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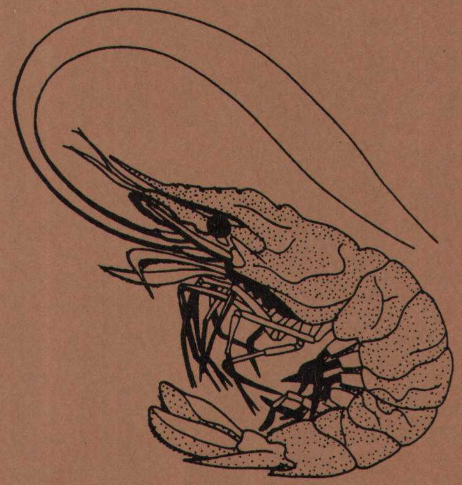
INTERIM REPORT OF THE WORKSHOP ON THE SCIENTIFIC BASIS FOR THE MANAGEMENT OF PENAEID SHRIMP

KEY WEST, FLORIDA

NOVEMBER 1981



Brian J. Rothschild and
John A. Gulland, Conveners

Sponsored by:

Southeast Fisheries Center
Gulf States Marine Fisheries Commission

in collaboration with

Food and Agriculture Organization of the United Nations
Fishery Resources and Environment Division

April 1982

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
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INTERIM REPORT OF THE WORKSHOP ON THE SCIENTIFIC BASIS FOR THE MANAGEMENT OF PENAEID SHRIMP[1,2]

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Brian J. Rothschild[3] and
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Sponsored by:

U.S. Department of Commerce, NOAA/NMFS
Southeast Fisheries Center
Miami, Florida

Gulf States Marine Fisheries Commission
Ocean Springs, Mississippi

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April 1982

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
John V. Byrne, Administrator

NATIONAL MARINE FISHERIES SERVICE
William G. Gordon, Asst. Administrator for Fisheries

FOOTNOTES

[1]A Final Report, which includes the papers at the Workshop, is in preparation.

[2]Contribution No. 1243, Center for Environmental and Estuarine Studies of the University of Maryland.

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1. INTRODUCTION

The annual global catch of tropical or "penaeid" shrimp amounts to 700,000 tons. Some of the largest fisheries for shrimp appear to be in waters off Indonesia, Thailand, India and in the Gulf of Mexico. Shrimp are extremely valuable, often of importance for domestic use, but also as a valuable export item. The great value of the shrimp emphasizes the importance of shrimp management, especially since substantial increases in global shrimp production are not expected, hence, making it important to improve management and make most efficient use of stocks in existing fisheries.

However, shrimp management is somewhat different in concept than the management of other fisheries. This is because of the unique life history, population dynamics, and the character of the shrimp fisheries. In terms of life history; shrimp generally spawn offshore; the young shrimp then move into estuaries which serve as a nursery area; the various species spend a variable amount of time in the estuarine areas before moving offshore and spawning. The dependence of shrimp upon estuaries raises considerable concern for the estuarine habitat. Yet, curiously, the quantitative extent to which man's activity, except for complete estuarine destruction, affects the actual production of shrimp has not been made clear. In terms of population dynamics, penaeid shrimp are fast growing and very generally live only about one year. They thus have unusually high mortality rates and because of this determination of the best sizes at which to capture shrimp are critically sensitive to determinations of mortality and growth rates. Despite apparently intense fisheries for shrimp, it is not clear how recruitment is affected by stock size or the environment and thus there is concern as to whether high levels of fish effort generate population instabilities or whether high levels of fishing effort push shrimp population precipitously close to being in danger of collapse. In terms of fisheries, the best biological level of fishing effort and the best economic levels of fishing effort are difficult to determine. In addition to determining the best levels of fishing effort, it is also critical for many fisheries to determine how effort should be allocated between inshore "artisanal" or "small-scale" fisheries and offshore "industrial" or "large-scale fisheries". Further, most shrimp fisheries in the world take substantial quantities of small fish which are sometimes discarded, and there is considerable concern as to developing feasible means for utilizing the discards.

The importance of the fisheries and the various problems associated with shrimp management suggested bringing together experts on the management of shrimp to consider the problems and bring them closer to solution.

Accordingly, the Workshop on the Scientific Basis for the Management of Penaeid Shrimp was held at Key West, Florida from 18 to 24 November. It was attended by 45 participants from 15 countries. A list of those attending is given in Appendix 1. The discussions were based on a set of papers reviewing the current situation in the major shrimp fishing countries, and other papers examining particular situations. A list of papers available at the meeting (most of which had been circulated to participants in advance of the meeting) is given in Appendix 2.

The participants were welcomed by Mr. Larry Simpson on behalf of the Gulf States Marine Fisheries Commission, by Dr. William W. Fox on behalf of the U.S. National Marine Fisheries Service, and by Dr. John A. Gulland on behalf of the Food and Agriculture Organization of the United Nations.

The following served as Rapporteurs: Dr. Donald A. Hancock, Australia; Dr. Scott Nichols, U.S.A.; Dr. Joan Browder, U.S.A.; Dr. Serge Garcia, FAO, Rome; Mr. Terrance Leary, U.S.A.; and Mr. Bernard Bowen, Australia.

The Workshop was arranged to consider and identify the problems associated with shrimp management; the biology of shrimp and rate measurements; the data base; methods of analysis, multispecies problems; environmental aspects; management, and future work.

2. THE PROBLEMS

The Workshop began with reviews from each country of their shrimp fisheries, and of the problems that these fisheries (and those responsible for these fisheries) are facing. These can be summarized as follows:

Australia

Management in most Australian prawn fisheries, except those off eastern Australia, includes license limitation. Full exploitation in virtually all areas was achieved by 1975, but only in Western Australia did limited entry controls precede full exploitation. However, recently increased effort levels in the major fisheries resulting from larger vessels built under a federal ship building progrm are causing concern. Also, two years of low catches of the brown tiger prawn in Western Australia are being examined for stock/recruitment implications. Western Australian management objectives, which are effectively those of other Australian limited entry fisheries, have been defined as "the prime objective must be the maintenance of the resources at a level approaching the maximum sustainable yield, while giving proper attention to the economic viability of the fishing units with a view to maintaining a profitable industry" (Bowen and Hancock). Concern has been expressed about the extent of habitat modification.

Indonesia

In the 1970's the trawl fisheries expanded rapidly, resulting in increased shrimp and fish production, greater earnings of foreign exchange (up to US$ 200 million in 1979), and higher employment. However, there have also been negative aspects, through the over-exploitation of limited stocks. These have particularly serious in the over-crowded areas of Java and Sumatra. Here there have been serious conflicts between traditional inshore fishermen and the trawlers.

As as result, a ban on trawling in the waters around Sumatra, Java, and Bali was introduced in 1980. The number of boats fell from 3,500 to 1,000, mostly so-called "baby trawlers". This has been followed by a big drop in catch, but stocks seem to have recovered. Crowding and conflict is less serious in Kalimantan, and in West Irian the only fishing is by large trawlers whose numbers are controlled.

Though the recent actions have reduced some of the immediate problems of social distress and conflict, much more study is needed to determine the best methods of management to deal with the social problems of the over-crowded areas of Java. There is also concern over the effects of the destruction of mangroves, and other changes in the coastal area, on the long-term well-being of the shrimp stocks.

China

At present the main problems in the fishery are heavy fishing effort, poor economic benefit and extravagant power consumption, which will eventually bring about population fluctuation. The goals of management are in conflict with each other, and their corresponding optimum efforts also differ greatly from each other. Attainment of optimum economic results from the fishery will require a reduction in fishing effort. Increased employment, however, will require a sacrifice of economic benefit and increased power consumption. We cannot have both at the same time. Young prawns need to be protected from illegal netting, but more so from destruction by saltworks, which in some years exceeds the number caught. Spawning stock is well below the numbers needed for maximum recruitment.

Thailand

Total landings of all species of shrimp have been increasing, but these include a large and probably increasing quantity of small non-penaeid shrimp. Most penaeid shrimp are taken, together with many species of demersal fish, in the mixed-species trawl fishery. This has been suffering for several years from over-exploitation, and a far too great fleet capacity, which has been exacerbated by the loss of free access to distant water fishery grounds under the new ocean regime.

India

Landings of shrimp increased rapidly until 1973. Recent catches are now below the peak years of 1973 and 1975, although fishing effort has probably continued to increase. There is therefore serious concern about depletion of the resource, as well as the severe conflict between the different groups of fishermen, especially between the traditional fishermen harvesting the small shrimp in the estuaries and lagoons, and the mechanized fleet of trawlers harvesting the larger shrimp in the offshore waters.

Gulf area

Recorded catches in the industrial fisheries along the eastern coast of Arabia have fallen considerably in recent years. The downward trend in total catch is less clear due to increased artisanal catches, which are not well known. Recruitment appears to have decreased, though it is not known whether this is due to reduced spawning, damage to nursery grounds by land reclamation, or purely natural causes. A long closed season has been introduced.

Senegal

The stocks are fully exploited. Economic factors have caused a reduction in effort by the industrial fleet, but formal controls of the effort, as well as of mesh size, are under consideration.

United States (Gulf of Mexico)

The goal of managing the shrimp fishery is to attain the greatest overall benefit to the nation with particular reference to food production and recreational opportunities on the basis of maximum sustainable yield as modified by relevant economic, social and ecological factors (Center for Wetland Resources in Griffin *et al*). On one hand, a reduction in effort would almost certainly lead to economic benefits. On the other hand, an increase in effort would be of limited economic value to the fishermen and could result in increased risk of population collapse or a sustained reduction in the production of the population (Gulf of Mexico Fishery Management Council *in* Rothschild, Brunenmeister, and Parrack). Concern has been expressed about the nature of the stock-and-recruitment relationship.

Mexico (Pacific Coast)

Fishing effort has doubled in ten years with no increase in catch. Management objectives are maximum catch and maximum employment. Management and conservation measures refer to closed seasons and mesh regulation so as to maximize yield per given recruitment. Revenue from the fishery is still sufficiently high to create a potential for further effort increase.

Guianas/Brazil

Fishing effort considered to be excessive for the past ten years, possibly causing local over-exploitation. There has been a temporary reduction in the number of vessels permitted under international arrangements, but the expected licensing policy could result in an oversized total fleet which could aggravate even more the decline in the relative abundance detected for some species and in the economic yield from the fishery. Effects of human activities on nursery areas, and plans for artisanal fisheries could both be of concern for juvenile stocks. Also introduction of fin-fish trawlers will add to fishing pressure. Scientific advice for management is rather limited.

In other parts of Brazil the exploitation of shrimp resources has also reached a high level, the larger part coming from the artisanal fishery, possibly causing over-exploitation. Also, human activities may have been affecting the juvenile stocks.

Nicaragua

The present goal of management is to obtain the best economic and social benefits, and more productive catch per unit of effort. A dramatic reduction in fishing effort caused no reduction in catch, but still did not improve the economics of the individual boats. This is believed to be because fishing effort over the past ten years has been greatly in excess of the optimum required for maximum catch. This had resulted from priority having been given to economic pressures rather than biological advice, which had suggested that MSY had been reached about thirteen years ago.

General Comments on Problems

Most shrimp fisheries throughout the world face similar problems. The stocks are fully exploited, with little opportunity of increasing total catches. Fishing effort continues to increase, giving rise to serious economic or social problems even when the stocks themselves may be in no danger.

The meeting was therefore believed to be more than timely. Despite the growing problems being faced by the managers of shrimp fisheries, the scientists were, in many countries, not well prepared to provide the managers with the advice they require. One reason for this has been lack of definition of the ultimate management objectives. Even for a single fishery these may be incompatible, contradictory, and sometimes amazingly vague. Unless the scientist has clear guidance on what the fisheries are being managed for, it is difficult for him to plan his research and frame his advice in an appropriate manner. Usually they will be biased on objectives that can be expressed in simple biological terms, e.g., attaining MSY, and may not be helpful in determining the management actions needed to achieve other types of objective, e.g., economic efficiency, or the resolution of social conflicts. The meeting then discussed the problems that scientists met in advising the managers to tackle his problems. One general problem is that of anticipation and timeliness.

Without careful thought about the need for data gathering and analysis on a real time basis, the point at which the problem becomes serious may be reached, and passed, so quickly that remedial action becomes difficult or virtually impossible. Once full exploitation is approached - not reached - a conservative view must be taken on the potential for biological danger and provisions made accordingly. In a common property resource too much emphasis may be given to particular objectives, such as maximizing employment in the harvesting section alone or maximizing throughout for processing facilities, etc., while missing the telltale signs that all is not well in other sections, e.g., with the state of the stocks, or the economics of individual operating units, because of tardy or inadequate availability of data. If no action is considered until a target is achieved (directly or indirectly) by the time action is actually taken the target will certainly have overshot and another fishery will have been added to the long list of documentation of failure - failure to recognize and failure to act. Three examples can be offered:

(1) Maximum Sustainable Yield (MSY) can be a useful concept for general guidance, but as a specific target it can easily be exceeded. This has been the experience of both the rock lobster and prawn fisheries of Western Australia, even where fishing effort has been allowed to expand gradually under tight controls (Bowen and Hancock).

(2) Failure to identify the potential for changes in effective fishing effort can allow dramatic escalation beyond the calculated optimum in a very short time. For example, in the prawn fisheries of Australia (Walker, Bowen, and Hancock; Penn) a shipbuilding bounty scheme has led to the building of larger boats which dramatically increased the pressure on the stocks. In Western Australia this caused an increase of effective effort from a comfortable level to excess in a very few years.

(3) Failure to identify economic signals is, if anything, even more reprehensible. While future stock levels are usually not predictable except in specific instances (Lhomme et Garcia; Staples, Dall, and Vance) several economic factors may well be known with some reliability in advance of the season, e.g., likely fuel prices, labor costs, market prices - which should put the emphasis on early economic advice - not years behind as often seems to be the case. The paper by Poffenberger, amongst the economic papers, provides some very useful information, but the assumptions he uses will probably need to be revised in the light of some of the practical experiences recorded in other papers.

A particularly difficult but important problem is that of stock and recruitment. For years fishery biologists rested in the assumption that recruitment was independent of the size of the adult stock and hence also of the effect of fishing. This belief has now been effectively challenged, notably at an ICES symposium held in Aarhus, Denmark in 1970, but in the only contribution to that meeting Hancock (1973) noted that no established relations between stock and recruitment had been identified in crustaceans. In contrast to this, possible stock-recruit relations have been examined for several shrimp stocks in papers submitted to this meeting (Penn; Rothschild and Parrack; Morgan and Garcia; Ye, Brunenmeister; Ehrhardt). Also, the Ricker model has been shown to give a good representation of the stock and recruit relation in the Western Australia rock lobster (Morgan, Phillips, and Joll, in press). If, as now seems likely, a sufficient reduction in the adult stock of shrimp can cause a fall in recruitment, the implications for management, especially laissez-faire management, are very serious. It cannot be assumed that, whatever may happened to the economics of the fishery, the biological production will always be maintained.

In addition to the problems of stock and recruitment, the following scientific problems were identified as being important to the way in which scientific advice is given to managers.

1. The variation in stocks may mask trends. In order to detect trends, observations must be made over extended periods.
2. Nursery areas are separate from adult stocks, and may be especially vulnerable to effects of the environment, and man's activities, other than fishing.
3. Most fisheries are carried out by several groups of fishermen, using a variety of gears. In addition to the major problems for the fishery manager in terms of conflict between the groups, the presence of distinct fisheries on different sizes of shrimp causes a number of scientific problems, particularly in calculating fishing effort.
4. Many fisheries are based on several species of shrimp and techniques need to be developed for estimating population dynamic parameters and management in a multiple species setting.

5. Age of individual shrimp cannot be determined directly, and, therefore, techniques which depend upon knowing the age of shrimp must be used cautiously.

6. Entry into the fishery, either by recruitment, or mesh selection is not sharp. The minimum size of shrimp in fisheries is subject to considerable variation because the size of recruits varies and the effects of mesh selection do not precisely control the minimum size of shrimp.

7. Some individual stocks of shrimp stocks occur in waters of one or more coastal states, and thus require concerted international cooperation for effective management.

These are discussed in the following sections and in the final section where proposals are made for dealing with the problems.

3. THE BIOLOGY OF SHRIMP AND RATE MEASUREMENTS

Growth

Papers containing new data or analysis of growth included those by Lhomme and Garcia, Mathews, Nichols, Parrack, and Pauly. All addressed the seasonal variability of growth, although Parrack noted that seasonal variation was relatively unimportant for offshore *Penaeus aztecus*. Nichols presented a way of considering seasonal variation by examining growth-rate variation. Pauly presented a method for extracting growth curves from length-frequency data.

Discussion centered on evaluating the potential importance of growth variability. Adequate modelling mechanisms appear to be available for dealing with predictable variation. The question arises: are the growth parameters obtained (in any study) biologically meaningful? Clearly, they should be, or the estimation becomes merely a curve fitting exercise that summarizes growth over only a portion of the lifespan, and not a means to "predict" growth outside the observed range.

The general pattern of shrimp growth seems to be well known, and reasonably consistent from area to area and species to species. For most purposes the available information appears adequate for management purposes. Further study may be needed in special circumstances. For example, the determination of the optimum date to open the fishing season may require particularly accurate knowledge of growth. Again, if a management policy induces large changes in density, knowledge of possible density-dependent growth could be important.

Natural Mortality

New estimates of M were reported by Brunenmeister, Lhomme and Garcia, Mathews, Nichols, Parrack, and Ye. The high sensitivity of yield-per-recruit results to typically uncertain estimates of M was reported by Nichols.

In the discussion, the poor precision and accuracy among existing M estimates was stressed. Published estimates appear to be include extraordinarily high values of M. However, even the "reasonable" estimates are highly variable. There is an important distinction to be made between real variation and error variability of estimates. Real variation most certainly occurs with age and size, as the shrimp progress through several different environments during their life history. Variations among years, perhaps in response to variation in abundance predators, or in occurrence of disease (which might be density-dependent) must also be considered. Improving estimates of M will probably be costly, but may be worth the investment. Detailed investigation of the mechanisms of natural mortality, such as predation or disease, could provide some better understanding of the process of natural mortality, and some indication of the significance of various causes of mortality such as the abundance of predators. Careful re-examination of existing techniques (mark-recapture analysis, etc.) might also be considered.

The value of comprehensive inter-specific comparisons (such as those made by Pauly) was stressed particularly in providing an objective first approximation in stocks where direct estimates were unavailable. At the same time the danger of certain values of natural mortality being prematurely adopted and the importance of obtaining direct and independent estimates of natural mortality were stressed.

Migration and Stock Identification

Several papers considered stock-structure explicitly (Brunenmeister, Lhomme and Garcia, Mathews, Parrack, Rothschild and Parrack, and Ye). Recognition of stock structure impacts directly on the validity of the production models, and on development of stock recruitment relationships. A possible latitudinal gradient in migratory behavior was mentioned. The discussion included recognition of the importance of migrations across international boundaries. When such movements occur it is important, in reaching agreement between the countries concerned, for there to be good information on the positions of the main nursery and fishing grounds relative to the national boundaries (this may be accomplished by developing a series of maps showing the location of the main concentrations of each size of shrimp, and of the fishing grounds during each season).

Other Biological Topics

Latitudinal differences were noted in the relative strength of two seasonal spawning peaks in some species. Apparently there are no examples of a secondary peak declining continuously with time, or with increasing fishing effort. Some "two-peak" cases may be discrete enough to function as separate stocks within the same general geographic area.

The paper by Penn introduced a behavior-based classification scheme for shrimp species, in which he introduced the concept that some species may have changed from a schooling to a non-schooling behavior as fishing pressure increased. This appears to have occurred in some stocks of P. merguiensis in Australia. Possible evidence, pro and con, for similar changes among species that he suggested might show similar behavioral changes was discussed. The variability of aggregative behavior in response to environmental variation, particularly turbidity, was also considered. Understanding these modifications in behavior has a direct impact on understanding (and forecasting) the relationships between fishing effort and fishing mortality.

4. THE DATA BASE

Catch Statistics

The importance of adequate data, comprising at least comprehensive statistics on catch and fishing effort, distinguishing catches of different species of shrimp, and some data on the sizes of shrimp caught was assumed to be generally recognized. The meeting therefore discussed situations where, despite this recognition, the data are still inadequate.

Statistics on total catch are readily available for most if not all the main industrial shrimp fisheries, but several participants expressed concern that significant catches were not recorded at all, e.g., from sport, subsistence, or artisanal fisheries. Two examples of misreporting (or failure to include a significant part of the fishery) were mentioned for the white shrimp in the U.S. Gulf Coast (Christmas), and for the Kuwait-Bahrain area (van Zalinge). In the latter exclusion of the increasing catches of the artisanal fishery had resulted in a much greater apparent decline in total catch than had actually occurred.

As complete catch data are basic to many analytical approaches (production modelling, cohort analysis), ommissions of potentially large components of the total catch can be a serious problem. The sizes of these unreported components may vary radically over time. Inability to address or even detect such changes could create a very biased picture of the condition of a stock.

The practice of discarding fish in the shrimp fisheries is well known, but it was pointed out that in several fisheries small shrimp are also discarded. Quantitative estimates of both kinds of discards and of the species involved is most important. The meeting noted that FAO was planning to produce a report or manual setting out appropriate and cost-effective methods of estimating the quantity of discards.

Identifying individual shrimp by sex in samples of catches for species with strong growth differences between the sexes is a problem, that impacts on any analyses involving length or age composition of catch statistics. Precision of these analyses could also be improved with better resolution of size data.

Effort Data

Fishing effort standardizations by vessel and gear characteristics were incorporated in several of the submitted papers: Bowen and Hancock, Brunenmeister, Lhomme and Garcia, Mathews, Penn, and Ye. Brunenmeister's paper presented an extended analysis included vessel characteristics, spatial and temporal variation, and catches of other species. Penn's paper considered differences in catchability generated by differences among activity patterns and schooling behavior among species, and suggested that the utility of CPUE data may be low for species with highly variable catchabilities.

In the discussion, note was made that standardization is not often attempted, and that it is important to anticipate changes that might occur, particularly regarding fishermen's ability to increase fishing power even with controls in place. The effectiveness of effort is strongly mediated by catchability variation, and by spatial and temporal distribution of effort relative to the distribution of shrimp. Because of this variability, prediction of fishing mortality from effort projections may always require monitoring.

The group was reminded that otter trawls are not the only gear in many fisheries. Thus, a broad consideration of fishing effort as it is applied to shrimp would need to take into account various other gear.

For many applications effort standardization can require more than consideration of just fishing power. Catchability variations may occur at several scales: physical aspects of gear performance, reaction of shrimp to gear, general aggregating behavior of shrimp, the larger scale distribution of stock density and fishing effort over a stock's range, and the distribution of effort in time within the time interval used in analysis. Decisions are required about what types of effort data and auxillary information must be collected. (For example, experience of vessel captains is often not measured).

5. METHODS OF ANALYSIS

Production Models

Production model results were presented in the papers by Bowen and Hancock, Brunenmeister, Ehrhardt *et al*, Mathews, Silas *et al*, and Unar and Naamin. Additionally, plots relating catch to effort, without fitting a model were presented by Bowen and Hancock, Penn, and Villegas and Dragovich.

While production models do not take explicit account of the effect of fishing on different size groups (e.g., juveniles or adults), they demand less data than age- or size-structured models, and are therefore likely to continue to be widely used. It was pointed out that the short life of shrimp meant that annual pairs of observation of catch and fishing effort were more likely to match the equilibrium condition (particularly if recruitment were not affected by fishing) than was the case in longer-lived fish. One serious limitation in using production models is that of determining a suitable measure of effort (or catch per unit effort). In this connection Garcia mentioned a technique developed by Csirke and Caddy at FAO in Rome which relates the catch directly to total mortality (as estimated, for example, from size or age composition), which under the usual simple assumptions gives rise to a parabola with intercept on the x-axis at M, rather than the origin. While this shares several theoretical drawbacks with other production models, and there can be difficulties in obtaining adequate estimates of total mortality, this approach appears to be promising for some situations.

The production models usually showed a curved left-hand limb, sometimes a suggestion of a maximum, but very seldom a declining right-hand limb. Various reasons were suggested. Yield-per-recruit analyses suggest a flat-topped curve so that if recruitment is not affected a flat-topped curve of total yield may be more representative of reality than a parabola. Alternatively, declining total catches, and therefore even faster declines in catch-per-unit-effort could cause the expansion of effort to stop for economic reasons before a declining right-hand limb can be observed. Difficulties in measuring true fishing effort were also mentioned.

Age- or Length-Structured Models

Models of this type, based more or less directly on the yield-per-recruit calculations of Ricker or Beverton and Holt are essentially to study the effects of changes in the fishing practice which involve changes in the pattern of distribution of fishing mortality with age. A number of yield-per-recruit analyses were presented (Ehrhardt et al, Nichols, Rothschild and Parrack). There were inevitably problems, especially in the estimation of certain parameters (notably natural mortality). This could be somewhat reduced by using figures based on comparisons with related stocks as first approximations.

It was pointed out in Pauly's paper, and in a presentation by Jones during the meeting, that given a growth curve, length composition data could be used directly to carry out several types of analysis, including cohort analysis, without having to estimate age-composition. These techniques which have been described in an FAO Fishery Circular (Jones, 1981) were felt to have wide promise in applications in analyzing shrimp fisheries. At the same time problems and difficulties, e.g., the need to consider the curve of age as a function of length, rather than the more normal growth curve (length as a function of age) were underlined. One of the advantages of a length-structured analysis was that the critical parameter was usually M/K rather than M, and it was suggested that M/K might be fairly constant within a species group, e.g., penaeid shrimp.

Stochastic Models

Stochastic modelling appears to be a fruitful direction for shrimp research. Possible uses in yield-per-recruit and stock-recruitment were considered. Stochastic modelling may be particularly critical in examining the true nature of "collapse", and in understanding the relationship of parent stock size and environmental variation in establishing recruitment strength.

There is a distinction between stochastic models in which an intrinsic, real, but random variability of one or more parameters is incorporated, and sensitivity analysis, which investigates the effects of either estimate error or real variability in a deterministic context. Both types of models will have applications in future research.

Stock and Recruitment

Shrimp recruitment shows considerable variations from year to year which are not connected with any obvious changes in adult stock. It is clear that whatever the relation between the size of the adult stock and the average recruitment from the stock, the actual recruitment in any one particular year is determined very largely by environmental conditions in that year. It is therefore better to describe the stock-recruitment relation by a family of curves, each corresponding to a given set of environmental conditions (weather, food supply, state of development of the coastal zone, etc.). Each curve gives the recruitment that would arise from a given size of spawning stock under the defined environmental conditions. (See Figure 1).

At best, the environmental effects add noise to the system and make it difficult to determine in what way the average recruitment changes with changes in adult stock, and in particular to detect at what point a reduction in spawning stock will cause a significant fall in recruitment.

In practice, the existence of environmental effects may bias the estimates of the stock-recruitment relation. The size of the adult stock of shrimp is largely determined by the success of the previous spawning season as modified by the intensity of fishing between recruitment and the spawning season. If there is a significant correlation between environmental conditions in successive years, this can give rise to a correlation between stock and subsequent recruitment which is really due to the influence of recruitment on subsequent stock size. In terms of Figure 1 it is likely that large spawning stocks will occur during periods of generally good environmental conditions giving rise to observations on the upper curve of the family of stock recruitment curves, and small spawning stocks observations on the lower curve. This is indicated in Figure 1

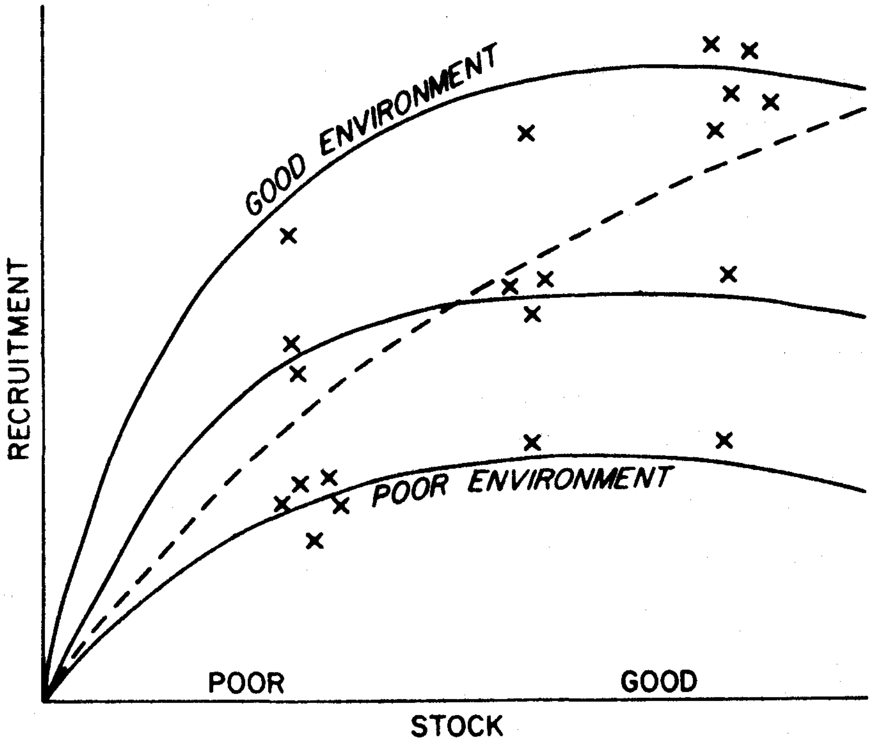

Figure 1. Stock-recruitment relations under different environmental conditions, and the likely distribution of observed points and empirically fitted curve.

where the likely distribution of observations give rise to an empirically fitted line (broken line). That suggests a much bigger change in recruitment with changes in adult stock than those corresponding to any fixed set of environmental conditions.

In some cases it is possible to determine what environmental factor is important, and to make allowance for it. In the Gulf of Carpentaria and elsewhere recruitment is strongly affected by rainfall. There has been a downward trend in recruitment over the past few years, which could have been ascribed to the effect of fishing, but when the effect of rainfall, (which also shows a trend) is taken into account, there is no trend in the residuals. The possibility of bias, and of observing a spurious relation between stock and recruitment is particularly high for changes in the coastal environment (developing for housing, roads, curring of mangroves, etc.) which have significant and (over the short-term at least) irreversible impact on recruitment. It is possible that the strong correlation between stock and recruitment observed in Kuwait waters and perhaps also in adjoining areas is due to a steady degradation of the coastal nursery areas.

Despite the difficulties of interpretation, the increasing number of cases in which lower spawning stock sizes are associated with lower recruitment, and which cannot be immediately explained by environmental factors (natural or man-made) are matters of great concern. If these are indeed cases of low stock causing low recruitment, and fishing on these stocks is maintained at a high level, the risk of a stock collapse ("recruitment overfishing") is very real. The reason for this is well known, and is illustrated in Figure 2. Figure 2 represented the simplified situation, in which environemntal factors are constant. Under a given pattern of fishing the spawning stock resulting from a given recruitment

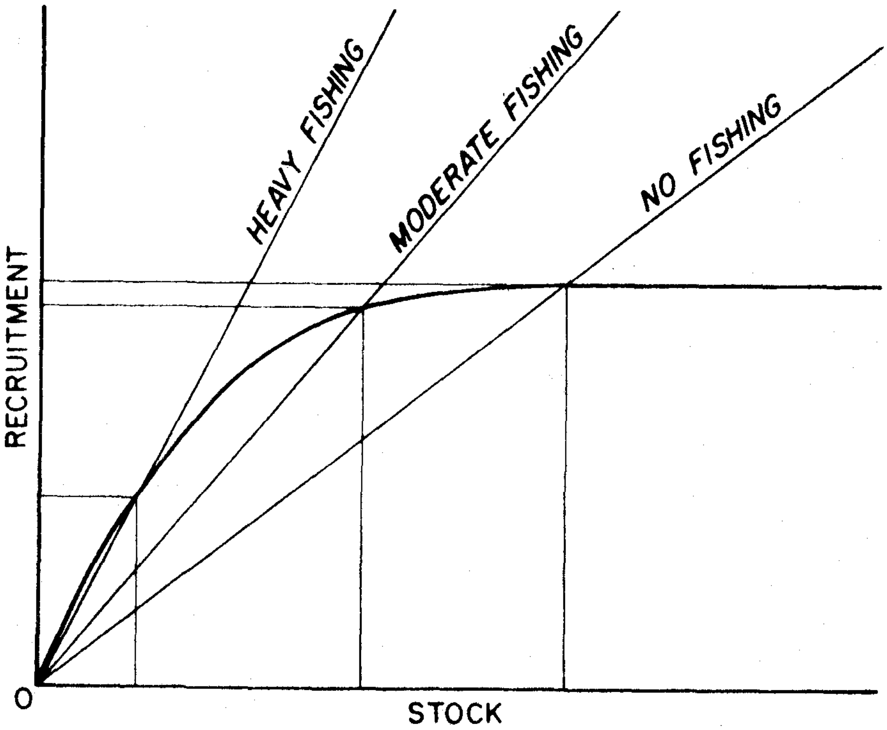

Figure 2. Equilibrium positions under a given stock-recruitment relation for various levels of fishing effort.

will be proportional to that recruitment. This is indicated by the straight lines, with slopes increasing with increasing fishing. Where the line cuts the stock-recruitment curve gives the equilibrium position for any pattern of fishing. If the fishery is on the fairly flat part of the stock-recruitment curve (recruitment is effectively independent of stock), then changes in fishing effort change the equilibrium recruitment little, but if the present fishery is near the left hand part of this curve, even a moderate increase in fishing effort can cause a great reduction in the equilibrium recruitment, and it may not take much increase in effort to cause a complete collapse. The observed relation between stock-and-recruitment where the relation of stock to recruitment is approximately proportional (e.g., for the Gulf of Mexico brown shrimp) is therefore very disturbing.

6. MULTISPECIES PROBLEMS

Several Species of Shrimp

Most of the papers presented to the meeting and most of the discussions treated the problem and the scientific analysis in terms of a single species (or at least of a single stock) without distinguishing species. In fact, shrimp fisheries with a few exceptions (e.g., the Chinese fishery for *P. orientalis*) are based on more than one species. Two types of interaction can be distinguished - first when the species are biologically separated in space or time, so that the interaction is only in terms of the operation of the fishery, and second, when there is significant biological interaction.

The second situation presents interesting scientific problems of management, for example, the possibility that the economic damage from the depletion of one species may be reduced by the increase of other species - the situation in the southeast Pacific where sardine stocks have greatly increased following the collapse of the anchovy offers an analogy in a different ecological context. Detailed examination of the life-history patterns of different species suggest that different species of shrimp do not have overlapping requirements, usually being on different grounds, or, if occurring on the same grounds, do so at different seasons. The likelihood of one species benefitting to any significant degree from the depletion of another shrimp stock seems small and there would be no justification in delaying implementation of needed management measures in the hope that such interactions would take place.

The first type (of operational interaction) causes the greatest management problem when the existence of a fishery on one stock allows fishing on another stock to continue even when the economic return from the second species is very low. It has generally been assumed that economic constraints will cause the expansion of fishing effort on a stock to cease before there is serious risk of recruitment overfishing. This assumption is being challenged on general grounds (see Section 5), but the possibilities of such overfishing are greatly increased in multispecies fisheries. For example, the stock of brown tiger prawn in Shark Bay, Western Australia, seems to have been reduced to a very low level because the fishery can continue by fishing principally on other species. The existence of two or more species can also cause difficulties in data collection and analysis, particularly in ascribing correctly fishing effort to one or other species. Usually this difficulty can be resolved by collecting statistical data in sufficient detail in space and time.

Fin Fish

Shrimp trawls are not selective, and, ususally large quantities of fin fish - up to 95% of the total catch - are taken by shrimp trawlers. (Exceptions are the fishery on schooling banana prawns in the Gulf of

Carpentaria, Australia, and the "mud-bank" fishery of southwest India, in which the catches consist almost entirely of shrimp.)

Most trawl fisheries have bycatches, but the proportion of the bycatch that is discarded is probably higher in shrimp fisheries than in most other fisheries and is due, largely, to the high disparity in price between shrimp and the bycatch species. (This price difference also occurs and leads to a high proportion of the bycatch discarded in tropical trawl fisheries for high valued products such as cephalopods, sea bream, etc., operated by long-range fleets off West Africa and by the larger Thai trawlers in southeast Asia.) Rough estimates of the quantities of discards involved in the major shrimp fisheries are given in Table 1; these are first approximations.

The fate of these fish once they leave the water is highly variable, though this variation is more systematic than the variation in the ratio of shrimp to fish in the catch. At one extreme are the artisanal fisheries, particularly in southeast Asia, operated by small vessels with no refrigeration or even ice. These vessels make trips of only a few hours, and usually all their fish are brought ashore. Not all of it may be used for direct human consumption, the rest being used for duck food, fish meal, etc. At the other extreme are the specialized shrimp fisheries with relatively large trawlers; these usually freeze their catch at sea, and make long trips. Their specialized interests and limited handling and storage capacity usually result in all or nearly all the incidental catches of fish being discarded. The rate of discards is particularly high in regions (the United States and the Gulf of Carpentaria - Arafura Sea area) where there is no great need of local demand for fish. The type of vessel may also affect the proportion of fish. Off Senegal the trawlers that keep their catch on ice catch a higher ration of fish than the larger freezer

Table 1. Rough Estimates of Bycatch and Discards in Penaeid Shrimp Fisheries[a]

COUNTRY	SHRIMP CATCH (1979) 1,000 tons	BYCATCH RATIO	BYCATCH TONS	% DISCARDED	QUANTITY DISCARDED	DATE OF OBSERVATION AND AUTHORIZATION
China[d]	7,500	8:1 - 4:1	35 - 60,000	nil	nil	October 1962
Indonesia (Arafura Sea)	6,000	variable 3:1 - 1:1 (inshore)	ca. 100,000	high	ca. 100,000	1970's (Unar)
Indonesia (other areas)	157,000	20:1 - 30:1 (offshore)	115,000	< 2%	< 2,000	
Australia	21,000	variable[b]	unknown	high	unknown	
Thailand	100,000	variable	750,000[c]	small	small	
India	183,000	4:1	316,000	< 2%	5,000	1970's (George)
Kuwait	1,600	10:1	15,800	95%	15,000	1978 (Mathews)
Senegal	5,500	variable	80,000	ca. 50%	40,000	1970's (Garcia)
United States (Atlantic coast)	105,000	2.8:1	37,000	ca. 100%	37,000	1970's (Pelligren)
United States (Gulf coast)		9:1	600,000	ca. 100%	600,000	1970's (Pelligren)
Mexico (Pacific coast)	46,000	10:1 - 15:1	400-500,000	> 95%	400,000	1970's and 1980's (Ehrhardt)
Brazil & Guyanas	21,500	10:1	215,000	high	200,000	Present (Villegas and Dragovich)
TOTAL	658,600		ca. 2,700,000		1,399,000	All Countries Above Except Australia

Total world landings, all types of shrimp 1,526,000
Total world landings (less pandalids, sergestids, etc.) 1,238,000

(a) All estimates are imprecise; the figures are presented here to illustrate the general magnitude of the quantities involved, and the regional variation.
(b) Bycatches are very low on schooling prawns, but can be high in other fisheries. Glaister reported bycatch of 21,700 tons (18,000 discarded) in the eastern Australia fishery that landed 2,500 tons of prawns in 1979.
(c) Taken as equal to the quantity of "unspecified marine fish" reported by Thailand in the Yearbook of Fishery Statistics.
(d) Yellow Sea fishery only.

trawlers which work further offshore, though the latter discard a higher proportion of the fish they do catch. Measures have been taken by a number of countries to encourage the landing of more fish. For example, the government of Guyana has required since 1974 that all shrimp trawlers include 909 kg of fish in each landing (Villegas and Dragovich). Increasing demand for fish is also increasing the proportion kept, e.g., in Senegal.

Discarding is a feature of most other trawl fisheries, though is particularly marked in shrimp fisheries because of the great difference in price, as well as in other tropical trawl fisheries for high valued fish (for example, in several of the fisheries for cephalopods, sea-breams, etc. operated by long-range fleets off West Africa, the croaker fishery in the United States and by the larger Thai trawlers in southeast Asia). Rough estimates of the quantities involved in the major shrimp fisheries are given in Table 1, though it must be stressed that they are only first approximations. Altogether the quantity discarded is probably between one and two million tons, with the greatest quantities occurring in North America, and the northwestern part of South America.

The failure to use this great quantity of potentially valuable protein food has attracted considerable attention and concern, particularly since much of this wastage occurs not far from places with large populations suffering from shortage of protein. The possibilities for better use of the discards was the subject of an FAO-IDRC Technical Consultation on the Utilization of Fish Bycatch in Shrimp Trawling, held in Georgetown, Guyana in October-November 1981. This aspect was therefore not considered in detail at the present workshop, though it was stressed that this aspect of discards was not just a technological problem of developing an appropriate methods of processing the bycatch, but included the economic problem of making it attractive (or indeed even viable) for the specialized shrimp trawlers to adopt these methods.

The present workshop concerned itself with other questions, particularly the following:

(1) What is the impact of the shrimp fishery on the fisheries (actual or potential) on the various species of fin fish?

(2) Do the discarded fish and small shrimp supply a useful source of food for shrimp, so that reduction of discards might affect future shrimp catches?

(3) Do some or all of the species of fish in the bycatch compete with, or prey upon, shrimp to the extent that a reduction in bycatch (through the use of selective trawls) would result in a detectable reduction in future shrimp catches?

No formal assessment of the impact of shrimp trawls on bycatch fish stocks was presented at the workshop - nor was any attempt made to evaluate the potential benefit of decresing trawling pressure on these stocks. The necessary calculations are straightforward, and similar work has been done for many multispecies fisheries, particularly in the North Sea. In exploring the question, Caddy (in an FAO paper presented to the Fisheries Commission for the Western Central Atlantic, WECAF) found that the fishery potential in the WECAF area that was lost due to such problems was high under any combination of assumptions used.

The question of discards as a food supply for shrimp was addressed by Cushing, and by Sheridan et al. Though there are a number of uncertainties remaining - including the degree to which shrimp do in fact feed on dead fish, it does appear that the additional growth of shrimp due to discards either by direct consumption, or through the recycling of nutrients, is at most small.

The impact of fish, as predator or competitor, on shrimp stocks is less clear. Shrimp do not appear to be an important element in the diet of most species of fish that occur in the bycatch. However, they do occur, and in view of the large number of fish compared with shrimp, the impact of predation on shrimp could be significant. It was suggested that most predation takes place on the fringe of the main distribution of shrimp. It thus may be due mainly to species that do not feature largely in the bycatch, the latter being on the whole about the same size as the shrimp.

Pauly analyzed the data of trawl surveys and commercial catches in the Gulf of Thailand and found a strong correlation between the survival of juvenile shrimp between spawning and recruitment, and the abundance of demersal fish. He found that in recent years this survival rate has increased, sufficient to balance the decrease in spawning stock of shrimp to heavy fishing.

The effects of predation may not be obvious. In the Irish Sea cod eat *Nephrops*, so that one might expect that reducing cod populations might increase the harvest of *Nephrops*. The true picture is more complicated; cod eat small fish which eat juvenile *Nephrops*, so that a reduced cod stock might result in more small fish and in less *Nephrops*.

In conclusion it was felt that there would be no significant disadvantages to the shrimp stocks (and hence the shrimp fisheries) by reducing discards, the bycatch being kept constant. There would be benefits, possibly large to any directed fishery for fin fish if the bycatch could be reduced, whether by gear modifications such as the separator trawl being developed in the United States, the use of a larger mesh size, or a general reduction in the shrimp trawling effort. The impact on shrimp of eliminating bycatch is less clear, and needs more investigation. It might be negative, but the effect is neither so large nor so certain as to argue against reducing bycatch for the other reasons already mentioned.

A final reason for reducing discards which emerged in discussion was that the fish dicarded by one vessel could, especially in areas of heavy fishing, be picked up in the trawl of another vessel, and badly affect the keeping qualities of the catch.

7. ENVIRONMENTAL ASPECTS

Shrimp are sensitive to the environment in which they live at all stages of their life. The environment also affects the operation of the fishery in many ways. There are therefore many aspects of the interaction between shrimp and shrimp fisheries and the environment which could be studied. The meeting agreed that the important aspects to study were those that can enable us to limit unfavorable changes such as habitat destruction or to predict changes.

In studying the effect of the environment a number of general problems arose. These included:

(a) Lack of experimentation

The data base used is mainly extracted from the fishery and because of the impossibility to do any experimentation, the environmental effects have been studies most of the time by correlation analysis. As a consequence, the cause-effect relationships suggested are to be taken as suggestions only.

(b) The environment parameters available are limited in numbers and not independent

Temperature, oxygen, and salinity are linked and describe water mass. Turbidity, plankton density, photo-period are not independent parameters. The same holds often true for depth, sediment texture, organic content, benthic biomass. Any of these parameters may be taken as an indicator at best, and cause-effect relationship with any one parameter of the set is difficult to ascertain. This is complicated by the fact that the number of parameters usually measured is limited (usually consisting of temperature, salinity, and sometimes dissolved oxygen). Others (turbidity, photo-period, currents, amount of food, etc.) are often not recorded, so that it is impossible to establish correlations, even when their influence may be important.

(c) Measuring the biological phenomenon

An appropriate index for measuring the phenomenon of interest in the shrimp stock (spawning, migration, recruitment, etc.) may not be availble, or can only be obtained at the cost of considerable research.

(d) The correlation obtained sometimes between magnitudes oscillating seasonally may be largely spurious, and so the proper lag-time needs to be carefully researched.

(e) The signal/noise ratio should be taken into consideration when trying to identify a cause-effect relationship. This ratio varies from one region to another and depends on the parameter(s) considered. In temperate and subtropical countries, temperature might be an important triggering factor while in an equatorial type rainfall, food, turbidity and associated change might be more important. In this connection signal refers to "long-term" conditions as opposed to short-term ones (considered as noise). At any time scale the noise can be interpreted as the result of variations at higher frequency than the signal, e.g., a "noise" is only non-understood information and when it becomes too important it has to be analyzed. This refers particularly to stock-recruitment relationships and to production models.

Despite these difficulties, a number of environmental influences on shrimp stocks have been established, as reported in the published literature, and at the meeting. These include the following:

(a) Survival - for larvae and juveniles it is governed by the combined effect of temperature and salinity. A combination of low t° and low S°/oo is very unfavorable.

(b) Distribution - the main parameters governing distribution of shrimps are the following (Garcia and LeReste):

-- Temperature - the shrimps often react to strong change in t° by migration (geographic or bathymetric ones).

-- Concentrations of shrimp are associated with the presence of estuaries. There are apparent exceptions (Mexico, Ehrhardt et al; Arabia, van Zalange). The association tends to by highly variable from species to species.

-- Shrimp concentrations are also associated with fine sediments (from sand to mud) and the preferenda are different species or groups of species.

A clear distinction has been suggested between "white" and "brown" shrimps, the "whites" being littoral species, closely associated with areas of high runoff, low, variable salinity and very muddy bottom. The "browns" are found on more typically marine areas hydrologically more stable, and on sandy or sandy mud bottoms.

It has also been suggested that the different requirements of larvae, sub-adults and adults apparently lead to a decrease in overlapping in time and space for the different species, possibly reducing interspecific competition within the shrimp group.

(c) Migration - considerable information is available on migration (Garcia and LeReste). The suggested triggering factors for the sub-adult migration are marked changes in temperature (cold fronts) (Rothschild and Parrack), salinity, currents (Walker) (linked with river outflow seasonal changes). Daily cycle and moon phase also seem to be important.

It must be noted that the migration rate out of an estuary is also linked to the amount of shrimp available for migration and therefore to the seasonal pattern of reproductions at sea and environmental conditions in the estuaries a few months before migration starts. The number of migrating shrimp is in fact the result of various superimposed seasonal patterns - reproduction (larval production), coastal hydrography (currents, larval transport), estuarine environment (larval survival) before migration in addition to the environment factors at migration.

The main findings are:

(i) The strength of a migrating cohort depends on the conditions prevailing during the estuarine period. There is an optimal time-space window.

(ii) The size/age at migration varies seasonally between years (Staples et al; Garcia and LeReste).

(iii) The "normal" migration pattern, corresponding to the temporal pattern of reproduction is distorted by events like floods, cold fronts, etc.

(iv) The shrimp swimming behavior is linked to changes in salinity. This may explain how shrimp orientate themselves in the inshore/offshore salient gradients when migrating. The generalization of the theory is, however, still to be established.

(d) Spawning - This aspect of the shrimp biology was discussed in the paper by Garcia. The main problems lie in the measure of spawning activity (% of gravid females is not enough) and on the limited availability of environmental parameters.

It can be said that in general two spawnings occur - in Spring and Autumn. The first is generally found to be the more important and stable one.

There are, of course, some differences between species and areas and the amplitude of the seasonal reproduction pattern depends upon the overall stability of the environment.

The literature is rich in statements about factors triggering reproduction. Temperature seems to trigger an increase in % of gravid females in some areas while rain is the apparent triggering factor elsewhere. The increase in actual spawning presumably follows the increase in gravid females after some delay period, but has seldom been observed directly. The real effect of some other factors (plankton bloom, food) has not been looked into enough especially in oligotrophic environments.

The most important problem is that generally the autogenic aspect of shrimp reproduction has not been considered (adaptive process) and that environmental aspects of reproduction have been studies more at the individual than at the population level.

In short-lived species like shrimp (limited number of year classes) the close adaptation of the seasonal spawning potential to seasonal change in environment may be the key to their permanence in oscillating environments.

(e) Catchability has been shown to vary with turbidity and temperature. The apparent answer of the shrimp to these parameters may depend on species behavior (burying or non-burying, nocturnal or diurnal).

(f) Growth is certainly affected by temperature and this meeting has provided an interesting set of observations on that aspect (Garcia and LeReste, Nichols, Pauly et al). In general, growth increases with temperature for a given size. However, Nichols found that growth was not so linearly correlated with size as implied with the von Bertalanffy growth function. Growth is also slowed down by spawning.

(g) Abundance (Staples et al, Garcia and LeReste, Ehrhardt et al, Walker). Most of the papers presented touch on this problem, several extensively. Abundance (or measured catch rate and catches) is apparently correlated with sunspot activity, temperature, mangrove area, latitude, estuarine/marine interface length, rainfall, river outflow, etc.

The relations have been shown to be positive or negative, depending on the area and the species considered, and it has been suggested that the relation with environment may not be linear within the whole range of possible values.

Abundance is linked directly to recruitment and there is evidence that the success of a cohort depends on the environment during its larval/juvenile phase. A number of factors interact, with rainfall and river outflow being particularly mentioned as affecting the year-to-year variations.

Relationships between favorable nursery areas and production have been demonstrated and it has been proposed that the important parameter is the "ecological volume" defined as the overlapping between a "static" habitat (favorable depth/area) and a dynamic one (the optimum characteristics of the water mass). This raises the problem of the conservation of the physical habitat (marshland area, estuarine-marine interface length, etc.) and implies the necessity, in addition to the traditional management measures aiming at optimizing the yield-per-recruit, to strengthen the measures aiming at reducing undue larval mortality by littoral management.

Periodic and aperiodic changes

A distinction between these two types of change is important because the first refers to naturally reversible phenomenons, e.g., periods of drought, while the second most probably refer to non-reversible ones, such as development of the coastal zones for housing, industry, etc. The latter can lead to completely different problems and may require quite different management solutions.

One useful question is: What can a manager do in front of periodic natural variations? It is felt that there is still a need to detect and understand them in order to avoid unnecessary troubles in the fishery (claiming for a collapse when it is not the case) and take eventually the necessary steps for reducing the adverse predictable consequences of the variations. In the case of the aperiodic changes, the management advice is straightforward if the changes are the consequences of man's activities even if the implementation of the advices measure may raise some problems.

Predictive Models

Their usefulness for management purposes was discussed. It was felt that it was necessary that the important changes be detected and predicted in order to look for appropriate measures of lessening of the effects. Short-term predictions have been made in Louisiana, China, and Australia over a long period of years and are felt to be useful.

In fact the usefulness of a predictive model is inversely related to the unexplained variability. It has been often stated that in general these models very often fail to predict when they are confronted to the test of time, and that they are only able to make useful predictions at the extremes of the range of possible environmental values.

One way of testing the accuracy of the model is to build it using only part of the information available (e.g., part of the time series) and then predicting later values that can be readily compared with observed ones.

It has been pointed out that more useful research is to be done along these lines, but that the first priority should be given to the development of "understanding model" before the mathematical ones are developed.

It was also remarked that relations with the biological environment should also be looked at. For example, the abundance of predators may provide a good indicator of recruitment levels.

When building mathematical models, a progressive procedure, introducing more and more variables in order to explain more and more of the observed variances is useful. However, the number of variables must stay small as compared to the number of data points available.

The attention was finally shown to the necessity of checking long term changes in catchability before changes in abundance (and recruitment) are inferred.

8. MANAGEMENT

Management Objectives

For the purpose of this discussion we might define fisheries management in a broad sense as the manipulation of factors to achieve societal goals from a stock of fish. More specifically this goal is usually quantifiable in terms of societal benefits in the form of food production, gross or net value, employment, the income of individual fishermen, or some combination thereof while maintaining the stock at some high level for sustainable production. The objective is usually to achieve an optimum balance between inputs and various outputs. As the fishery is developed and societal needs and values change, the management goals will change.

The goals and values to be obtained from the fishery are determined by the society and it is the responsibility of a decision maker (fishery manager) at some level to decide how to obtain these benefits from the fishery. The manager must be able to identify the need for action and be prepared to act promptly. If there is to be a scientific basis for the management program, the manager needs biological, economic, and sociological information to assist in the decision making process. Also included in influencing the decision process are people whose decisions affect the investment in new or larger vessels, either directly (e.g., in regional development banks) or indirectly (e.g., through tax policies). It is not the responsibility of the scientists to formulate the management objectives but to provide the fishery manager with the scientific basis for a range of management options and the ramifications of their implementation.

The scientist should take care that he does not second guess what he believes to be the desires of the manager, but provide him with an appropriate range of options.

Simple bioeconomic models to predict the outcome of fishery management actions are needed to aid the fishery manager in the decision process. However, the models should go beyond catch and effort relationships, should not be overly expensive, and should concentrate on the significant parameters.

After the manager selects his option and implements his program, there are others who influence its effectiveness. Fishermen must be willing to accept and employ the measures, while bankers and investors can influence the development of the fishery by distribution of capital.

The shrimp fisheries throughout the world are generally fully exploited, and there is concern in many areas (China, Mexico, Australia, Indonesia) over the impact of the high level of exploitation on the stocks. In nearly all areas the abundance of shrimp, as measured for example by the catch-per-unit-effort, has sharply declined. In some areas (in parts of India and in the Kuwait-Saudi Arabia region) total production has also sharply declined, possibly as a result of heavy fishing. The fisheries in some countries face economic problems resulting from the high energy costs (fuel) in shrimp production (China, United States, Australia). Allocation among user groups offshore, inshore, and artisanal fishermen is another problem in nearly all countries.

It was the consensus of the Workshop that because of the highly developed nature of the world's shrimp fisheries some form of management is in order for all stocks. This management will almost certainly involve control of the total amount of fishing, and will probably have direct or indirect effects on how this total is distributed. Stock maintenance is of increasing concern, and the precarious position of some stocks may be masked by high gross economic yield.

Various objectives such as adjustment of fishing mortality, fishing capacity, size at first harvest, and allocation among user groups have been sought through a variety of management measures. These are described in the papers and discussions as meeting with varying degrees of success.

Age-Specific Fishing Mortality

Because of the rapid growth of young shrimp - and of the even greater increase in value of the individual shrimp - "growth overfishing" is likely to occur in shrimp; that is, the total weight and total gross value of the shrimp catch is likely to be increased by shifting fishing mortality from the smallest sizes of shrimp onto the larger sizes. The separation in space and time between the main concentration of small and large shrimp mean that there are several ways of doing this, as discussed below. This separation has also encouraged the growth of distinct fisheries on the two groups - typically artisanal fishermen catching small shrimp with traditional gears in the lagoons, and industrial vessels trawling for large shrimp offshore. Management is often concerned in giving preference to one of these groups. This decision will be based ultimately on overall national policies (e.g., the decision in Indonesia to ban trawling where there are many small-scale fishermen), but it is important that the managers are supplied with sufficient information on the costs and benefits involved (for example the calculations of Griffin of the differences in value from catching shrimp in the inshore and offshore fisheries of the Ivory Coast). Once the decision is made, the procedures to give priority to one or the other sector are likely to be fairly straightforward, and were not discussed further. The meeting therefore concentrated on controls on the ages (or sizes) of fish caught within a fishery, particularly the industrial trawl fishery. Several measures have been employed.

Seasonal Closures

Seasonal closures can be used effectively to select the size at first harvest in some shrimp stocks where there is a seasonality of recruitment of major portions of the stocks. Mathews discussed closed seasons in the Arabian Gulf off Kuwait to protect young recruits and which by reducing mortality would be expected to protect young recruits and which by reducing mortality would be expected to increase biomass. Winter/Spring spawners would also be directly protected by one of the seasonal closures. He concludes that if relatively high values of Z are assumed to be applicable, then a 3-5 month closed season is clearly useful, and a 5 month season is more likely to increase recruitment and landings than a 3 month closed season.

Poffenberger described the United States' closure of its western Gulf of Mexico to increase the harvest size of juvenile brown shrimp emigrating from estuaries. Data indicate increased yields and a higher value for the larger shrimp taken.

In Australia's Gulf of Carpentaria Kirkwood reports a decline in the sizes caught in 1976 due to a 15 day earlier re-opening of a closed season.

Garcia and LeReste suggested an advantage of closure of sea fishing at the moment of most intense recruitment to avoid exploitation of concentrations of juveniles at a time of rapid growth. They suggested this closure might be coordinated with a closed season in the estuaries if a fishery exists there. They caution that consideration should be given to the economic impact on an idle fleet.

Ye described China's unilateral seasonal closure of a northern portion of the Yellow Sea and the need to expand this closure to afford protection of the *Penaeus orientalis* brood stock in its extensive migration for spawning.

Area Closures

The permanent closure of an area which serves as a nursery to juvenile shrimp and contains few individuals of a preferred harvest size has been effectively employed. In the Mexican Pacific fishery managers have closed to trawling two well identified nursery areas which contain juvenile shrimp throughout most of the year, according to Ehrhardt *et al*.

Van Zalinge reported a somewhat larger average size in the months following the 1980 closed season adopted by all of the west coast countries on the Arabian Gulf.

A permanent closure of the Tortugas Shrimp Sanctuary in the U.S. eastern Gulf of Mexico was initiated to protect juvenile pink shrimp from growth overfishing. Small shrimp migrate through the area (which extends offshore to about ten fathoms) throughout the year. Poffenberger discussed the economic gains of such a measure. Such regulation (though it may be effective in increasing catch and value) has socio-economic consequences because it may eliminate small boats that are unable to fish beyond the closed waters.

Closed seasons and areas are used in Australia to protect nursery areas and control size of harvest (Walker).

Minimum Size Limits

Control of size at first capture by use of minimum landing sizes of shrimp has encouraged the wasteful practice of culling and discarding undersized shrimp. In an open access resource fishermen have little incentive to refrain from fishing mixed stocks when there is a profit to be made from retaining the larger individuals. Therefore, this measure has proven ineffective where employed until recently in the U.S. Gulf of Mexico. A recently implemented set of regulations in federal offshore waters adjusts harvest size by area closures. Two states, Florida and Texas, have subsequently repealed their landing size restrictions.

Griffin et al estimated that if small shrimp previously being culled in the Texas fishery could have been landed, the value of excess profits to vessel owners would range between \$18.6 and \$27.4 million and to their crews between \$4.65 and \$6.84 million.

Mesh Size Regulation

The adjustment of net mesh size may be used to release small individuals of the stock, small shrimp in a mixed stock, and unwanted bycatch. The theoretical dynamics of mesh size selection with reference to shrimp are discussed by Jones. Since the selection range in shrimp selection curves extends over a relatively large part of the exploited length range, assessment methods that permit the rate of exploitation to vary continuously with length are to be preferred to those that assume knife-edge selection and a constant value of fishing mortality for the exploited length groups.

It was agreed, primarily because of the wide selection range that regulation of mesh size was unlikely to be particularly useful in terms solely of the shrimp catch. However, it could be useful for controlling the fish catch, especially in the many areas (Indonesia, Thailand, etc.) where the fishery is based on a mixture of shrimp and fish. Cushing reported on this type of application of mesh size in the Nephrops fishery of the Northeast Atlantic. In such cases the optimum mesh size would have to be based on a compromise between the large mesh, which would be best for larger species of shrimp, and the smaller mesh, appropriate for smaller fish and shrimp. This still might be considerably larger than the mesh in use of several fisheries, especially in Asia, for which the use of a larger mesh could be beneficial.

If a mesh size regulation is being considered, a number of factors need to be examined. These include the selection pattern (including the effect of different types of net and twine, and of different sizes of catch and towing time), the assessment of the immediate and long-term effects (for which the length-structured models, such as those discussed in section 5, are likely to be useful), and the determination of effective measures of enforcement (which include controls on the use of chafing gear, double layers of netting, etc., as well as a legally acceptable method of measuring the meshes).

Control of the Amount of Fishing

A variety of methods have been employed to reduce fishing mortality with varying degrees of success. Shorter fishing seasons. less area open to fishing, less efficient fishing methods and gear, quotas, limited entry, and limitation of capital are some methods considered.

Because the abundance of stocks may fluctuate greatly as a result of environmental factors, as discussed by Christmas in the U.S. Gulf of Mexico, the manager must be provided with current predictive information if he is to control fishing pressure to prevent recruitment over-harvest. The manager must also be aware of any change in fishing effort or practices which may affect the total catch. The shift of catch and effort by the industrial and artisanal fisheries of the Arabian Gulf in the 1970's is one example of a changing fishery and the impact on stocks.

The manager must also consider the socio-economic impact of reducing the efficiency of the fishermen particularly during a period of rapidly increasing costs of fishing and processing the catch.

Gear Restriction

Catch can be reduced by restricting the efficiency of the fishing unit provided that the fisherman does not compensate by increasing effort. Methods commonly employed include limitation of trawl size (of footrope) or even elimination of the trawl from specific areas. Where several groups of fishermen exploit the same stock controls on the type of gear that can be used can be very effective in discriminating in favor of one group. Thailand has prohibited the use of trawls with motorized boats within 3,000 meters of shore (Srimukda). Unar described the experience in Indonesia to restrict trawling from waters where high densities of small shrimp may occur, and where many small-scale fishermen are operating a variety of traditional gears. This action has a great socio-economic impact because it allocates a portion of the resource to an artisanal fishery.

Catch Quotas

Though quotas on the total annual catch have been a common method of management for long-lived animals (whales, halibut, cod, etc.), annual catch quotas are not a suitable measurement for shrimp. Since they are short-lived, an annual quota does not control the fishing mortality, and might in fact encourage intense fishing at the beginning of the season - though this might be dealt with by setting quotas for short periods, e.g., months.

A daily vessel or trip catch limit have been used to limit mortality. It also affects capacity. This measure applied in some inshore waters of the U.S. Gulf of Mexico to restrict harvest of juvenile shrimp requires a high level of monitoring for enforcement to be effective.

Controls on Fishing Effort

While other measures such as catch quotas can achieve the biological objectives, some direct control on the fishing effort (or the capacity of the fleet) is likely to be necessary to realize the significant economic benefits that could come from effective management. These measures are also likely to result in what is in effect, an allocation of the resource between different user groups.

Criteria to be considered in setting a level of fishing effort includes maintaining stock at a desired level of productivity, keeping costs to a minimum, and obtaining the support of the affected fishermen.

Some possible ways to restrict effort are quotas, limited entry, delegation of fishing rights, and taxation or license fees. Catch quotas, in addition to the disadvantages discussed earlier, require a high level of enforcement to be effective in large fisheries.

Limited entry (or the restricting of the number of fishing units - usually the number of vessels licensed to fish) does not necessarily result in limiting effort. In the Australian experience of limited entry, which resulted in a restriction on the number of vessels, fishing effort continued to increase.

The objective of such a system should be the maintenance of the resource at the desired level while maintaining an economically viable fishery and industry. This is essentially the objective in Western Australia. Under United States law, limited entry cannot be implemented solely for economic purposes, but must also consider biological, sociological, and other factors.

Limited entry can tend to generate increasing real fishing effort in two ways. First, each fisherman will try to increase his effort within the terms of his permit. For example, the increased size of boat in Australia.

Second, the degree to which the measure is successful and generates income for those in the fishery, will stimulate the fishermen to improve their effectiveness still further. In principle this should be controlled by the terms of entry limitation, but the ability of fishermen to outwit regulations is great.

Unar described the Indonesian program as successful to limit effort in Irian Jaya based on the optimum effort suggested by production models. He cautions that fishing mortality is dependent on effort, and in some Indonesian fisheries there is a trend to increase vessel power, net size, and fishing hours.

Fishing rights are usually delegated in small, local fisheries and may have some value in allocating and restricting inshore artisanal fisheries.

Taxation in the form of high license fees is a method of limiting entry but as in limited entry could stimulate increased effort by those authorized to fish. To the extent that the fees would return some of the economic rent to the society, this stimulation will be reduced.

Some of the more broad measures which may affect capacity are import duties and quotas which increase markets for domestically produced shrimp in an importing country. Government subsidy of vessel construction, loan guarantees, or fuel costs would also tend to increase fishing capacity, maintain excessive effort, and generate excess capital.

Habitat Modification

Although the maintenance of the quality of the fishery habitat affects natural mortality and recruitment to the fishery, it is not always within the direct control of the manager of the fishery. Habitat may be lost as described by Christmas in the case of the white shrimp in the Northern Gulf of Mexico. Shrimp habitat can be enhanced by such programs as water management and pollution control.

Enforcement

To be effective, a management measure must be enforceable as well as acceptable to most of the fishermen who are regulated. The cost and level of enforcement necessary to implement regulations should be considered at the onset.

Monitoring Program

The fishery managers and scientists should monitor the condition of the fishery and be prepared to take prompt action to revise the management objectives and techniques if the need arises. Advisory boards of fishermen and technical experts in fields closely associated with the fishery can be useful for this purpose.

9. FUTURE WORK

The Workshop was concerned with the scientific basis for the management of penaeid shrimps. In considering future work it was therefore necessary to have in mind that the purpose of fisheries research is to provide a basis for management decisions. This is not to say that each research program will have a direct management application, but in the final analysis the integration of the research data should provide an understanding of the penaeid shrimps about which management decisions have to be made.

Much research has already been undertaken on the shrimp stocks of the world and it is not the purpose of this Workshop to attempt to provide either a catalogue of that research or a manual of research requirements. Diverse programs of research on the shrimp stocks, the environment in which they live, and on the units exploiting those stocks will continue to be undertaken. However, the Workshop was convened because the research undertaken so far has brought about a number of concerns regarding some of the shrimp fisheries, and the time was opportune to consider those areas of research which appear to require special attention so that the scientific basis for management decisions might be strengthened.

In general, the concerns being expressed are:

(a) Most shrimp stocks are now being heavily fished;

(b) The abundance of some shrimp stocks appears to have declined and the reasons for the decline are unclear;

(c) The heaving fishing pressure in some fisheries may have resulted in a decrease in the abundance of spawning stocks to a level which is resulting in reduced recruitment;

(d) In some areas there is a decline in the quality of the juvenile habitat;

(e) The cost of operation of some segments of shrimp fisheries is increasing at a rate faster than income;

(f) There is conflict among user groups as to area and size at which shrimps are to be harvested. This can be at both the national and international level;

(g) The large fish bycatch can damage directed fisheries on the fin fish species, and if used for human consumption, could increase the world's supply of high-grade protein.

Within this framework of concern about the state of many of the world shrimp stocks, the Workshop discussed future research needs, and proposed that special attention be given to the following areas of research:

1. <u>Stock and recruitment relationship</u>

Concern was expressed that whereas management decisions in the past had mostly been made on the basis that recruitment numbers are independent of parent stock abundance at the levels of exploitation being experienced (with variations being determined by environmental conditions), data from a number of fisheries now indicate that this degree of independence may not hold true for all shrimp fisheries when exploitation rate is high.

In researching stock/recruitment relationships special attention needs to be given to:

(a) definition of index of breeding stock abundance;

(b) fecundity, with a view to estimating an index of egg production;

(c) definition of index of recruitment;

(d) recruitment variability due to environmental factors.

Emphasis should be given in establishing causal mechanisms that could affect recruitment, and where feasible identifying density-dependent effects which could generate a stock-recruitment curve.

2. Natural mortality

While there have been advances in the determination of estimates of natural mortality, the range of estimates is so wide and the parameter of such importance for management advice, there is an urgent need for special attention to be given to research which will provide a greater understanding of the value of M. In this regard, the following lines of research were suggested:

(a) Comparative studies using data already available to obtain a greater understanding of the natural mortality of the different shrimp types.

(b) Studies of the underlying causes of mortality - predation, physiological death, diseases.

(c) Further tagging studies with particular attention being given to the degree of tagging mortality.

(d) Life table studies and DeLury type techniques. In this regard, attention was drawn to a recent paper by Chien and Condrey, 1981 manuscript.

3. Identification and standardization of effective fishing effort

Many shrimp fisheries consist of an inshore and an offshore segment. The inshore segment involves the use of different types of fishing gear - fixed nets, small boats with nets, and so on. The offshore segment is the industrial fleet of multi-rigged trawl vessels. It is of increasing importance to have a sound understanding of the effective fishing effort, preferably of both segments of the fishing industry but at least of the industrial fleet.

The nature of the inshore fishery may make difficult the calculation of effort estimates of this segment. However, even if this is not possible, data (e.g., the numbers of fishermen and the types of gear used) should be gathered to understand whether changes are taking place in the fishing effort of the inshore fishery and the relative strength and direction of these changes.

It is important to establish the unit of effective fishing effort of the industrial fleet when the data are first being collected from that fishery. Failure to do this will result in the data set being of less value when stock analyses are undertaken.

Even though estimates of fishing mortality may not be available for the inshore fishery, managers will be called upon to make decisions about the use of the shrimp resources by different user groups. It is important therefore to attempt to assign a fishing effort figure to all segments of the fishery to aid the decision making process.

Areas of research which should be considered in the future include:

(a) Independent estimates of the stock, e.g., by fish locating techniques.

(b) Catchability studies - behavior of the animals and fishing pattern of the fleet.

(c) Gear research - to estimate amount of fishing mortality generated by a particular gear type and to establish the selectivity of nets of different meshes for shrimp and for the main species of fish occurring in the bycatch.

(d) Methods of analyzing length frequency data, including adaptations of cohort analysis.

4. The Habitat

The immediate coastal zones are the main nursery areas for shrimps, and it is these zones where several changes may occur. The changes may either occur naturally, e.g., variations in river run-off, or be man-made, e.g., dredging of the estuarine system or removing mangroves.

As changes in the habitat are likely to have a major influence on shrimp recruitment, it is important to pursue studies on the nursery habitat so that causes in recruitment variation can be better understood. There is very little data available on habitat destruction and its effect on shrimp stock abundance.

Information on habitat changes is not only important in analyzing the stock production data and stock-recruitment data, but also in providing the administrator with information about the likely effect of proposed man-made changes to the nursery habitat. Furthermore, such studies provide an opportunity for advice to be passed to the fishing industry indicating the likely relative abundance of shrimp some months ahead of the fishing season for the industrial fleet.

In summary, research should be undertaken on the life history of shrimp species in relation to the critical environmental influences. Also, a valuable contribution to the development of future research programs would be a global view of types and areas of inshore habitat in relation to shrimp abundance, and including information on habitat changes which have occurred.

5. Data base

The Workshop identified the establishment and continual updating of a data base as being of critical importance. The data base should be a historical description on an annual basis of the fishery describing:

(a) catch, catch composition and effort data (including bycatch species, discards and estimates of unreported catch);

(b) number and type of fishing units;

(c) number and type of personnel operating the units;

(d) description of the fishing grounds, e.g., artisanal and industrial;

(e) method of handling the production on the fishing units and in the factories;

(f) the market system;

(g) the value of the product at specified points of sale, and easily obtainable allied economic data;

(h) significant changes which have taken place in the fishing units; personnel, grounds, marketing;

(i) simple description of the environment, quantified where possible.

It is recognized that the amount and sophistication of data collection will vary from country to country. However, it was emphasized that whatever data are available should be properly identified so that they are in a form capable of being used by those providing advice as well as by administrators.

6. Data integration

Fisheries scientists collect an array of data on shrimp stocks, and some of these data are essential for other studies, such as those undertaken by economists. It is important, therefore, that fisheries scientists understand the requirements of economists, and the sociologists too, so that the date base is capable of being used by all personnel who have a responsibility to provide advice to management. Furthermore, the advice of the fishery scientist will be more meaningful if the scientist has a basic understanding of the work being undertaken by the economist and sociologist.

Future work should be undertaken with greater attention being given and to all personnel having an understanding of the method of collection and accuracy of the original data set. The data set will increase in complexity and value as research workers from the various disciplines start to work the data and make more specific their requirements for data collection. An appropriate technique of management information system should be adopted to assist in the integration of the data set, and this integration should include the financial implications.

7. Use of models

Production models are of value in gaining an understanding of the effect of fishing on the stocks. However, concern was expressed that too much reliance should not be placed on their use in terms of achieving optimum yield on a long term basis. The production model suggests what will happen on the average, but does not provide information early enough on the possibility of a severe reduction in catch if effort is increased significantly.

The assessment obtained with a production model will be more valid the longer the series of data on which it is biased. There is danger with assessments based on short periods of confusing variations due to environmental changes with those due to changes in effort. It is important that continuity research be undertaken to examine the causes of the variations.

Age- or size-structured models (of the Ricker/Beverton and Holt type), giving the relation of yield-per-recruit to different fishery patterns are essential in determining the effect of changes in the balance between different sectors of the fishery (inshore/offshore, etc.). Because of large variations in estimates of some parameters of shrimp stocks, such as natural mortality, thus reducing the applicability of the yield-per-recruit model, attention should be given to providing scientific advice in terms of the probability of the result of taking a particular management decision.

On the development of new models it was pointed out that there were a number of outstanding problems for which adequate models were not available. Examples given were the requirement for bioeconomics, recruitment, decision making and allocation models. Furthermore, there is a requirement for future work to include a model in conceptual form describing how the fishing fleet might respond to management options being considered and to identify influences such as a rapid increase in fuel price and describe the effects on the stocks of the fleet response.

8. Analysis of the system

The Workshop drew attention to the importance of scientific advice being presented in a manner which integrates the array of data available on the stock, the fishing units, and the environment. In the transfer of information there is a need to develop simple models which draw together the dominating variable factors of the environment, stock parameters and the fishing practice, and describe their integrated effect on stock abundance and fishing industry success. Some of the important elements of the system to be considered are:

(i) Fishing section - industrial fleet, inshore fishery

(ii) Estimates of F, M, K, L_∞

(iii) Length at entry into the fishery, length at maturity

(iv) River flow

(v) Rainfall

(vi) Temperature

(vii) Cultural encroachment on estuarine habitat

9. Ecological interactions

In some shirmp fisheries, such as that on banana shrimp in the Gulf of Carpentaria, there is very little bycatch taken with the shrimp. However, in others the capture of shrimp is accompanied by considerable quantities of fish, much of which is discarded; while in others again the fishery is directed at both shrimp and fish.

Research is required on the ecological interactions of the fauna on the shrimp grounds to provide information on the likely consequences in terms of total yield of introducing gear changes such as a shrimp separator trawl.

In relation to this subject, studies are required on the selectivity in feeding habits of the fish, measurement of the relative biomass of the various prey in the stomach of the fish, and a comparison with the relative biomass of these prey items in the prawn area environment.

10. Socio-economics

Future work should include greater emphasis on the role of the socio-economist in providing advice to management. Areas of work needing particular attention are those which:

(a) Clarify management objectives for any particular fishery taking into account the existence of an inshore and an offshore fishery. In considering this subject consideration will need to be given to such matters as quantifying trade-offs between net revenue, employment, and individual income.

(b) Determine costs and how these might be lowered by variations in the balance of elements of capital, manpower, energy, and in cost structure.

(c) Determine the multiplier effect under various management options. For example, it is important to determine whether F for maximum employment is far to the right of F for maximum net revenue or F for optimum individual income. Such a study would assist in the resolution of conflicts between management objectives.

(d) Provide information on the mobility in and out of the fishery of labor (especially in rural areas where there are cultural barriers), and of capital (access to loans, indebtedness, etc.).

(e) Provide information on fishermen's earnings.

(f) Add to an understanding of the benefits of management options; this should include the collection of information on management schemes used in some traditional fisheries, such as property rights.

11. <u>Priority and balance of research programs</u>

Attention needs to be given to developing methodology for determining criteria for the allocation of finance for research. While the management objectives will differ from country to country thus affecting the priorities for research, the methodology will have general application.

An example of a process which could serve as a useful guide to establishing research priorities is set out in Table 2. It must be emphasized that the priority ratings given to each factor is by way of an example only, and the research objectives and management objectives (and the priorities given to them) are likely to vary from country to country. Each country therefore needs to determine its own management objectives, the research needed to attain each of these objectives, and the current state

Table 2. Example of Decision Analysis of Research Priorities (Example Priorities in the U.S. Fishery)

Research Objectives	Management Objectives				Total Score	Mgmt. Need Rank	State of Knowledge Rank **	Combined Rank
	Optimum Size	Max.Economic Function	Min.Biol. Risk	Habitat Mgmt.				
1. Growth	1 *	3	2	3	9	6.5	H / 9	9
2. M	1	3	2	3	9	6.5	L / 3	4
3. F	1	1	1	2	5	1	M / 4	1
4. S/R	2	2	1	2	7	3.5	L / 2	2
5. Inter-species Relationships	3	3	1	1	8	5	L / 1	3
6. Environmental Interactions	2	1	2	1	6	2	H / 8	5
7. Harvesting Economic Dynamics	2	1	3	1	7	3.5	H / 7	6
8. Processing Economic Dynamics	3	2	3	2	10	8	M / 6	7.5
9. Market Economic Dynamics	3	2	3	3	11	9	M / 5	7.5

* Score Description (only 3 of each per objective)

1 = Essential
2 = Primary Supporting Information
3 = Secondary Supporting Information

** Level of Current Knowledge

H = Highest
M = Moderate
L = Least

of knowledge relevant to each field of research. For example, countries with urgent social problems may find that high priority should be given to research into the economic dynamics of the harvesting and processing sectors. Nevertheless, it is believed that a tabulation of this type would be found useful by most countries in assessing their national research priorities.

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APPENDIX I

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APPENDIX II

WORKSHOP ON THE SCIENTIFIC BASIS FOR THE MANAGEMENT OF PENAEID SHRIMP

List of Papers

1. "The Limited Entry Prawn Fisheries of Western Australia: Research and Management", by B.K. Bowen and D.A. Hancock.

2. "Ecological Interactions Between Penaeid Shrimp and Associated Bottomfish Assemblages", by J. Browder, J. Powers, and P. Sheridan.

3. "Standardization of Fishing Effort, Temporal and Spatial Trends in Catch and Effort, and Stock Production Models for Brown, White, and Pink Shrimp Stocks Fished in U.S. Waters of the Gulf of Mexico", by S. Brunenmeister.

4. (a) "Do Discards Affect the Production of Shrimps in the Gulf of Mexico?"
   (b) "The *Nephrops* Fishery in the Northeast Atlantic", by D.H. Cushing

5. "Catch Prediction of the Banana Prawn, *Penaeus merguiensis*, in the Southeastern Gulf of Carpentaria", by D.J. Staples, W. Dall, and D.J. Vance.

6. "Biologie et Exploitation de la Crevette Penaeide *Penaeus notialis* (Perez-Farfante, 1967)", by F. Lhomme and S. Garcia.

7. "Analysis of Management Alternatives for the Texas Shrimp Fishery", by W. Griffin.

8. "Some Principles of Mesh Selection, with Particular Reference to Shrimps", by R. Jones.

9. "Modelling of the Gulf of Carpentaria Prawn Fisheries", by G.P. Kirkwood.

10. "Exploitacion de los Recursos Camaroneros en Nicaragua:, by S. Martinez.

11. "Impacts of Variation in Growth and Mortality Rates on Management of the White Shrimp Fishery in the U.S. Gulf of Mexico", by S. Nichols.

12. "Application to Shrimp Stocks of Objective Methods for the Estimation of Growth, Mortality and Reruitment-Related Parameters from Length-Frequency Data (ELEFAN I and II)", by D. Pauly.

13. "The Behavior and Catchability of Some Commercially Exploited Penaeids and Their Relationship to Stock and Recruitment", by J.W. Penn.

14. "The Relationship Between Catch and Time of Fishing for the Pink, Brown, and White Shrimp of the Northern Gulf of Mexico", by P.L. Phares.

15. "A Review of the Shrimp Fisheries of India: A Scientific Basis for Management of the Resources", by E.G. Silas, M.J. George, and T. Jacob.

16. "A Review of the Indonesian Shrimp Fisheries and its Management", by M. Unar and N. Naamin.

17. "A Review of the Shrimp Fisheries in the Gulf Between Iran and the Arabian Peninsula", by N.P. van Zalinge.

18. "The Guianas-Brazil Shrimp Fishery, its Problems and Management Aspects", by L.C. Villegas and A. Dragovich.

19. "The Prawn (Penaeus orientalis Kishinouye) in Pohai Sea and Their Fishery", by Ye Chang Cheng.

20. "Australian Prawn Fisheries", by R.H. Walker.

21. "Introductory Guidelines to Shrimp Management: Some Further Thoughts", by. J.A. Gulland.

22. "The Impact of Environmental Factors on Gulf of Mexico Shrimp Stocks", by J.Y. Christmas.

23. "Review Paper on the U.S. Gulf of Mexico Shrimp Fishery", by B.J. Rothschild and M.L. Parrack.

24. "An Economic Perspective of Problems in the Management of Penaeid Shrimp Fisheries", by J.R. Poffenberger.

25. "A Historical Assessment of the White Shrimp (Penaeus setiferus) Fishery in the U.S. Gulf of Mexico", by S. Nichols.

26. "Review of Eastern King Prawn Fishery, East Coast of Australia", by J.P. Glaister.

27. "A Review of the Fisheries Biology and Population Dynamics of Kuwait's Shrimp Fisheries", by C.P. Mathews.

28. "Shrimp Fisheries in the Gulf of Thailand", by Pichit Srimukda.

29. "Fishing Configurations of Common Shrimp Trawl Designs Employed in the Southeastern United States", by J.W. Watson, Jr., I.K. Workman, C.W. Taylor, and A.F. Serra.

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32. "Life Cycles, Dynamics, Exploitation and Management of Coastal Penaeid Shrimp Stocks", by S. Garcia and L. LeReste.

33. "Exploracao Do Camarao Na Regiao Norte Do Brasil" by J.X. de Mesquita.

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35. "Growth Rates of White Shrimp as a Function of Shrimp Size and Water Temperature", bu S. Nichols.