
BEAM ANGLE(dB)  -21.4        -19.3
TS(dB)          -00.0        -00.0
```

```
---------------------------------------LAYER
INT. LAYER(meter)
        L#       CH1         CH2
        1      003:050     003:050
        2      050:100     050:100
        3      100:125     100:125
        4      125:150     125:150
        5      150:175     150:175
        6      175:200     175:200
        7      200:250     200:250
        8      250:300     250:300
        9      300:400     300:400
        10     003:400     003:400
DISP. LAYER
        L#       CH1         CH2
        1        03          03
        2        04          04
        3        05          05
        4        06          06
        5        07          07
                 CH1         CH2
SA LAYER         10          10
STRES MSK(dB) * -70.0       -70.0
              ** -50.0      -50.0
---------------------------------------
```

Fig.11 Typical parameters of echo integrator.

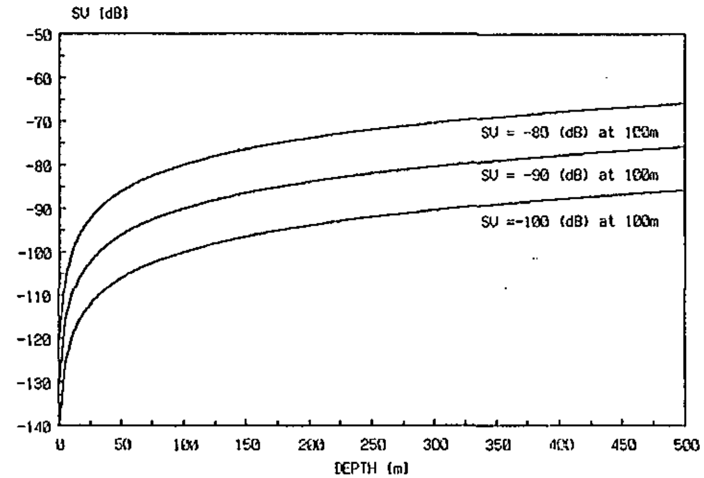


Fig.12 Example of threshold functions of echo integrator (+ 20 log r).

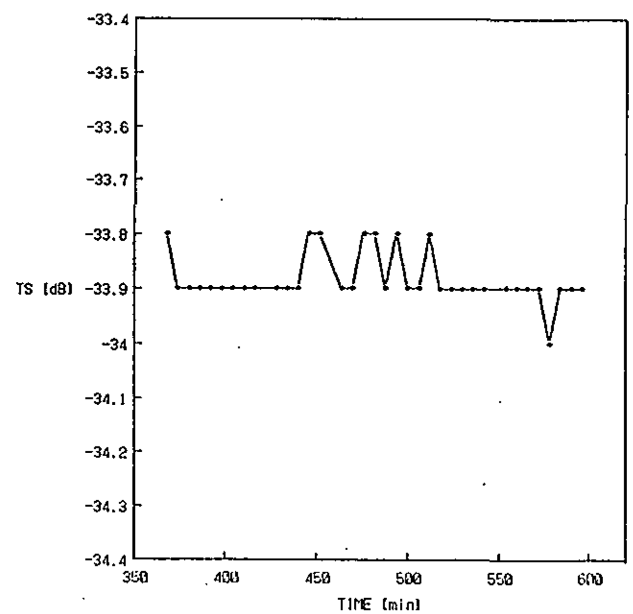


Fig.13 Target strength of cupper sphere (TS = -33.7 dB) measured by dual-beam processor.

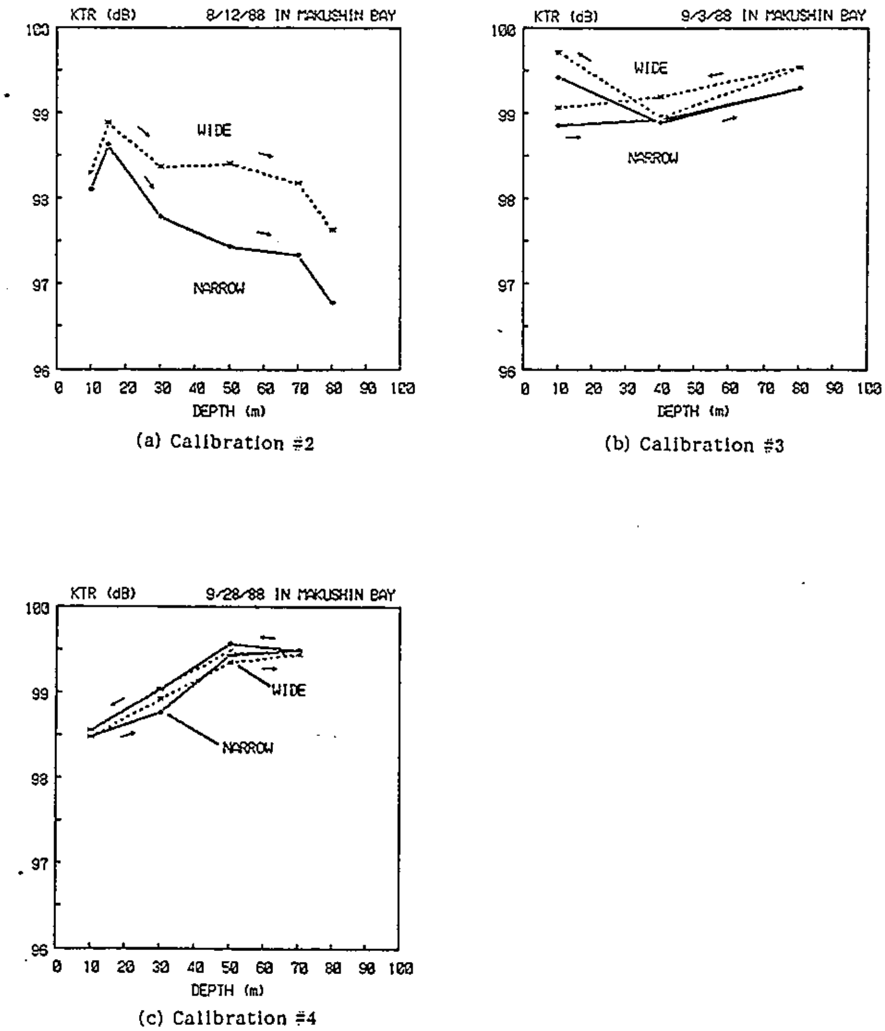


Fig.14 Measured TR-factors as a function of depth.

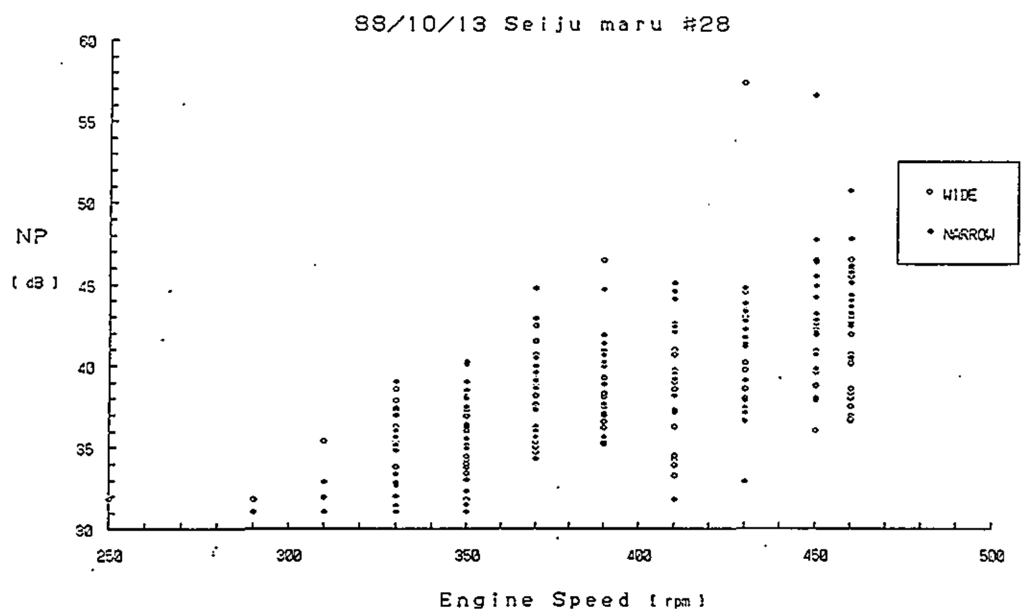


Fig.15 Relationship between noise spectrum level and ship engine speed measured by echo integrator.

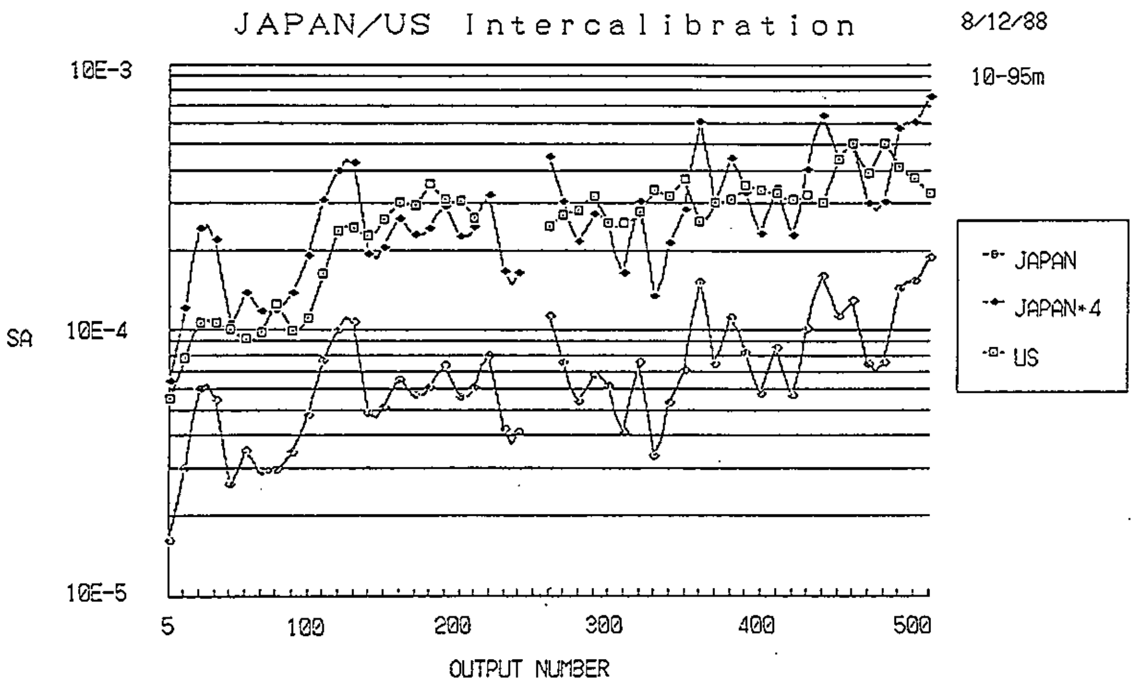


Fig.16 Time sequence of SA values in intership calibration at Makushin Bay.

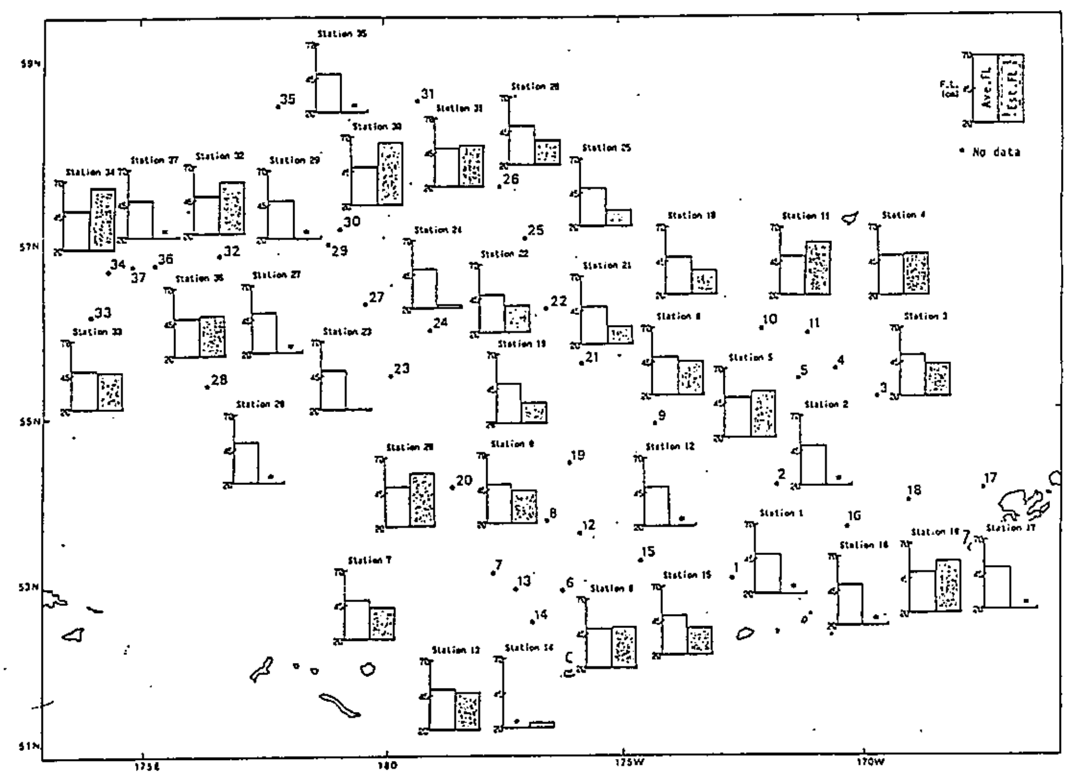


Fig.17 Comparison of average fish length obtained by trawl samples and by measured TS.

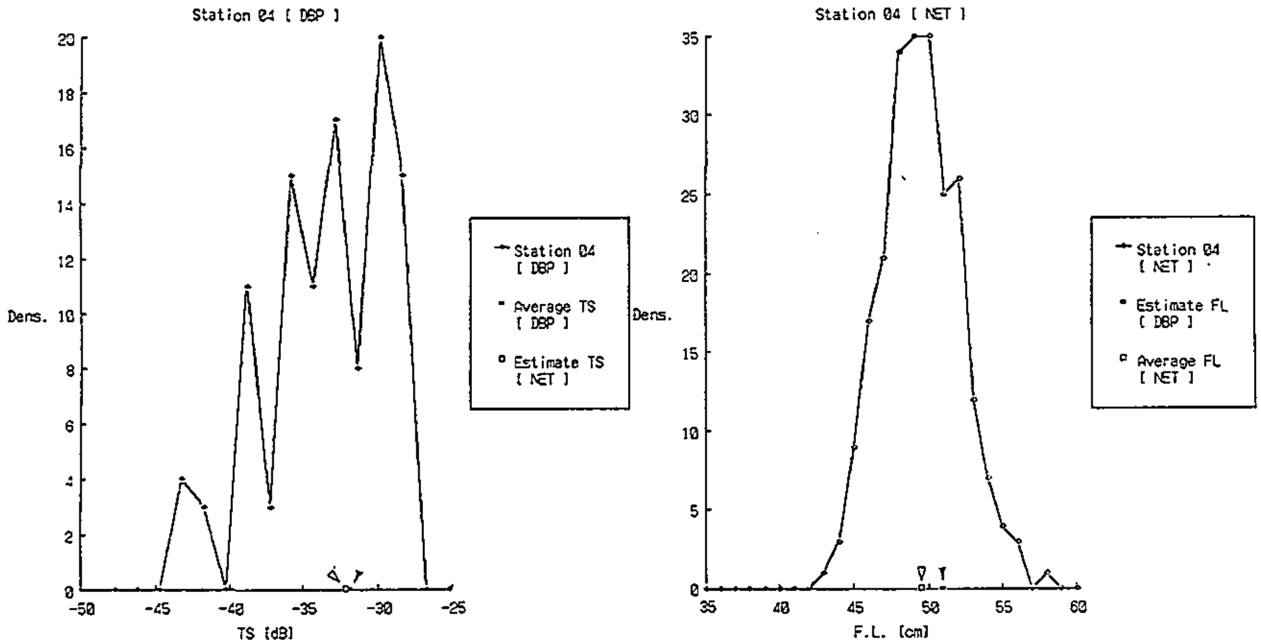


Fig.18 Comparison of fish length distribution by trawl results (right) with TS distribution (left).

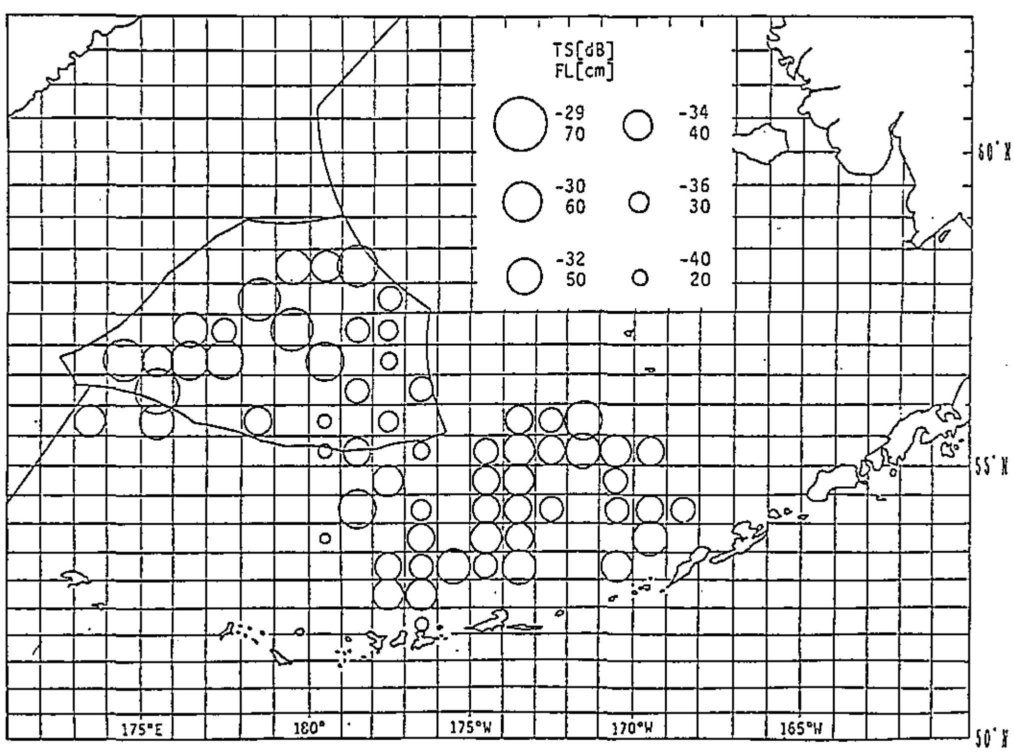


Fig.19 Distribution of average TS by area.

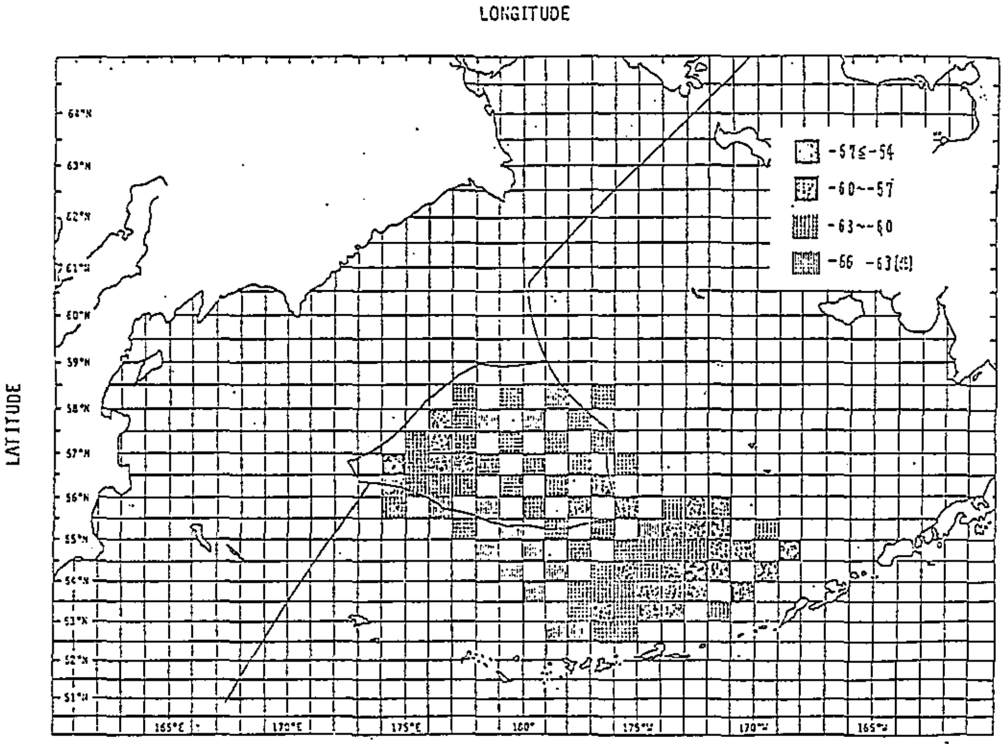


Fig.20 Distribution of SA by area.

LONGITUDE

LATITUDE \ LONGITUDE	174°E–175°E	175°E–176°E	176°E–177°E	177°E–178°E	178°E–179°E	179°E–180°	180°–179°W	179°W–178°W	178°W–177°W	177°W–176°W	176°W–175°W	175°W–174°W	174°W–173°W	173°W–172°W	172°W–171°W	171°W–170°W	170°W–169°W	169°W–168°W
N 58°30'–58°00'				-0.1		0.5		0.5		1.3								
58°00'–57°30'			0.1	0.2	0.5		0.3		-0.1		-0.4							
57°30'–57°00'		0.6	0.3	0.6		0.4		-0.3		0.3								
57°00'–56°30'	1.2	0.5	1.1	0.4	0.8		-0.5		0.1		0.3							
56°30'–56°00'	0.7	1.0	0.1	0.2		0.0		0.4		0.3								
56°00'–55°30'	1.0		0.3		-0.2		0.4		0.1		0.5		1.2	0.5	0.4			
55°30'–55°00'				1.3		0.5		0.2		0.6		0.0	0.7	0.0	0.1	0.0	-0.2	
55°00'–54°30'					-0.1		-1.2		0.3		0.7	0.2	0.0	1.0	0.0	0.3		1.4
54°30'–54°00'						0.1		0.7		0.8	0.6	0.7	0.3	0.0	0.4		-0.3	
54°00'–53°30'							0.4		1.1	1.4	0.4	-0.1	0.0	0.4		0.4		
53°30'–53°00'									-0.1	-0.4	0.6	0.4	0.3		-0.5			
53°00'–52°30'								0.5	-0.5	0.5	0.2							

Fig.21 Difference of SA between composite and narrow channels.

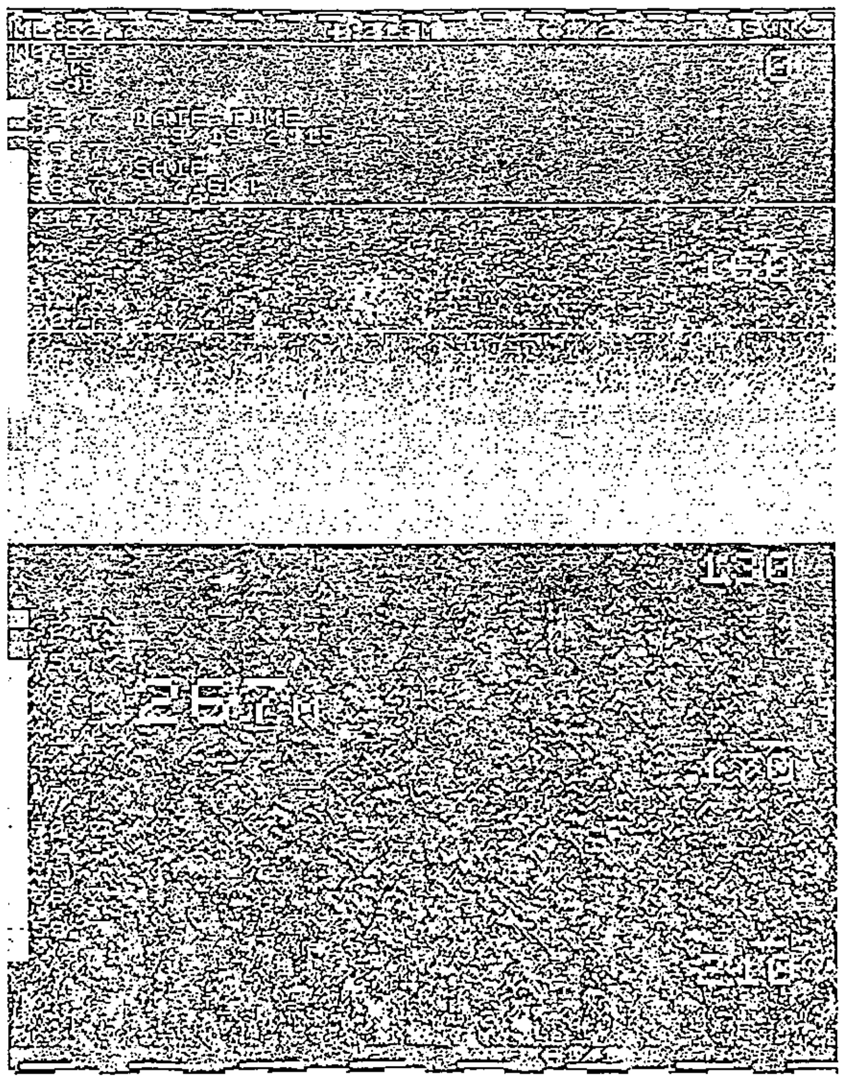


Fig.22 An example of color display (Leg 3, evening).

Specific Composition and Biomass of the Bering Sea Mesopelagic Fishes

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Data obtained lately as a result of ecosystem surveys in the Far-Eastern seas change considerably our notion of mesopelagial as a part of pelagial poor in fish (Shuntov,1985). It has been revealed that fish biomass in mesopelagial rather exceeds the total biomass of epipelagic fish. The question arises about the actual role of mesopelagic fish in the sea ecosystem. This paper is only the first step in solving the problem. The aim pf this work is to determine the biomass of mesopelagic fish and specific composition of ichthyocenosis of mesopelagial of the western Bering sea.

Material and methods

Data on trawl survey in meso- and bathypelagial conducted in the western Bering sea from 05.23 to 07.01.89 were used in this work. Scheme of stations is given in Fig.1. Two oblique trawlings by midwater trawl were conducted in each point, in 500-200m layer and 1000-500 m layer where depths enabled to carry out second trawling. Aperture of a trawl is 3500 sq.m. Speed of trawling is 3,5-4 knots, over the entire length of a codend there was 12mm small-meshed insertion.

Biomass was estimated with the help of the volume method using the following formulae: $B = (C * V)/(v.K)$, where B - is biomass, C - mean catch, V-volume of a surveyed volume, v-volume of trawled water, K-fishing efficiency. Whereas the density of a trawl net was quite different in different sea areas, the biomass of species was separately calculated by statistical areas (Fig.1). Total values are used in the paper for the sea as a whole.

Fishing efficiency was taken to be 0,1 for all fish, where fishing efficiency is unknown from literature. When choosing efficiency we proceeded from the following consideration. Dominant species (Leuroglossus schmidti, Stenobrachius leucopsarus) are the most similar to Pacific capelin as for body length and morphology. Fishing efficiency for this fish was determined to be 0,1 on an average for midwater trawls (Naumenko,1986). Therefore, for mesopelagic fish of rather smaller size from the North Atlantic, fishing efficiency was determined to be 0,087 (Popkov,1986). Taking into consideration that among other species there are smaller as well as larger fish, it can be assumed that total biomass of mesopelagic fish being calculated at fishing efficiency - 0,1, is close to their actual total biomass. For larger commercial specimen, fishing efficiency was taken usually used for estimation of their stocks: grenadier (Macrouridae) - 0,4, Laemonema - 0,2, smooth lumpsuckwe - 0,5. It is clear that specific structure at such allowance is rather misrepresented, however, the differences in body length of the rest mesopelagic fish are insignificant and make it possible to depend on fluctuations of fishing efficiency for them no more then two times.

When drawing up specific lists data of the previous research cruises and literature data were used concurrent with the data of this research cruise. (Rass,1954, Rass,Kashkina,1967, Fedorov,1973a,1973b; Mukhacheva,1974, Bolin,1939; Rass,1958; Wilimowski,1956, Hart,1973).

Results and discussians

Specific composition of fish in meso- and bathypelagial is presented in Table 1. Altogether, 62 species were observed in the surveyed horizon, belonging to 54 genera and 35 families. The main number of families and genera is represented by 1 or 2 species. Two families have the widest representation. Family Myctophidae has got here 8 species and Bathylagidae - 4 species.

In previous works (Fedorov,1973a,1976b) 61 specie were marked for surveying horizon,which could be found here.Benthal species,which do not leave benthopelagic layer (For ex. Antimora rostrata),were put by the author in this group. He marked 35 species out of actually mesopelagic fish. Only 12 species were cought by us in meso- and bathypelagial which are not actually mesopelagic but they frequently occur here, for ex. Coryphaenoides pectoralis, C.cinereus, Laemonema longipes, Theragra chalcogramma and others.

Seven species have been first found by us for the Bering sea: Nansenia candida, Dolichopteryx sp., Malacosteus niger, Pachystomias microdon, Scopelengys tristis, Bertella idiomorpha, Thalassobathia pelagica.

18 mesopelagic species are "characteristic",that is,they occur all over the sea, for ex. all four species of Bathylagidae,Lampanyctus jordani; L. regalis, Stenobrachius nannochir, S. leucopsarus, Chauliodus macouni, Macropinna microstoma families and others.These species can probably be regarded as a nucleus,defining ichthyofauna of meso- and bathypelagial of the sea.

Total biomass of mesopelagic fish in the western Bering sea is estimated to be 5.921 mln.t., that is 9gr per square meter on the average. This value exceeds fish biomass of epipelagial,was estimated by us to be 2,8 mln.t in the surveyed period. Therefore, we do not include the biomass of pollock (Theragra chalcogramma) as epipelagic species into the biomass estimate of mesopelagic fish. But in the deep-water areas of the sea, a part of pollock constantly occurs in mesopelagial. By our estimates the biomass of such pollock in the Bering sea was 1,141 mln.t (19,2% of the total biomass of fish of meso- and bathypelagial). Given value is daily average whereas significant part of pollock has daily migrations between epi- and mesopelagial. The value of this part is significantly varied in time and space.

94,2% of total biomass of mesopelagic fish (Tabl.2) comes for the share of six families. Two most polyspecific families dominate among them: Myctophidae (47,1%) and Bathylagidae(33,8%)

A group of seven dominant species is 84,1% of biomass of mesopelagic fish (tabl.3). S.leucopsarus dominates among them (37,6%). B.pacificus and P.Milleri (12,0 and 10,3% respectively) comes next and are about one third of its biomass. Other species of the group were a constant component of trawl catches.

The basic part of biomass is comprised of a low number of species,that is characteristic of the surveying horison of the Bering sea as well as of the entire temporate area. Moreover, one species dominates by biomass over the rest species though it is not clearly expressed. Biomass of dominant species averages only two fifth of the total biomass. Species coming after the dominant species have the biomass three times less than that of the dominant species.

Mesopelagic species have disperse distribution in 200-1000 layer,they do not form aggregations. Their catches are more significant in mesopelagial,particularly near the continental slope (Fig.2). The maximum yield (0,2t per one hour of trawling) was caught on the boundary of Shirshov ridge and Olyutorskie--Navarin part of the slope.

CONCLUSION

Biomass of mesopelagic fish of the western Bering sea is estimated to be 5,92 mln.t. Moreover, 1,14 mln.t of feeding pollock occured in mesopelagial.

98 species were observed in the sea belonging to 51 genera and 33 families.

The basic part of biomass (84,1%) is comprised of 7 species One species (Stenobrachius leucopsarus) dominates by the biomass among the rest ones though not clearly expressed. The biomass of the dominant species averages two fifth of the total biomass. The following species have the biomass three times less.

Mesopelagic fish are dispersely distributed in 200-1000 layer,they do not form aggregations. Its catches are more significant in mesopelagial. The maximum concentrations are observed on the continental slope,particularly near the Shirshov ridge.

Table 1

List of species and occurence (O) of fish in layer 200-1000 m in Bering sea

Taxon	O
fam. Petromyzonidae	
1. Entosphenus tridentatus (Gairdner, 1836)	+
fam. Squalidae	
2. Somniosus pacificus Bigelow et Schroeder, 1944	+
fam. Microstomatidae	
3. Nansenia candida Cohen, 1958	+
fam. Bathylagidae	
4. Bathylagus pacificus Gilbert, 1891	++
5. Pseudobathylagus milleri (Jordan et Gilbert, 1898)	++
6. Lipolagus ochotensis (Schmidt, 1938)	++
7. Leuroglossus schmidti Rass, 1955	++
fam. Opisthoproctidae	
8. Dolichopteryx sp.	+
9. Macropinna microstoma Chapman, 1939	++
fam. Gonostomatidae	
10. Cyclothone atraria Gilbert, 1905	+
11. Gonostoma gracile Gunther, 1878	+
fam. Chauliodontidae	
12. Chauliodus macouni Bean, 1891	++
fam. Malacosteidae	
13. Aristostomias scintillans (Gilbert, 1915)	+
14. Malacosteus niger Ayers, 1848	+
fam. Melanostomiatidae	
15. Tactostoma macropus Bolin, 1939	+
16. Pachystomias microdon (Gunther, 1878)	+

Table 1 -- continued

Taxon	O
fam. Alepocephalidae	
17. Bajacalifornia megalops Lutken, 1898	+
18. Rouleina attrita (Vaillant, 1888)	*
fam. Platytroctidae	
19. Holtbyrnia innesi (Fowler, 1930)	+
20. Maulisia argipalla Matsui et Rosenblatt, 1979	*
21. Sagamichthys abei Parr, 1953	+
fam. Scopelarchidae	
22. Benthalbella dentata (Chapman, 1939)	++
fam. Notosudidae	
23. Scopelosaurus adleri (Fedorov, 1967)	++
24. Scopelosaurus harri (Mead, 1953)	++
fam. Anotopteridae	
25. Anotopterus pharao Zugmayer, 1911	+
fam. Alepisauridae	
26. Alepisaurus ferox Lowe, 1833	+
fam. Myctophidae	
27. Diaphus theta Eigenmann et Eigenmann, 1890	+
28. Lampanyctus jordani Gilbert, 1913	++
29. Lampanyctus regalis (Gilbert, 1892)	++
30. Lampanyctus ritteri Gilbert, 1915	*
31. Protomyctophum thompsoni (Chapman, 1944)	+
32. Stenobrachius leucopsarus Eigenmann et Eigenmann, 1890	++
33. Stenobrachius nannochir (Gilbert, 1890)	++

Table 1 -- continued

Taxon	O
134. Tarletonbeania crenulare (Jorden et Gilbert, 1890)	*
fam. Neoscopelidae	
135. Scopelengys tristis Alcock, 1890	+
fam. Paralepididae	
136. Paralepis atlantica atlantica Kroyer, 1868	*
137. Notolepis rissoi rissoi (Bonaparte, 1841)	+
fam. Cetomimidae	
138. Gyrinomimus sp.	*
fam. Nemichthydae	
139. Avocettina infans (Gunther, 1878)	+
fam. Oneirodidae	
140. Oneirodes bulbosus Chapman, 1939	++
141. Oneirodes thompsoni (Schultz, 1934)	++
142. Bertella idiomorpha Pietsch, 1972	+
fam. Ceratiidae	
143. Ceratias holboelli Kroyer, 1845	*
fam. Moridae	
144. Laemonema longipes Schmidt, 1938	*
145. Halargyreus johnsoni Gunther, 1862	+
fam. Gadidae	
146. Theragra chalcogramma (Pallas, [1814])	+
fam. Macrouridae	
147. Coryphaenoides cinereus (Gilbert, 1896)	++
148. Coryphaenoides pectoralis (Gilbert, 1891)	++
fam. Melamphaidae	

Table 1 -- continued

Taxon	O
149. Melamphaes lugubris Gilbert, 1891	++
150. Poromitra crassiceps (Gunther, 1878)	++
fam. Caristiidae	
151. Caristius macropus (Bellotti, 1903)	*
fam. Chiasmodontidae	
152. Kali indica Lloyd, 1909	*
fam. Zoarcidae	
153. Lycogramma brunnea (Bean, 1890)	+
154. Lycogramma soldatovi Schmidt, 1950	+
fam. Bythitidae	
155. Thalassobathia pelagica Cohen, 1963	+
fam. Icosteidae	
156. Icosteus aenigmaticus Lockington, 1880	+
fam. Psychrolutidae	
157. Malacocottus sp.	+
fam. Cyclopteridae	
158. Aptocyclus ventricosus (Pallas, 1789)	++
159. Pelagocyclus vitiazi Lindberg et Legeza, 1955	*
fam. Liparidae	
160. Nectoliparis pelagicus Gilbert et Burke, 1912	+
161. Paraliparis sp.	+
fam. Pleuronectidae	
162. Reinhardtius matsuurae Jordan et Snyder, 1901	++

Notes: occurrence above 50% - ++,
occurrence below 50% - (+ - by our data, * - by literature data)

Table 2

Biomass (1) and ratio (2) of dominant families of mesopelagic fish of the Bering sea

Family	1 thsd t	2,%
Myctophidae	27[illegible]	47,1
Bathylagidae	2001	33,8
Chauliodontidae	270	4,6
Macrouridae	213	3,6
Cyclopteridae	165	2,8
Scopelosauridae	141	2,4
Others	343	5,8
Total	5921	100,0

Table 3

Biomass (1) and ratio (2) of dominant species of mesopelagic species of the Bering sea

Species	1 thsd t	2%
Stenobrachius leucopsarus	2224	37,6
Bathylagus pacificus	710	12,0
Pseudobathylagus milleri	608	10,3
Stenobrachius nannochir	470	7,9
Leuroglossus schmidti	380	6,4
Lipolagus ochotensis	315	5,3
Chauliodus macouni	270	4,6
others	944	15,9
Total	5921	100,0

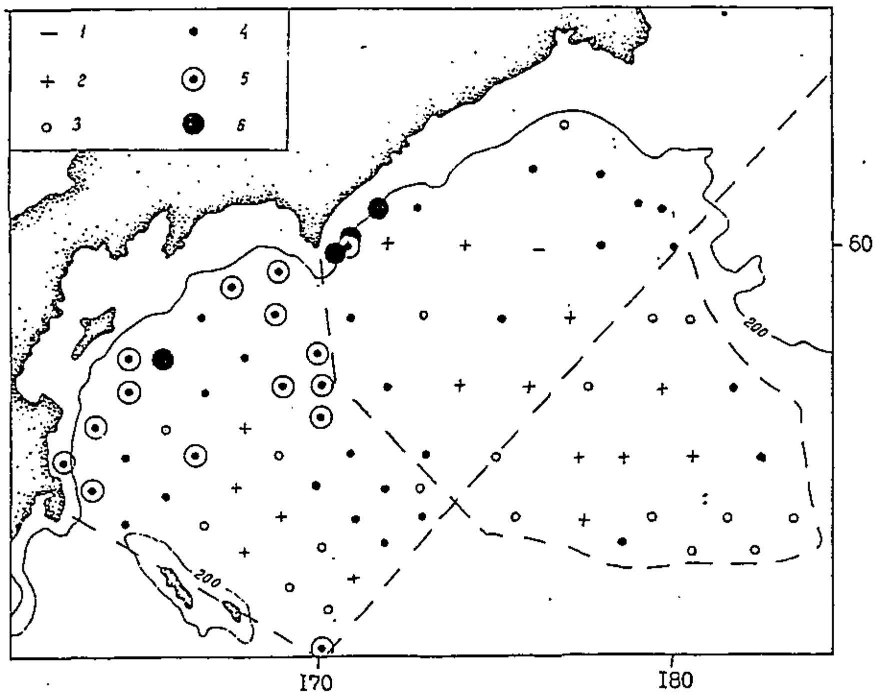

Figure I. Distribution of catches per unit (kg/hour) of mesopelagic fishes in lyer 200-500 meters. I - 0; 2 - below I0; 3 - II-25; 4 - 26-50; 5 - 5I-I00; 6 - above I00

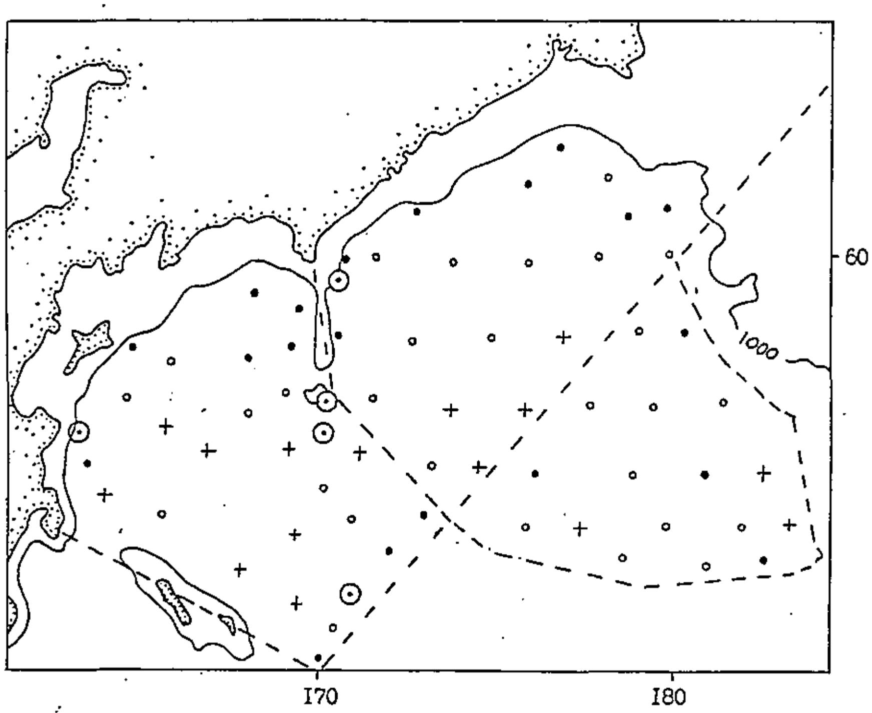

Figure 2. Distribution of catches per unit (kg/hour) of mesopelagic fishes in lyer 500-I000 meters. Legend as figure I.

The Spatial Differentiation of Walleye Pollock Yearlings in the Eastern Bering Sea

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When carrying out the bottom trawl surveys at the Eastern Bering Sea shelf in May - June 1988 - 1989, the walleye pollock juveniles' spatial differentiation could be traced in multisized groups.

In 1989 small yearlings with 10 - 12 cm modal group were distributed in the northern part of the trawl survey area, large yearlings with 13 - 15 cm modal group were distributed primarily in the lower shelf areas, and average yearlings with 12 - 13 cm modal group were in between the large and small ones.

The reason for the yearlings' different sizes' origination is the carrying of the eggs to the east and the northeast out of reproduction areas by current, and the different time of spawning.

The yearlings' separateness by different size seems to be also explained by the juveniles' active migrations as the consequence to the food selectivity.

Thus, the walleye pollock yearlings' distribution in the Eastern Bering Sea seems to be influenced by:

1. The current carrying the eggs and larvae out of the main spawning places;

2. Different time of spawning;

3. Distribution of the mesoplankton different fractions and the juveniles' active migrations as a consequence to food selectivity.

Outline of Biological Information obtained from Winter Pollock Stock Research in the Aleutian Basin by Kaiyo maru in 1988/89

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Introduction

This report presents an outline of midwater trawl survey conducted for sampling as part of the pollock stock survey in the Aleutian Basin by Kaiyo maru, a survey vessel of the Fisheries Agency of Japan, from December 1988 to March 1989. It also presents an outline of biological information concerning pollock obtained from the survey. Reports of the survey by Kaiyo maru under the title of entire survey cruise, biological survey, acoustic survey and marine environment research are now being prepared by respective authors and is scheduled to be published shortly.

Outline of the Survey

Kaiyo maru left the Tokyo Port on December 1 1988 and conducted survey on pelagic pollock stock for 55 days and returned to Japan on March 20, 1989 (Fig. 1). Under the initial program, it had been planned to conduct quantitative echo sounder survey, midwater trawling survey, research on marine environment (Fig. 2), but, as sea conditions were worse than anticipated, only the transect lines as shown in Fig. 3 were implemented. Further, only 24 samplings by midwater trawl nets were conducted.

Midwater Trawl Survey

During the survey period, a total of 24 samplings were conducted using midwater trawl nets in the locations shown in Fig. 3. Table I shows the location, date and time, towing hour, towing depth, collected specimens, etc. At each towing, the number and weight of collected specimens were measured, and then about 200 kg of pollock (or all the amount when the catch was below 200 kg) on a random sampling basis and dividing them into males and females and punching was made on the length punching cards to obtain length composition each for males and females. Specimens of 20 to 30 individuals by sex were selected from among the punched specimens so that they represent length range of collected pollocks. Their fork length (referred to as length hereafter), body weight and weight of gonads were measured, and stomach contents were identified. As regards gonads, their maturity conditions were observed and identified on board the vessel and then fixed by formalin for examination in the laboratory. The gonads were then turned into tissue fragments for further detailed histological study.

Table I shows total catch amount of pollock, the weight and number of specimens measured, CPUE (weight and number of pollock caught per one-hour towing) and the weight and number of catch of other fishes. Pollocks accounted for a predominant part of the catch. Besides pollock, smooth lumpsucker showed a relatively frequent appearance. One individual each of arrowtooth flounder and Greenland turbots, and two individuals of giant grenadier, which are seldom observed in the mesopelagic layer, were collected.

Pollocks were caught by all the trawl nets other than MT-14, and CPUE (catch per one-hour towing) was extremely high in Bogoslof area north of Umnak Island while it was relatively low in the international waters (Fig. 4). CPUE was also low in the Basin within the U.S. 200 miles zone other than Bogoslof area, showing little difference from the international waters, but relatively high CPUE was observed in MT-23 near the continental shelf of the eastern Bering Sea and MT-19 north of Atka Island of Aleutian Islands.

Biological Information

1. Length composition

Table 2 shows length composition of pollock by sex compiled on the basis of length punching cards in each midwater trawl sampling survey. Fig. 5 shows distribution of pollock length frequency from the international waters made on the basis of Table 2, the U.S. 200 miles zone and all the survey areas (Aleutian Basin).

The length composition of pollock in the Aleutian Basin was within a range of 34-60 cm, with their modes at 48-49 cm and average length at 48.3 cm. Modes for females ranged from 50 to 51 cm and their average length was 49.3 cm. Modes for males were 48-49 cm and the average length was 47.4 cm (Table 2). Comparing the length composition for males and females combined in the international waters and that in the U.S. 200 miles zone, the modes and average length in the international waters were 47-48 cm and 48.0 cm, respectively, which were slightly smaller than the corresponding figures of 48-49 cm and 48.4 cm for the U.S. 200 miles zone. Pollock of the body length of 40 cm or less, which appeared only in a small number in the U.S. 200 miles zone, were caught in the areas near the continental shelf (MT-22 and MT-23)

2. Length-weight relations

Fig. 6 shows the length-weight relations of pollock by sex for all the survey areas (Aleutian Basin), international waters and the U.S. 200 miles zone based on the data measured in each sampling survey. On the basis of these data, the following formulae were assumed concerning length-weight relations for pollock, males and females combined.

Total survey area: $BW = 7.1854 \times 10^{-6} \cdot FL^{2.9960}$
International waters: $BW = 25.8522 \times 10^{-6} \cdot FL^{2.7887}$
U.S. 200 miles zone: $BW = 4.2900 \times 10^{-6} \cdot FL^{3.0793}$

Here BW means weight (g) and FL means fork length (mm).

3. Stomach contents

Of all the 744 individuals for which stomach contents were examined, 403, or 54%, had empty stomach. The frequency of appearance of food items as regards 341 individuals for which stomach contents were observed, 54%, the highest percentage, were krills, followed by 16% of cephalopods (Fig. 7). The appearance of fish eggs was relatively high. This was due to the fact that the stomach contents of pollock collected in MT-24 on February 26 1989 were filled with what were believed to be pollock eggs.

4. Maturity conditions

The proportions of gonad weight to the body weight (maturity index, GSI) were obtained on the basis of pollock data measured on board the vessel. By order of collecting days, the GSI values for males stayed within a range of 4-14% throughout the survey period, showing no conspicuous trend (Fig. 8). On the other hand, GSI values for females showed increase in the course of time, peaking out at around February 22 and 23, and gradually declined since then. It was conjectured on the basis of the change trend of female GSI values that spawning started from around February 22 and 23 in 1989. Concerning female GSI values in the period after February 26 when _Kaiyo maru_ completed midwater trawl survey, we used data obtained by _Miller Freeman_, a research vessel of the U.S. National Oceanic and Atmospheric Administration, which conducted the joint survey in the same area.

Observation of mature male fish was conducted on board the vessel in four stages: _Developing_, _Mature_, _Spermatozoa discharge_ and _Spent_. Observation of mature females was conducted in five stages: _Developing_, _Premature_, _Mature I_ (having partially mature eggs), _Mature II_ (from those having considerably mature eggs to those immediately before spawning) and _Spawning_. Fig. 9 shows the frequency of appearance of each stage by sampling location. Pollocks in the process of spawning and spermatozoa discharge were collected only in MT-24, the area north of Umnak Island. Males remained in the mature stage constantly, except late February (MT-24) when they were in the stage of spermatozoa discharge. On the other hand, females were mostly (80%) in the premature stages except late February when they were spawning.

It was assumed from change trends of GSI values and maturity stages that spawning of pollock in the Aleutian Basin in 1989 started in the southeastern area of the Basin around late February.

Table 1. Records of operations and catch data on the midwater trawl survey conducted during the Japan-U.S. joint acoustic/midwater trawl survey by *Kaiyo maru* in the Aleutian Basin from December of 1988 to March of 1989.

Midwater trawl catch data

Trawl no	HT-1	HT-2	HT-3	HT-4	HT-5
Date trawled	9/12/88	11/12/88	12/12/88	22/12/88	23/12/88
Duration (min)	41	60	26	60	40
Total catch (kg)	191.3	57.2	76.7	77.6	144.1
Total number	*219	61	*90	97	177
CPUE (kg/hr)	280.0	57.2	177	77.6	216.2
CPUE (no/hr)	320	61	207	97	266
Sample size					
Female, kg	97.8	48.3	24.4	15.8	69.4
no	106	50	27	19	83
kg/fish	0.923	0.966	0.904	0.832	0.836
Male, kg	74.5	8.9	18.4	21.2	74.7
no	91	11	23	28	94
kg/fish	0.819	0.809	0.800	0.757	0.795
Other species,kg(no)					
Smooth l.s.		2.3(1)		21.3(24)	8.4(30)
Arrowtooth fl.					
Greenland tur.					
Giant gre'dier					
Myctophiform					
Chinook salmon					
Pac. sl. shark					
B. magister					
Squid unident				0.081(1)	4.3(4)
Octopus unide.					
Jellyfish					

*Estimated

Midwater trawl catch data

Trawl no	HT-6	HT-7	HT-8	HT-9	HT-10
Date trawled	24/12/88	25/12/88	25/12/88	26/12/88	26/12/88
Duration (min)	65	35	60	59	60
Total catch (kg)	230.9	17.2	87.0	116.7	74.2
Total number	274	21	119	148	100
CPUE (kg/hr)	213.1	29.5	87.0	118.7	74.2
CPUE (no/hr)	253	36	119	151	100
Sample size					
Female, kg	100.3	-	43.3	61.9	34.5
no	113	-	58	75	43
kg/fish	0.888	-	0.747	0.825	0.802
Male, kg	97.3	-	43.7	54.8	39.7
no	121	-	61	73	57
kg/fish	0.804	-	0.716	0.751	0.696
Other species,kg(no)					
Smooth l.s.	19.0(15)	10.5(19)	4.5(11)	22.4(24)	14.8(54)
Arrowtooth fl.					
Greenland tur.					
Giant gre'dier					
Myctophiform		0.044(5)	0.053(4)		
Chinook salmon					
Pac. sl. shark					
B. magister					
Squid unident		0.417(1)	0.411(4)		0.3(3)
Octopus unide.					
Jellyfish		0.732(4)			

Table 1. Continued.

Midwater trawl catch data

Trawl no	HT-11	HT-12	HT-13	HT-14	HT-15
Date trawled	27/12/88	27/12/88	29/12/88	31/12/88	2/1/89
Duration (min)	57	60	98	60	70
Total catch (kg)	4.2	162.2	155.6	0	82.4
Total number	6	202	190	0	99
CPUE (kg/hr)	4.4	162.2	95.3	0	70.6
CPUE (no/hr)	6	202	116	0	85
Sample size					
Female, kg	3.0	84.7	74.7	-	46.3
no	4	101	86	-	54
kg/fish	0.750	0.839	0.869	-	0.857
Male, kg	1.2	77.5	80.9	-	36.1
no	2	101	104	-	45
kg/fish	0.600	0.767	0.778	-	0.802
Other species,kg(no)					
Smooth l.s.	7.0(17)	9.2(14)	18.7(32)	2.5(3)	10.6(6)
Arrowtooth fl.					
Greenland tur.					
Giant gre'dier		3.3(1)			
Myctophiform					
Chinook salmon					2.8(1)
Pac. sl. shark					
B. magister					
Squid unident	0.4(1)	0.3(3)		0.06(2)	
Octopus unide.					0.5(1)
Jellyfish	0.3(2)				1.4(3)

Midwater trawl catch data

Trawl no	HT-16	HT-17	HT-18	HT-19	HT-20
Date trawled	23/1/89	25/1/89	28/1/89	5/2/89	6/2/89
Duration (min)	120	109	120	57	47
Total catch (kg)	142.9	53.9	38.5	875.2	4,441.4
Total number	175	66	48	*1,098	*5,350
CPUE (kg/hr)	71.5	29.7	19.3	921.3	5,669.9
CPUE (no/hr)	88	36.3	24	1,156	6,830
Sample size					
Female, kg	59.2	28.4	24.3	74.0	185.2
no	66	32	29	87	210
kg/fish	0.897	0.888	0.838	0.851	0.882
Male, kg	83.7	25.5	14.2	141.2	131.1
no	109	34	19	183	171
kg/fish	0.768	0.750	0.747	0.772	0.767
Other species,kg(no)					
Smooth l.s.	6.9(4)	6.2(9)	20.7(37)	11.1(6)	
Arrowtooth fl.					
Greenland tur.					
Giant gre'dier					
Myctophiform					
Chinook salmon					
Pac. sl. shark					
B. magister					
Squid unident	2.7(7)	1.0(7)		3.0(18)	
Octopus unide.					
Jellyfish					

*Estimated

Table 1. Continued.

Midwater trawl catch data

Trawl no	MT-21	MT-22	MT-23	**MT-24
Date trawled	7/2/89	13/2/89	16/2/89	26/2/89
Duration (min)	40	45	55	14
Total catch (kg)	3,797.2	3,336.1	1,252.0	-
Total number	*4,594	*3,823	*2,054	-
CPUE (kg/hr)	5,695.8	4,448.1	1,365.8	-
CPUE (no/hr)	6,891	5,097	2,241	-
Sample size				
Female, kg	186.6	215.3	78.4	8.7
no	217	233	116	10
kg/fish	0.860	0.924	0.676	0.870
Male, kg	121.7	65.7	95.3	316.5
no	156	89	169	429
kg/fish	0.780	0.738	0.564	0.738
Other species, kg(no)				
Smooth l.s.		1.9(1)	1.0(2)	
Arrowtooth fl.	-(1)			
Greenland tur.	-(1)			
Giant gre'dier			8.1(1)	
Myctophiform				
Chinook salmon				
Pac. sl. shark			20(2)	
B. magister		0.77(2)		
Squid unident			0.33(1)	
Octopus unide.				
Jellyfish				

*Estimated, **Net was broken during hauling. Total catch was estimated roughly between 12 and 15 tons.

Table 2. Size composition of pelagic pollock caught during the Japan-U.S. joint acoustic/midwater trawl survey by Kaiyo maru in the Aleutian Basin from December of 1988 to March of 1989.

Size class	International waters			U.S. waters			Whole survey area		
(cm)	♂	♀	Total	♂	♀	Total	♂	♀	Total
34-35	-	-	-	1	-	1	1	-	1
-36	-	-	-	9	-	9	9	-	9
-37	-	-	-	5	1	6	5	1	6
-38	-	-	-	6	-	6	6	-	6
-39	1	-	1	8	1	9	9	1	10
-40	2	-	2	15	2	17	17	2	19
-41	1	2	3	7	6	13	8	8	16
-42	3	3	6	12	9	21	15	12	27
-43	8	2	10	28	15	43	36	17	53
-44	26	7	33	26	13	39	52	20	72
-45	32	14	46	67	31	98	99	45	144
-46	61	19	80	161	52	213	222	71	293
-47	92	37	129	266	106	372	358	143	501
-48	85	57	142	328	135	463	413	192	605
-49	69	59	128	320	208	528	389	267	656
-50	41	77	118	231	238	469	272	315	587
-51	31	58	89	121	193	314	152	251	403
-52	7	47	54	56	166	222	63	213	276
-53	2	17	19	20	84	104	22	101	123
-54	3	13	16	11	59	70	14	72	86
-55	-	3	3	5	35	40	5	38	43
-56	-	3	3	-	12	12	-	15	15
-57	-	1	1	1	7	8	1	8	9
-58	-	-	-	-	4	4	-	4	4
-59	-	-	-	-	6	6	-	6	6
-60	-	-	-	-	3	3	-	3	3
Total	464	419	883	1,704	1,386	3,090	2,168	1,805	3,973
Mean	47.1	48.9	48.0	47.5	49.4	48.4	47.4	49.3	48.3

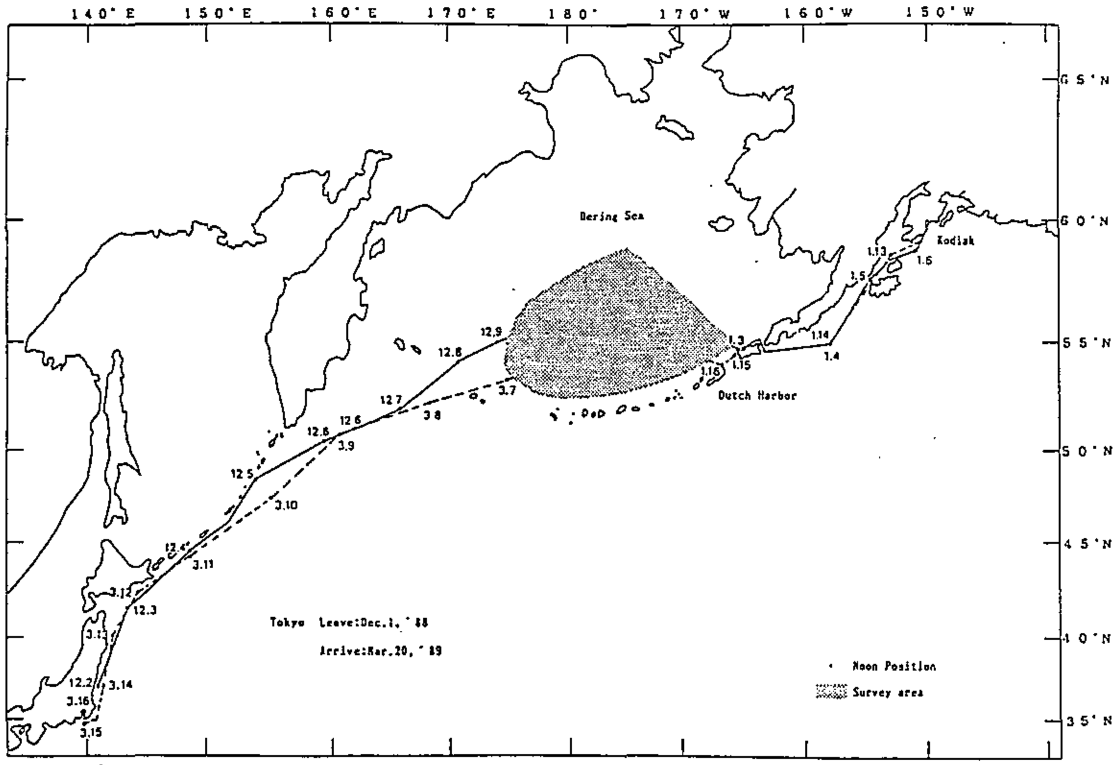

Figure 1. Track and noon positions of a cruise by Kaiyo maru during the Japan-U.S. joint acoustic/midwater trawl survey for pelagic pollock in the Aleutian Basin from December 1 of 1988 to March 20 of 1989.

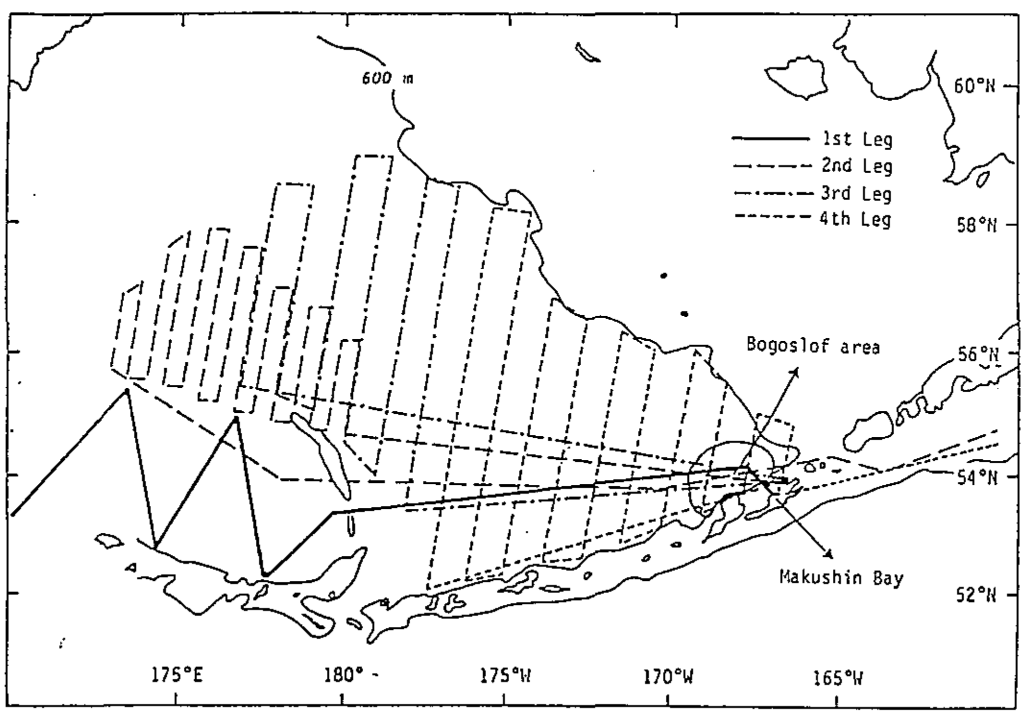

Figure 2. Prearranged transect lines for the Japan-U.S. joint acoustic/midwater trawl survey by Kaiyo maru in the Aleutian Basin from December of 1988 to March of 1989.

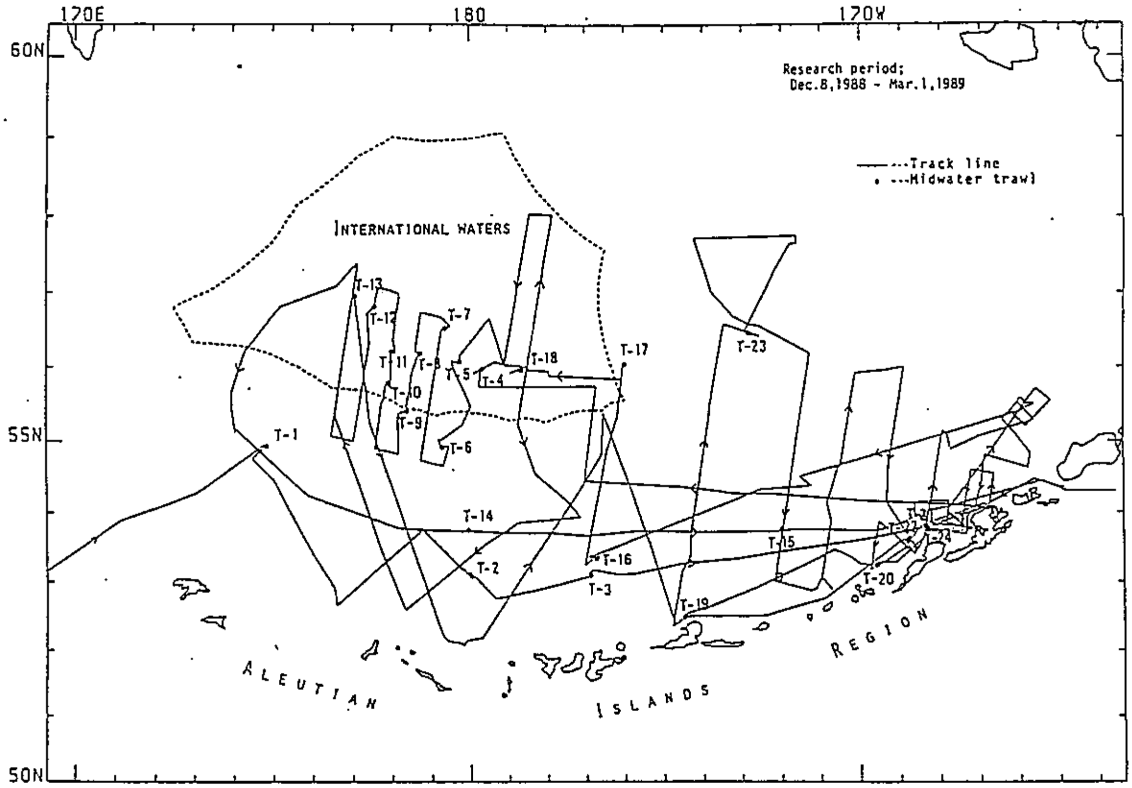

Figure 3. Actual track lines and sampling stations by midwater trawl gear conducted during the Japan-U.S. joint acoustic/midwater trawl survey for pelagic pollock by Kaiyo maru in the Aleutian Basin from December of 1988 to March of 1989.

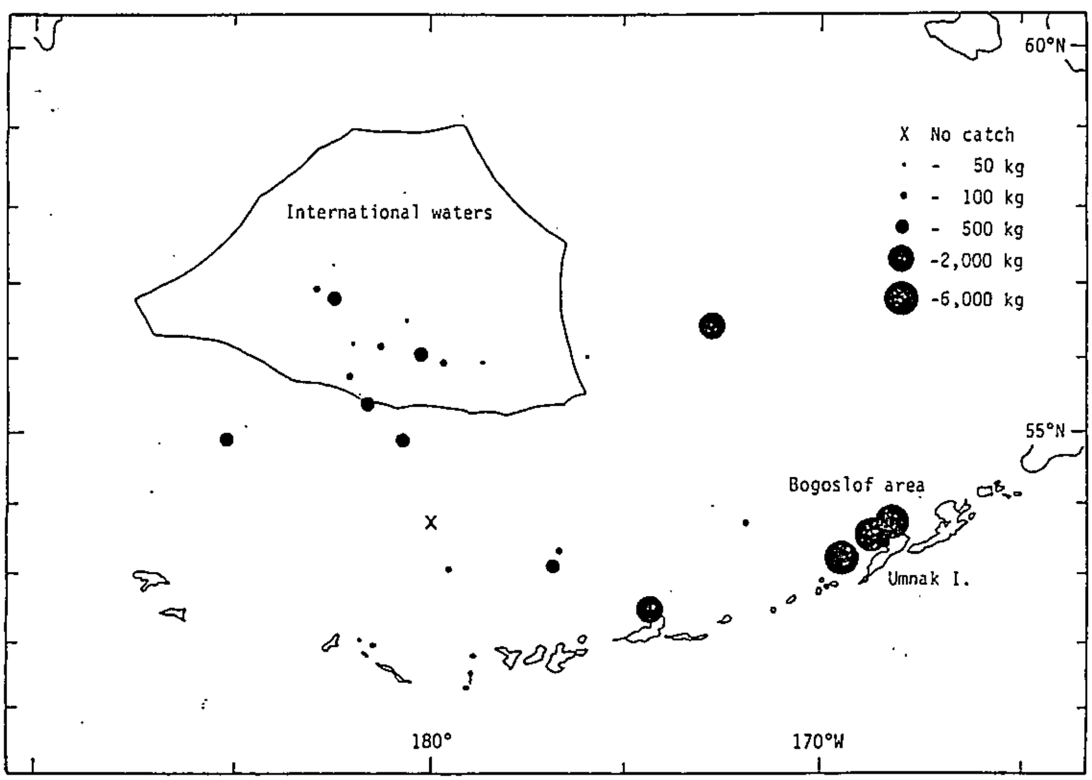

Figure 4. CPUE (kg/hour) of pollock by sampling station of midwater trawl during the Japan-U.S. joint acoustic/midwater trawl survey by Kaiyo maru in the Aleutian Basin from December 1988 to March 1989.

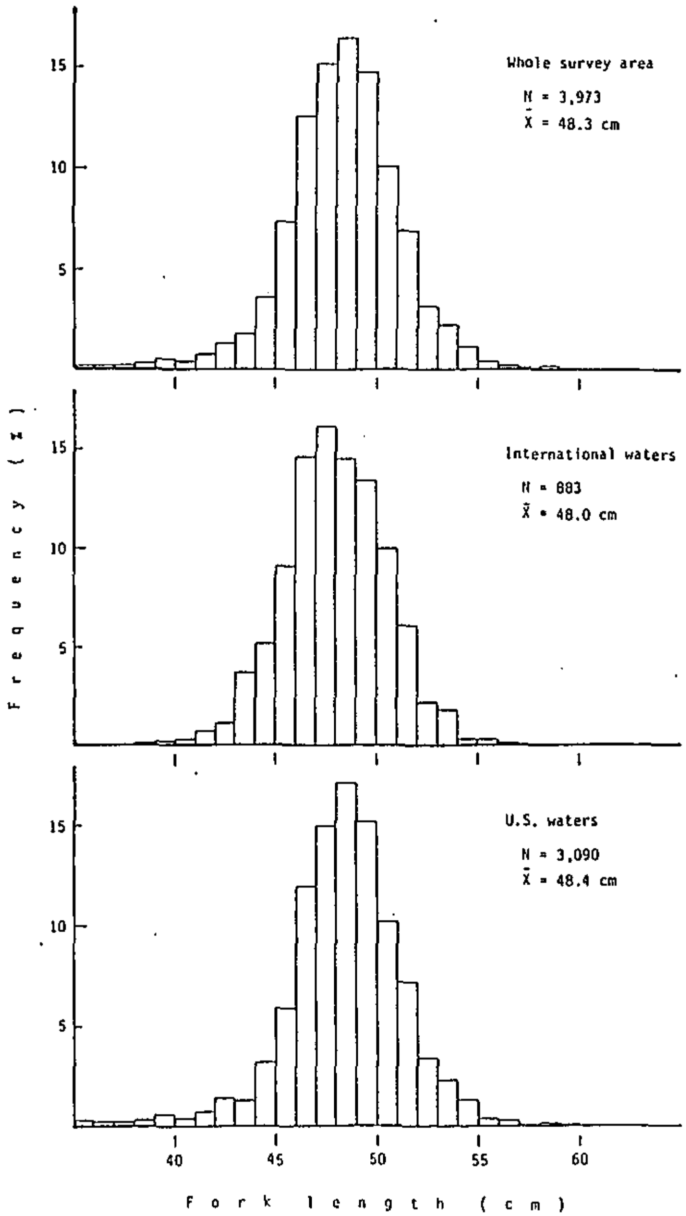

Figure 5. Size composition of pollock caught during the Japan-U.S. joint

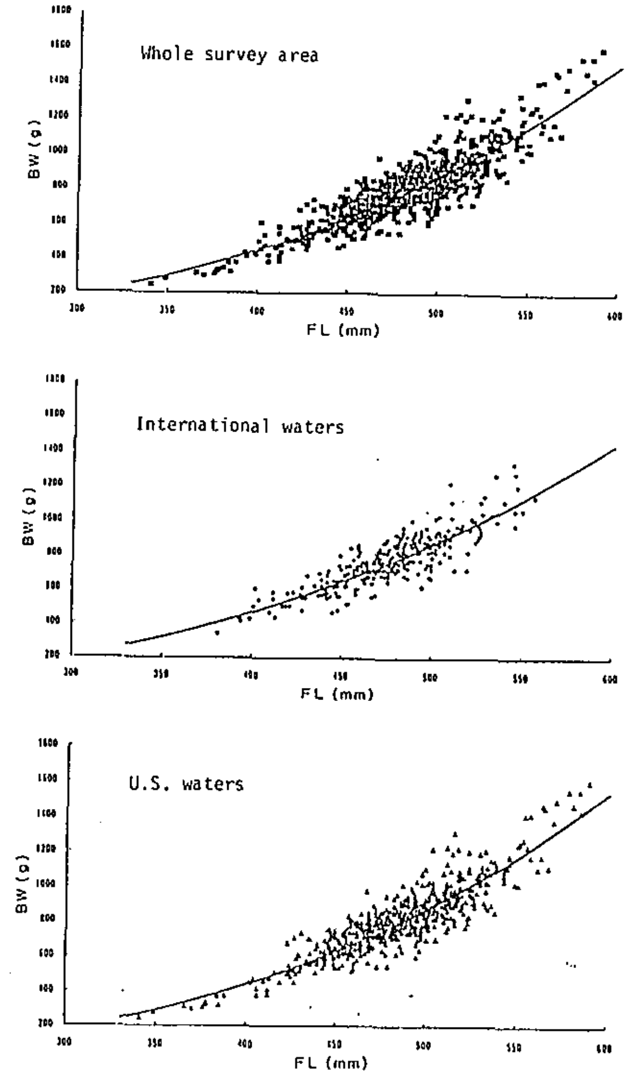

Figure 6. Length-weight relationship of pelagic pollock caught in midwater trawl survey by Kaiyo maru in the Aleutian Basin of the Bering Sea from December 1988 to March 1989.

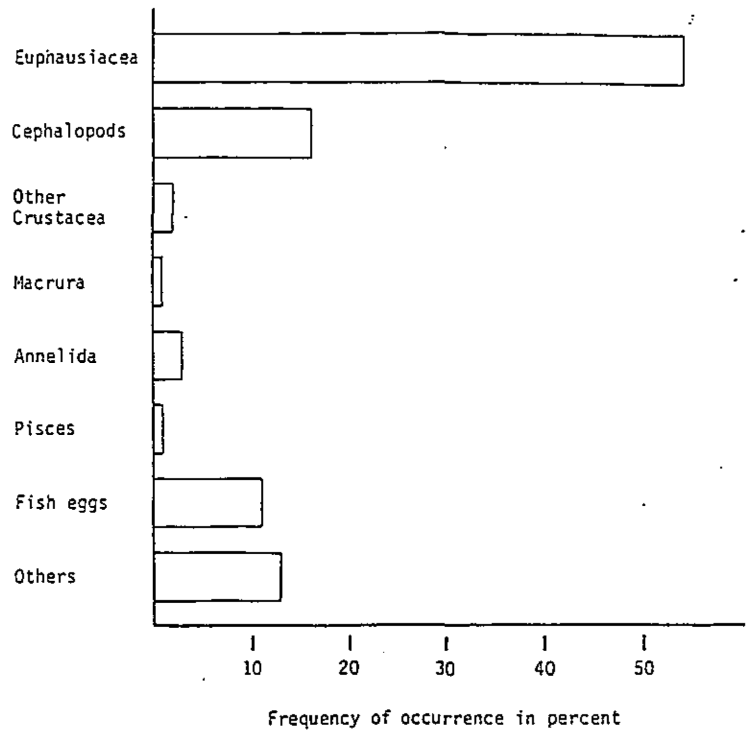

Figure 7. Stomach contents of pollock caught during the Japan-U.S. joint acoustic/midwater trawl survey by *Kaiyo maru* in the Aleutian Basin from December 1988 to March 1989.

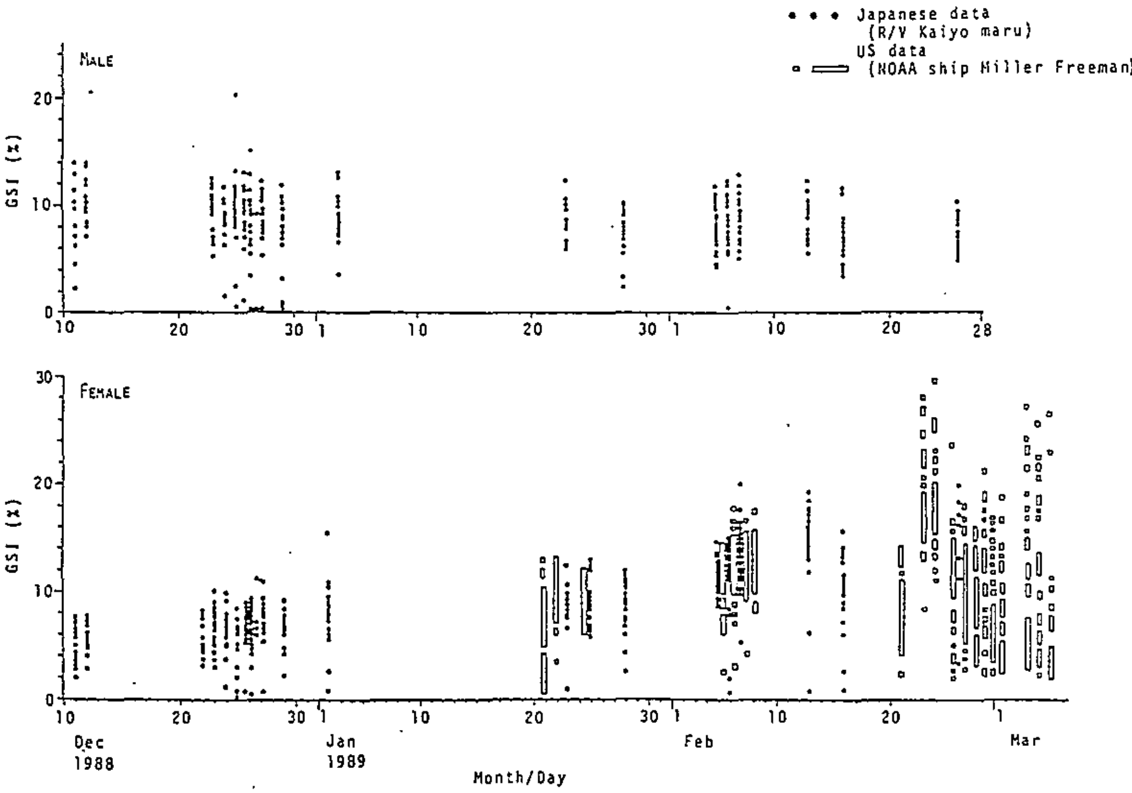

Figure 8. Changes of gonadosomatic index (GSI) of pollock in the Aleutian Basin during the period from December of 1988 to March of 1989.

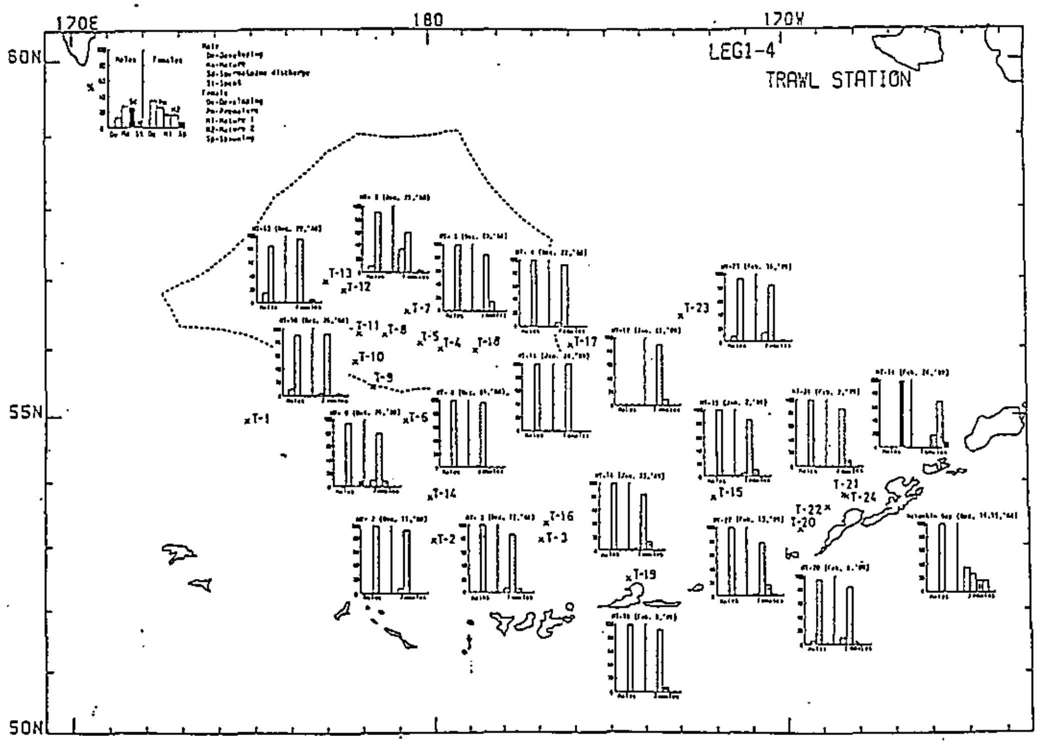

Figure 9. Composition of maturity stages of pollock gonad by sampling station observed during the Japan-U.S. joint acoustic/midwater trawl survey by *Kaiyo maru* in the Aleutian Basin from December of 1988 to March of 1989.

Migration of Eastern Bering Sea Herring, as inferred from 1983 - 1988 Joint Venture and Foreign Trawl Bycatch Rates

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INTRODUCTION

Migration of Pacific herring (*Clupea harengus pallasi*) in the eastern Bering Sea was first described during Soviet research in support of the Soviet directed herring fisheries in the early 1960's (Dudnik and Usol'tsev 1964, Rumyantsev and Darda 1970). Subsequent records of the location of Japanese directed herring fisheries summarized in NPFMC (1983) and by Wespestad and Barton (1979) supported the two major migration patterns observed by the Soviets. During June and July, a southwestward movement of herring was observed in the northern Bering Sea, from Norton Sound to Nunivak Island (Figure 1). In Bristol Bay, Japanese vessels followed herring moving along the Alaska Peninsula during the summer months, heading offshore from Unimak Island along the continental shelf edge to the northwest in late summer. It was commonly hypothesized that stocks from both the northern and southern coasts of western Alaska shared a common wintering ground northwest of the Pribilof Islands (Wespestad and Barton 1979). Soviet and Japanese commercial vessels exploited large concentrations of herring during the 1960's near the continental shelf edge between the Pribilof Islands and St. Matthew Island from October through March. Foreign directed fishing for herring ended in 1980. After that time herring became a prohibited species and foreign fleets no longer tracked the movements of herring in the Bering Sea.

Stock identification studies were conducted to determine the origins of herring captured in a food/bait fishery near Dutch Harbor in July and August. These studies established that most of the herring in this area were Togiak spawning stocks (Rowell 1986, Rogers and Schnepf 1985, Rogers et al. 1984, Walker and Schnepf 1982).

Spawning locations of herring in the eastern Bering Sea have been generally well-documented since the beginning of the Bering Sea herring sac roe herring fisheries in 1978. Other than the limited stock identification studies of the Dutch Harbor food/bait fishery, information about the herring migration at other times of the year has not been available since the cessation of foreign directed fishing for herring.

Observer records of herring caught incidental to foreign and joint venture groundfish trawling provide another source of information about the timing and location of herring migration. The NPFMC has required a high level of observer sampling of foreign and joint venture groundfish harvests since 1983. This

paper examines the ratio of the weight of the herring catch to the total weight of the groundfish catch in observer records from Pacific cod (*Gadus macrocephalus*) and pollock (*Theregra chalcogramma*) bottom trawl tows, in order to define an index of herring abundance. The index is used to determine the timing and location of herring stocks during their annual migration. This index would be expected to fluctuate with groundfish density as well as with herring density. However, because the herring migration is a relatively distinct phenomenon, the index is sufficient to delineate the general movements of herring stocks during the annual migration. Also, over the 1983 through 1988 period, the abundance of both herring and groundfish stocks was relatively constant.

METHODS

The weights of herring bycatch and total groundfish catches were recorded by observers aboard joint venture and foreign groundfish vessels from 1983 through 1988. These data were summarized by month, 1/2° latitude by 1° longitude area, and target fishery category. Target fishery categories were arbitrarily assigned in the observer records based on the species composition of the catch, using criteria established by the NMFS observer program. The observer records used for this study were primarily from pollock and cod bottom trawls, using the NMFS-designated categories "pollock bottom trawl" and "other bottom trawl". Trawl tows in these target categories were defined as consisting of less than 20% Atka mackerel, less than 20% flatfish, and less than 95% pollock. Tows with greater than 95% pollock are assigned to a midwater trawl category by the NMFS criteria. Because preliminary analyses showed that midwater trawl bycatch rates were substantially less than bottom trawls, trawl tows from the midwater trawl category were not used. Because little difference in herring bycatch rates was found between the "pollock bottom trawl" and "other bottom trawl" categories, tows from both of these categories were combined.

A herring bycatch rate index was computed by dividing the observed herring catch for each month and 1/2° latitude by 1° longitude area from 1983 through 1988 by the total observed groundfish catch for the same area and period. The resulting bycatch rates by latitude, longitude and month comprised a grid that covered much of the Bering Sea in most months.

The area of study was restricted to 160° W. to 180° longitude and 51° N. to 61° N. latitude. Although some flatfish trawling occurs east of 160° W., little pollock and cod bottom trawling occurs east of this longitude. Little groundfish trawling effort occurred north of 61° in the winter months, although herring did appear to occur in this area. For each month, the grid of herring bycatch rates was smoothed by distance weighted least squares[1] to aid in the interpretation of migratory patterns. These data were plotted as a 3-

[1]The SYSTAT/SYGRAPH distance weighted least squares algorithm was used for smoothing, with a tension parameter (weighting) equal to the inverse of the number of 1/2° latitude by 1° longitude squares containing bycatch rates for a given month over the 1983-1988 period (SYSTAT 1988).

dimensional surface, with the vertical axis representing the bycatch rate. In order to better define the location of the herring migration with respect to the NPFMC's management areas (Fig. 2), the bycatch rate data were also plotted as a contour surface. Graphs of these surfaces for each month were used to delineate the average distribution of herring in the eastern Bering Sea over the 1983 through 1988 period.

In some months few tows were made in some 1/2° latitude by 1° longitude areas. Bycatch rates computed from areas and months with small sample size may not be representative of actual herring abundance. To depict the sample size on which the bycatch rates are based, the magnitude of the observed total groundfish catch in each square was indicated by shading.

RESULTS AND DISCUSSION

The pattern of observed herring bycatch rates in the southeastern Bering Sea strongly supported the clockwise migratory pattern inferred from earlier stock identification studies and Soviet and Japanese research. During January, herring bycatch was almost nonexistent (Fig 3). However, almost no data were available for the month of January from the herring wintering grounds northwest of the Pribilof Islands, as indicated by the shading in the bottom panel of Figure 3. The occurrence of substantial trawling effort along the Alaska Peninsula coupled with no herring bycatch strongly suggests that no herring overwinter in the southern Bering Sea. In February (Fig. 4) the observed fishing effort shifted northward. A few vessels fished southwest of St. Matthew Island and recorded high herring bycatch rates, consistent with the earlier reports of the herring wintering location in this area. Substantial bottom trawling effort along the continental shelf edge from the Pribilof Islands south to Unimak Pass resulted in almost no herring bycatch. In March and April (Figs. 5, 6), almost no herring bycatch was reported, although there was very little effort in the area of the herring wintering grounds. During the May herring spawning period herring bycatch rates were again very low (Fig. 7), except for some moderate bycatch just north of the Pribilofs. This could be due to immature juvenile herring that remain on the wintering grounds year round as suggested by Rumyantsev and Darda (1970). Peak herring spawning for the large Togiak stock occurred during early to mid-May. In June, high herring bycatch rates were reported along the Alaska Peninsula, southwest of Port Moller (Fig. 8). Fishing effort during June covered much of the Bering Sea, with little herring bycatch reported elsewhere. By July, most of the high herring bycatch rates shifted to the "horseshoe" area just north of Unimak Pass (Figure 9), where the 100 fathom contour creates a "horseshoe" shape. The distribution of bycatch rates indicates that offshore movement toward the Pribilofs has already begun in July, with moderate bycatch rates reported to the north of the Pribilof Islands. Again, the widespread distribution of fishing effort indicates that few herring are found in other areas. By August, herring bycatch was relatively high along the entire continental shelf edge (Fig. 10), with high bycatch rates continuing in the horseshoe area. By September, bycatch rates in the horseshoe area declined, and the area northwest of the Pribilofs became the dominant area of herring bycatch (Fig. 11). Sampling effort covers a wide area of the Bering

Sea, with good coverage along the entire continental shelf edge. In October, despite a large amount of effort in the horseshoe area, no herring bycatch was reported (Fig. 12). Herring bycatch was reported from the immediate vicinity of the Pribilof Islands and from the area southwest of St. Matthew Island. Sampling coverage is adequate along most of the continental shelf edge. In November, herring bycatch was low except for the area southwest of St. Matthew Island, with good sampling coverage over most of the continental shelf edge (Fig. 13). In December, some very high bycatch rates were reported southwest of St. Matthew Island (Fig. 14). Sample size was small however, so that the data are best interpreted as indicating the presence of herring. Further quantification of the herring bycatch rate may not be appropriate when sample sizes are small.

The herring migration in the southern Bering Sea appears to be a discrete phenomenon in time and space. The distribution of herring is unlike that of other prohibited species such as crab and halibut, which tend to have much broader distributions over a wider range of time. Because herring occupy areas along the migration route for only relatively short periods, herring should be easier for groundfish trawlers to avoid than other prohibited species.

The sporadic occurrence of high bycatch rates on the wintering grounds is consistent with the locations of the earlier Soviet and Japanese directed fisheries. Because sample sizes during the winter months in these areas were small, high herring bycatch rates only occur occasionally in the aggregated data.

These data provide little information on the migration of the northerly component of herring stocks which spawn from Norton Sound to Etolin Strait. Groundfish trawling effort in the area north and east of the herring wintering grounds that would intercept these stocks was very low from 1983 through 1988.

The movement of herring offshore from the horseshoe area occurred earlier than previously reported. It appears that this movement begins in July, and that substantial numbers of herring are in the area northwest of the Pribilof Islands by August.

CONCLUSIONS

1. Herring bycatch rates from 1983-88 joint venture and foreign bottom trawling for Pacific cod and pollock strongly support the previous Soviet and Japanese hypothesis of a clockwise migration of herring around the southern Bering Sea, with a wintering ground northwest of the Pribilof Islands.

2. Herring stocks migrate along the Alaska Peninsula during the summer months, appearing in the Port Moller area in early to mid-June.

3. Offshore movement from the Unimak Pass "horseshoe" area to the Pribilofs begins as early as July, and is complete by mid-September.

4. Bycatch rates were extremely low along the Alaska Peninsula except for the summer months, indicating that all herring stocks winter offshore.

5. The herring migration is a relatively discrete phenomenon. At any one time, herring stocks occupy only a small proportion of the Bering Sea.

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ACKNOWLEDGMENTS

The joint venture and foreign trawl catch data on which this paper is based were collected under the auspices of the National Marine Fisheries Service Observer Program. The assistance of Russ Nelson and Jerry Berger of the Observer Program at the Alaska Fishery Science Center in obtaining summarized observer information is gratefully acknowledged.

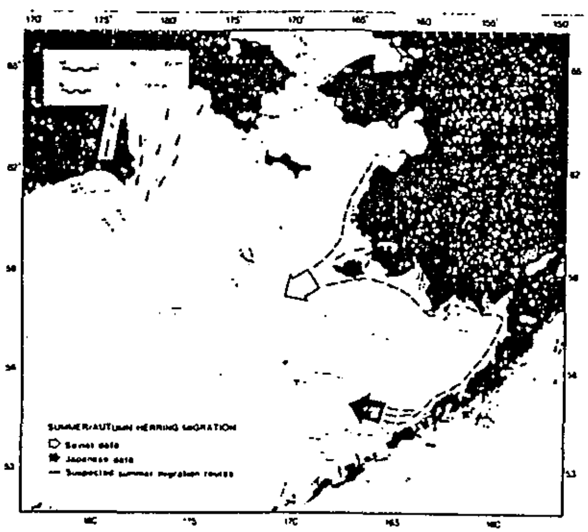

Figure 1. Summer and autumn migration routes to winter grounds. Large solid arrow: area of reappearance in offshore waters as determined by Soviet research and Japanese catches. Large open arrow: area of autumn reappearance in offshore waters reported from Soviet research. Small arrows: possible summer feeding routes and autumn migration routes (from Wespestad and Barton 1979).

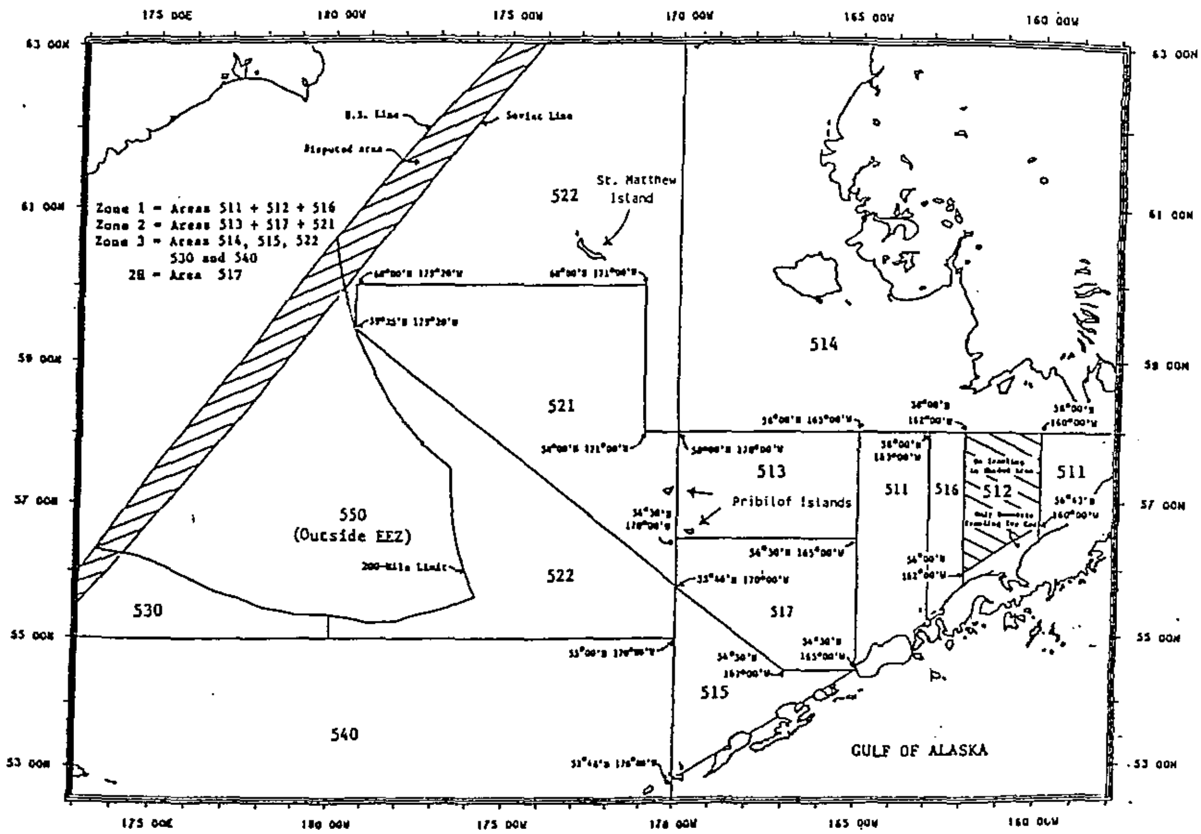

Figure 2. National Marine Fisheries Service regulatory reporting areas for the Bering Sea/Aleutians area.

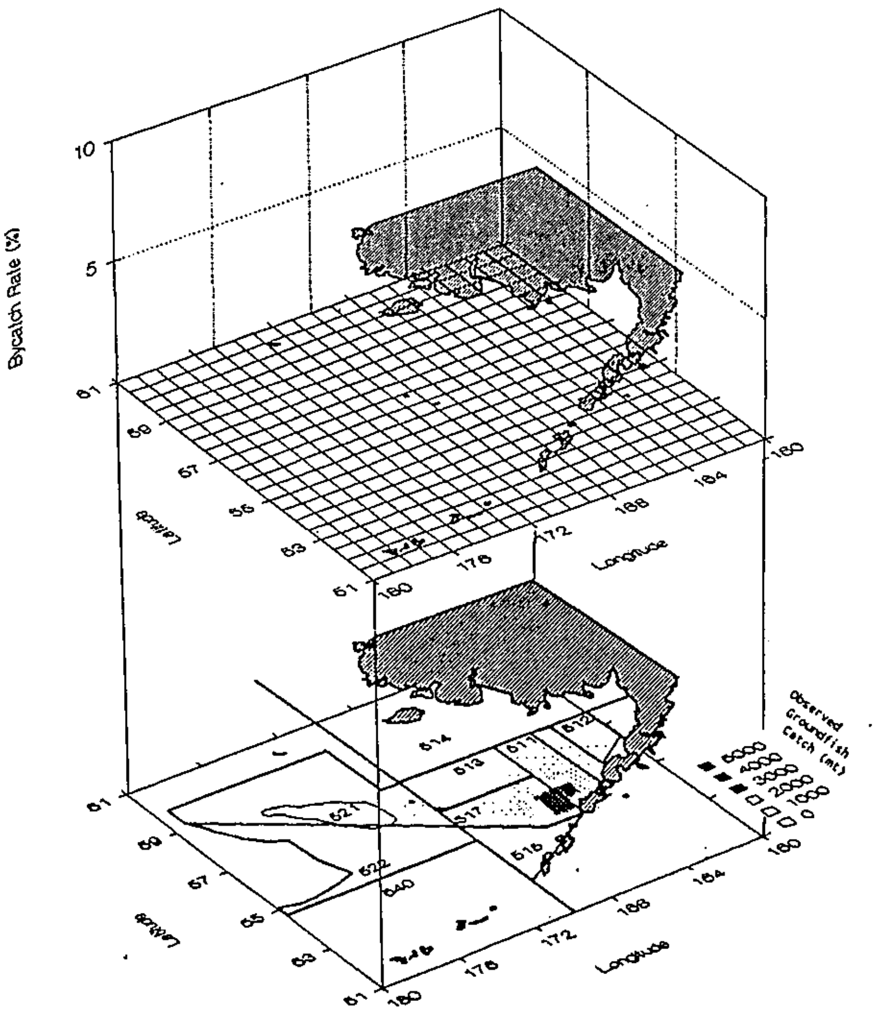

Figure 3. January herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

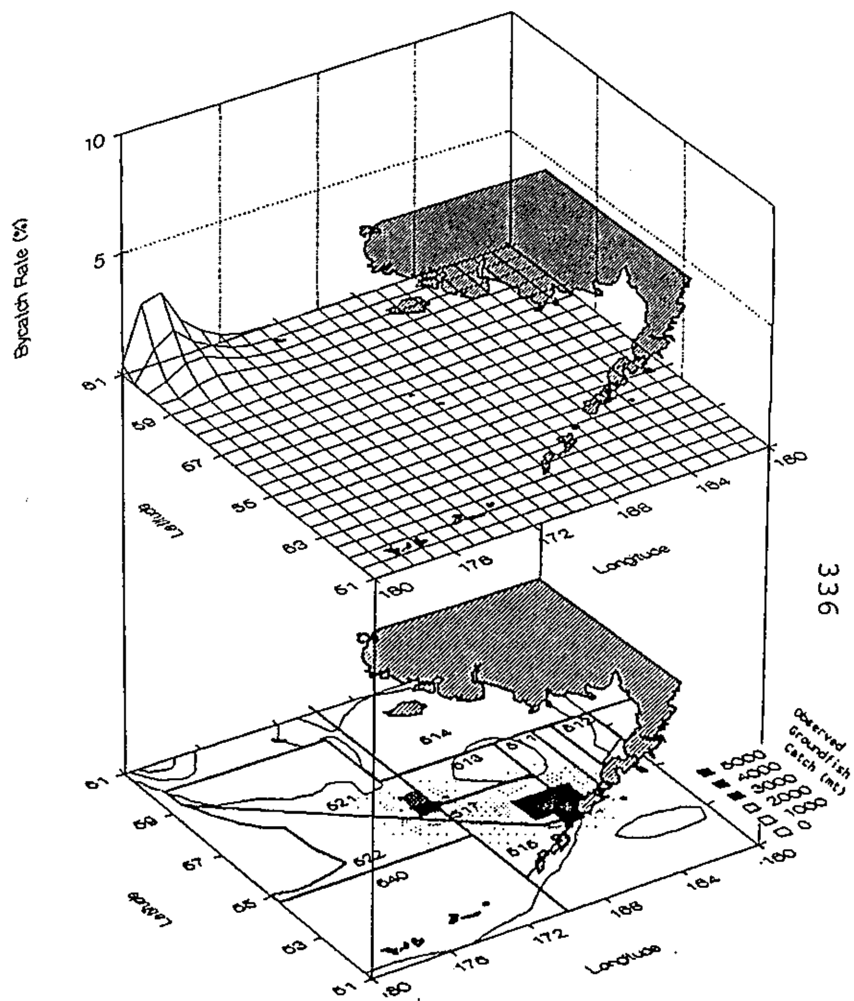

Figure 4. February herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

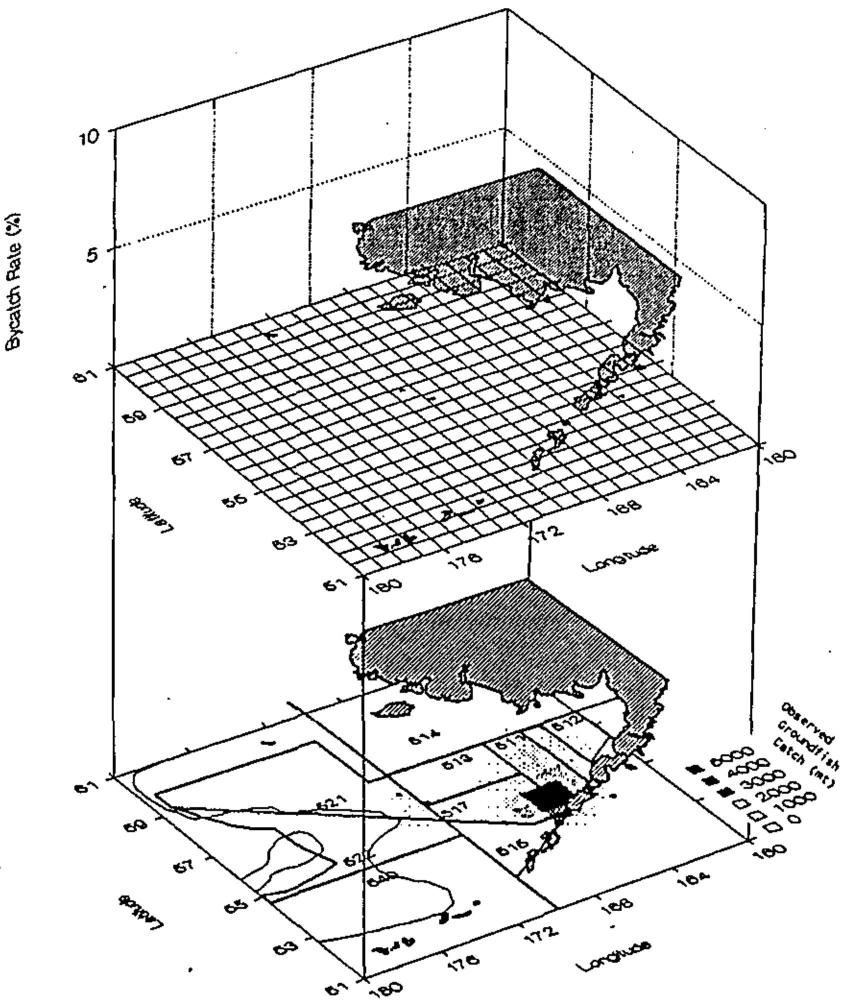

Figure 5. March herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

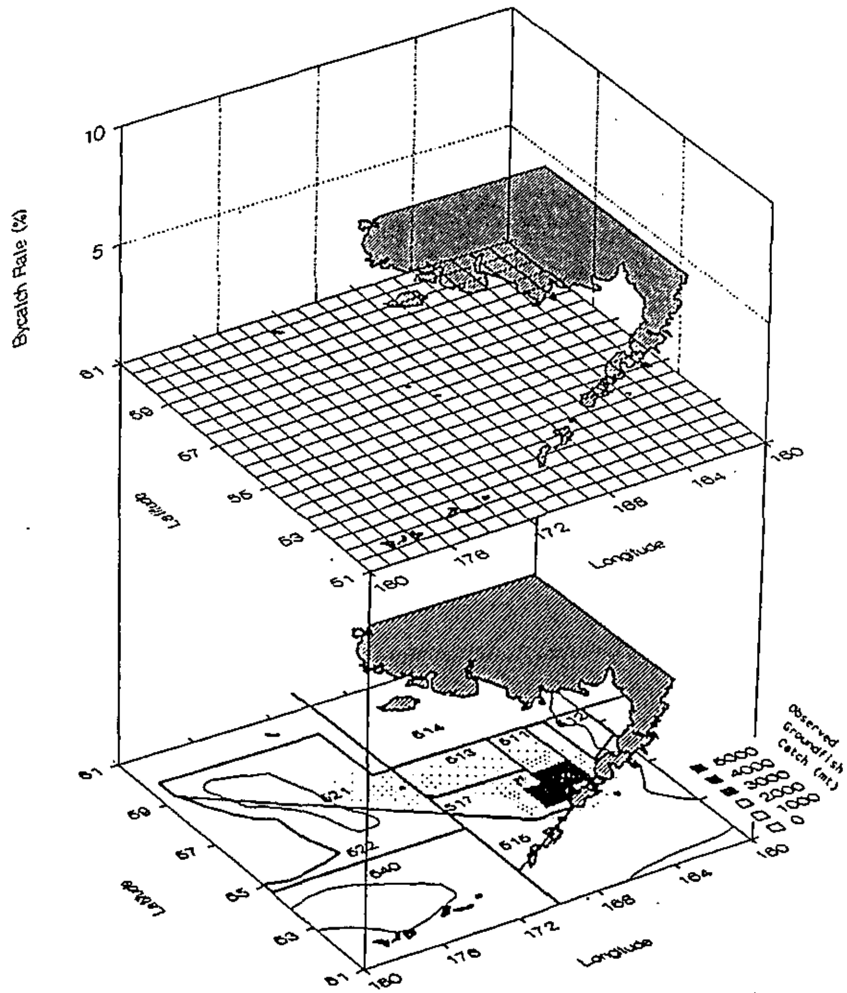

Figure 6. April herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

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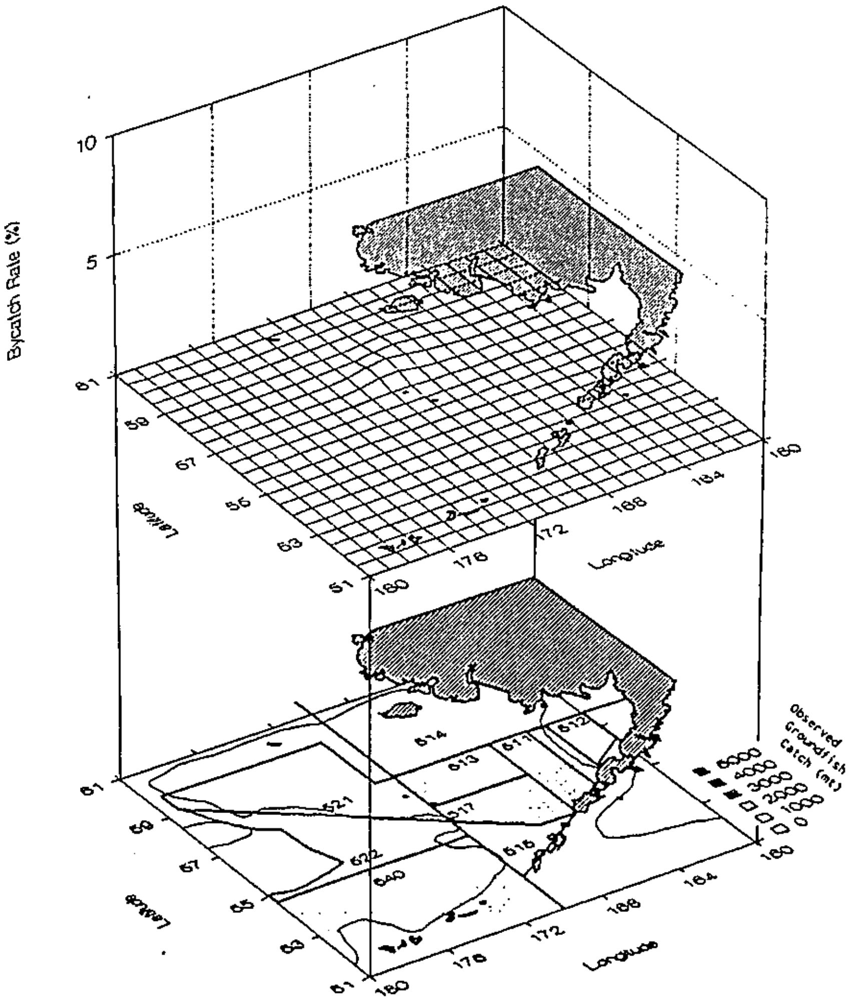

Figure 7. May herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas). 13

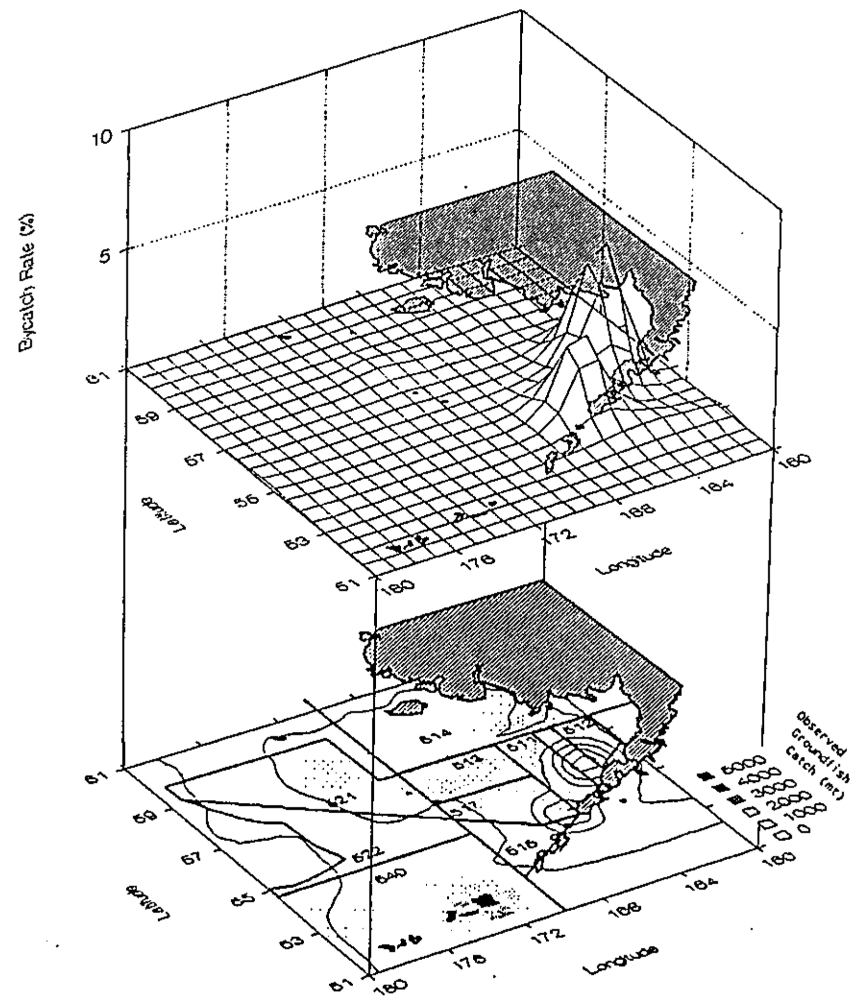

Figure 8. June herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas). 13

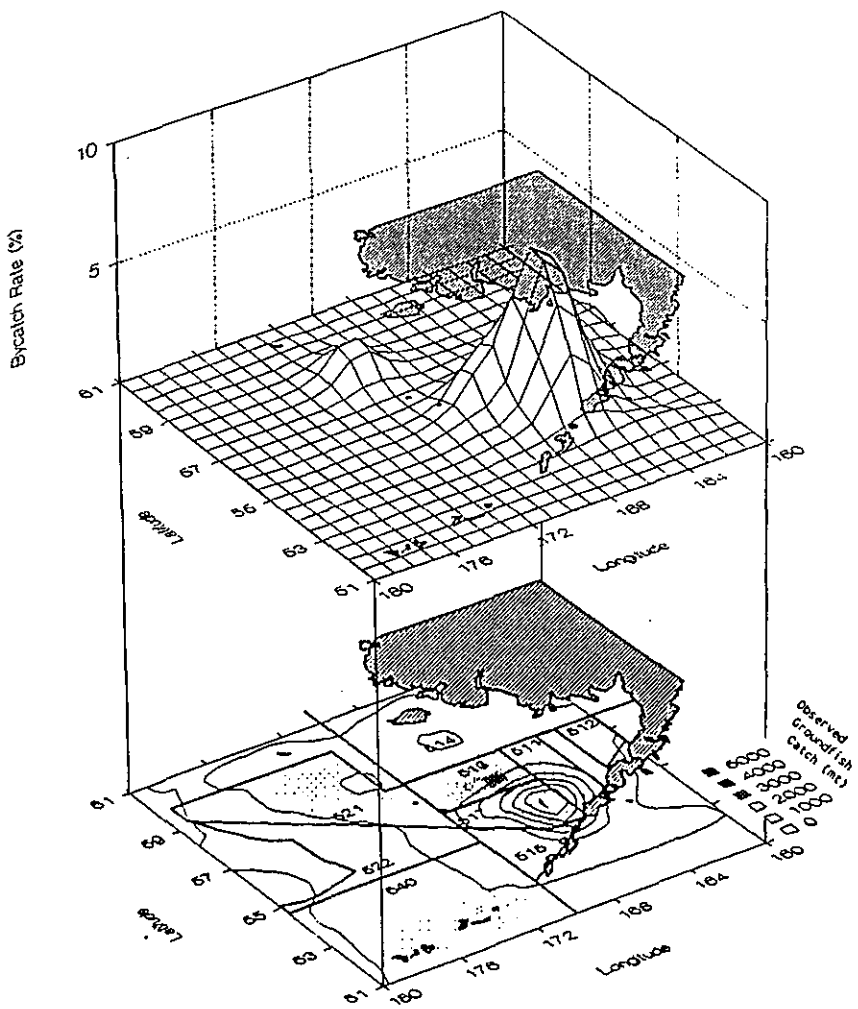

Figure 9. July herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

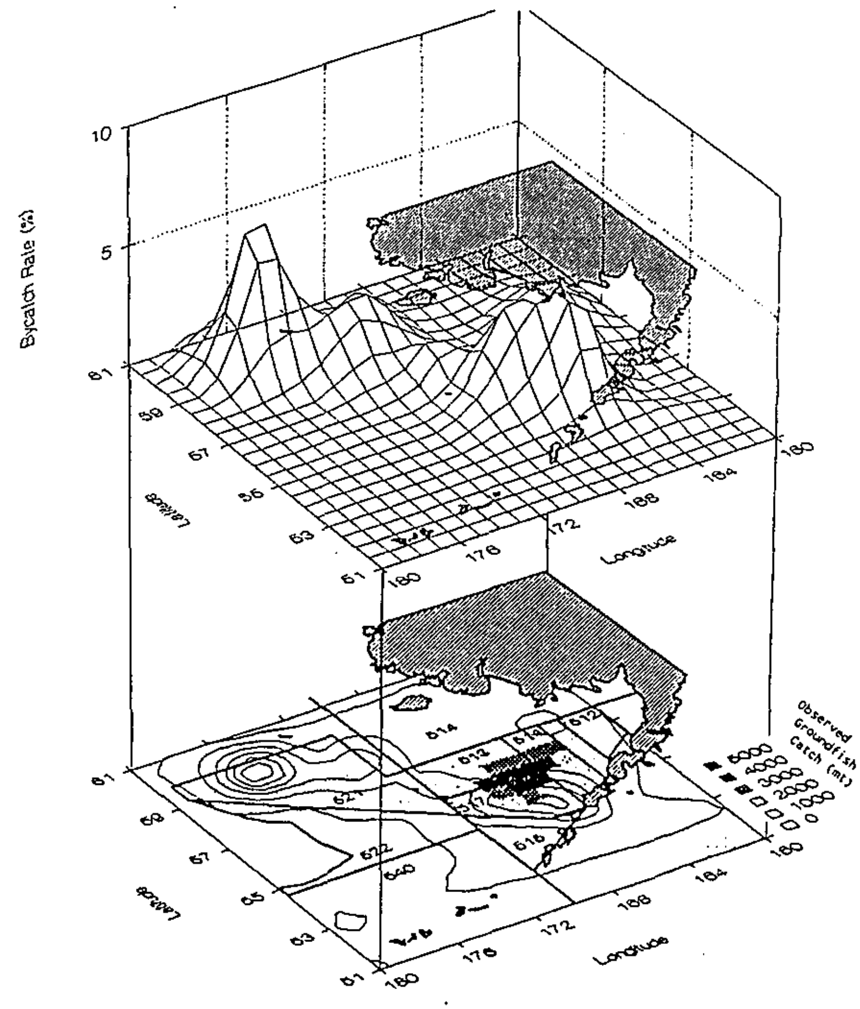

Figure 10 August herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

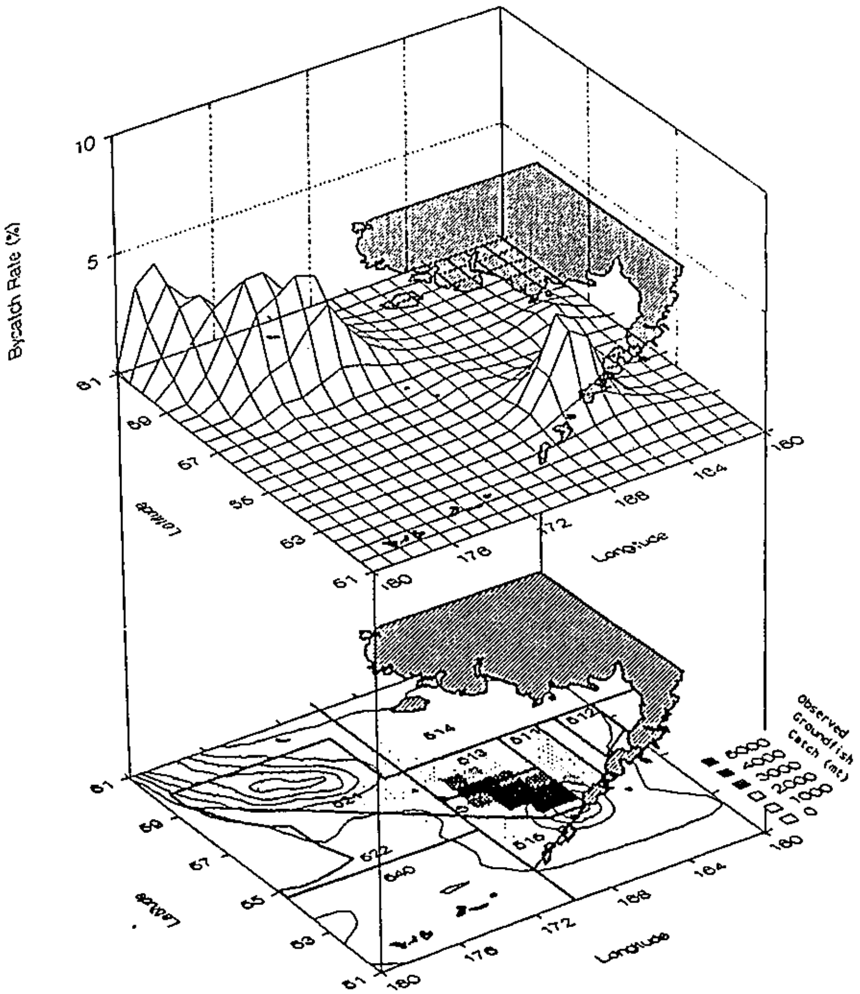

Figure 11. September herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988

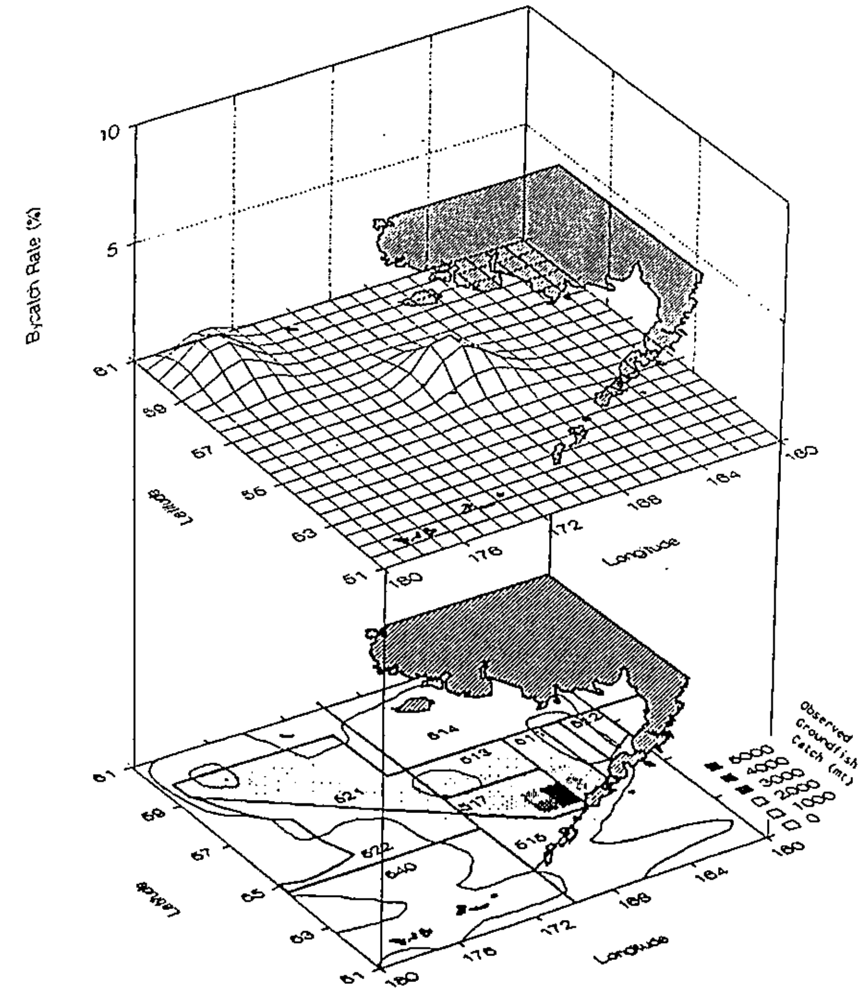

Figure 12. October herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

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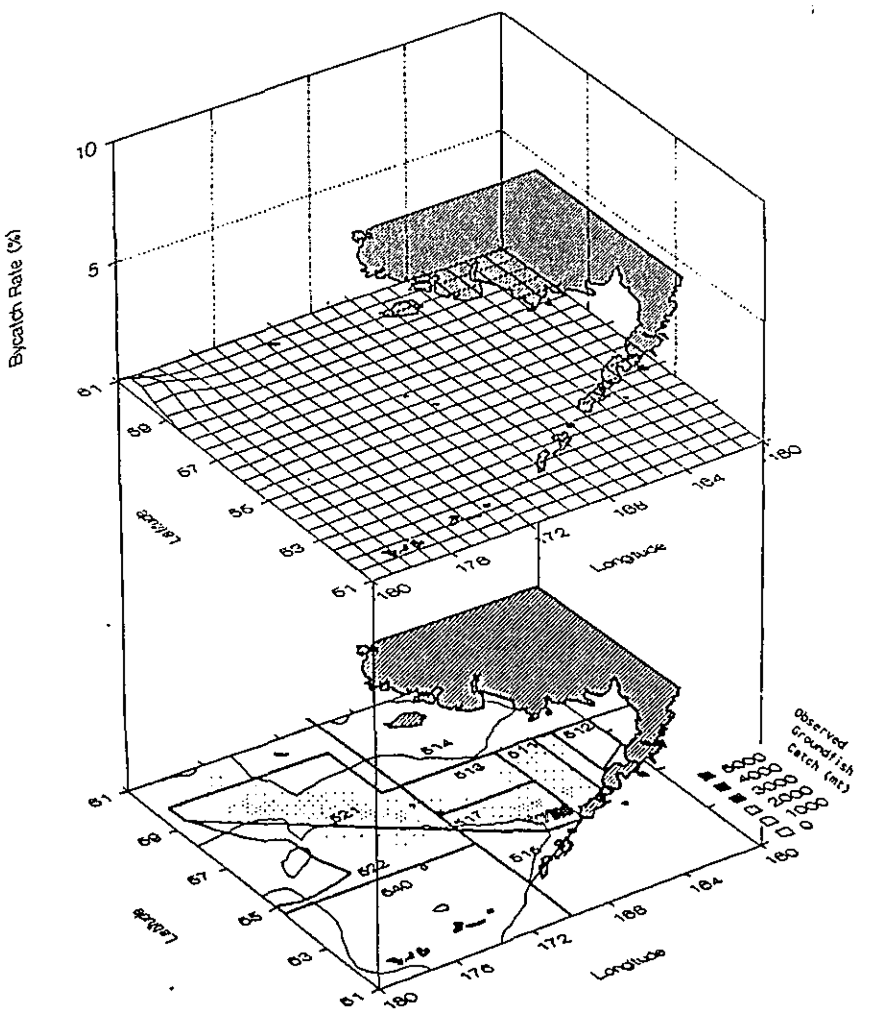

Figure 13. November herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

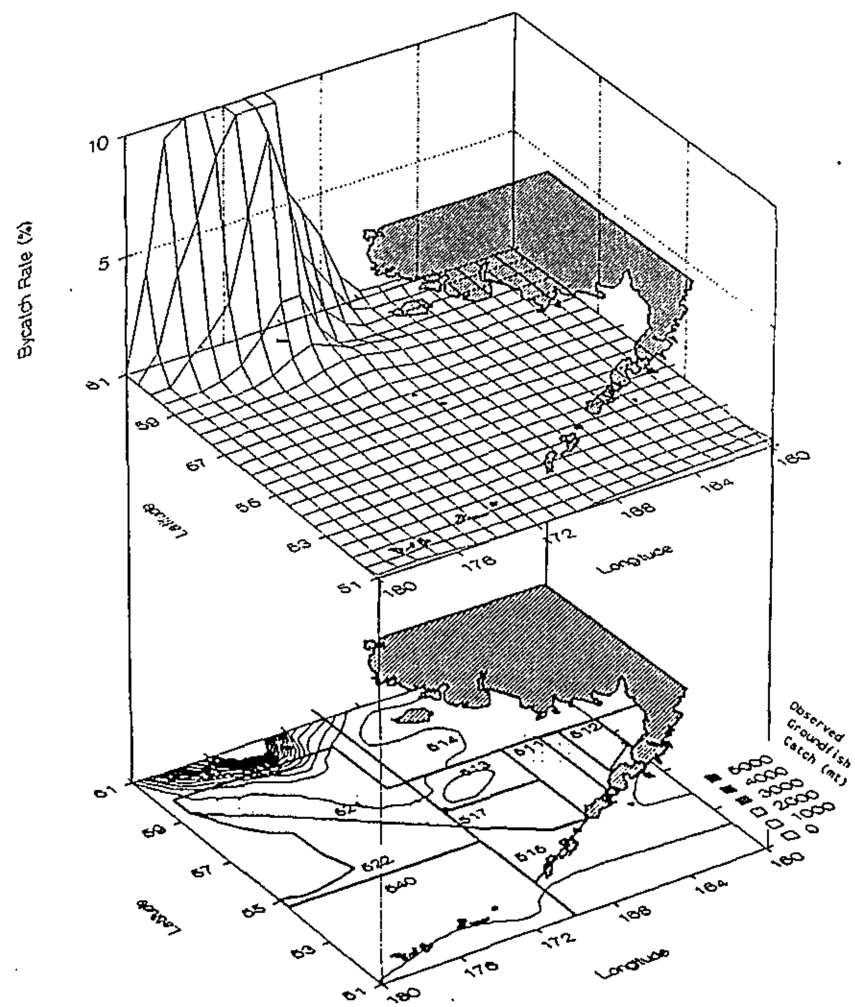

Figure 14. December herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

Future Field Research Plans for Walleye Pollock in the Bering Sea

Fisheries Agency of Japan
Tokyo, Japan

1. 1990 Summer survey

Type: Acoustic/midwater trawl survey.
Period: Middle June to Middle October.
Area: Aleutian Basin (Internal waters and U.S. Waters) and eastern Bering Sea Shelf.
Vessel: Chartered landbased trawler (350 ton class).

2. 1991 Summer survey

Type: Acoustic/midwater trawl survey.
Period: Middle June to Middle October.
Area: Aleutian Basin (Internal waters and U.S. Waters) and eastern Bering Sea Shelf. If possible western Basin area of U.S.S.R. Waters.
Vessel: Chartered landbased trawler (350 ton class).

3. 1992 Summer survey

Type: Acoustic/midwater trawl survey.
Period: Middle June to Middle October.
Area: Aleutian Basin (Internal waters and U.S. Waters) and eastern Bering Sea Shelf. If possible western Basin area of U.S.S.R. Waters.
Vessel: Chartered landbased trawler (350 ton class).

4. 1992/1993 Winter survey

Type: Acoustic/midwater trawl survey.
Period: Late 1992 to early 1993.
Area: Aleutian Basin (Internal waters and U.S. Waters) and western Basin area of U.S.S.R. Waters if possible.
Vessel: (New) *Kaiyo maru* (2,600 ton).

Methodology of Data Collection on Net Selectivity and Accidental Mortality of Fish passing through the Mesh of the Codend

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Abstract

This paper contains advice on determining mesh selectivity factors for trawl codends using a special liner. The design and technical specifications of the liner are described.

It also describes an experiment to determine the accidental mortality of fish passing through the trawl codend.

It contains proposals on standardising data collection and handling for mesh selectivity studies.

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METHODOLOGIE POUR LA COLLECTE DES DONNEES SUR LA SELECTIVITE DU MAILLAGE ET LA MORTALITE ACCIDENTELLE DES POISSONS PASSANT A TRAVERS LE MAILLAGE AU CUL DE CHALUT.

VNIRO
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Résumé

Ce document présente des avis sur la détermination des facteurs de sélectivité du maillage aux culs de chaluts utilisant un voile spécial. Le modèle et les caractéristiques techniques du voile sont décrits.

Le document présente aussi une description d'une expérience mer pour déterminer la mortalité accidentelle des poissons passant à travers le cul de chalut.

Il contient également des propositions sur la standardisation de la collecte et traitement des données pour les études sur la sélectivité du maillage.

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