COMMONWEALTH OF AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

Division of Fisheries and Oceanography

REPORT 41

# COLOMBO PLAN

# FISHERY RESOURCES RESEARCH INDIA
# REPORT TO GOVERNMENT OF INDIA

By G. L. Kesteven

Marine Laboratory
Cronulla, Sydney
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The views expressed in this document are those of the author and in no way commit the Government of India

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# FOREWORD

The initial request for the consultations which are the subject of this report was made in 1965. The request, from the Government of India to the Government of Australia, under the Colombo Plan, was for a brief visit by me to India to help to draw up a working plan for Fisheries Research to be included in the Fourth Five Year Plan. Various circumstances intervened to cause several postponements of the proposed visit and it was not until April 1967 that the visit became possible. I visited India from April 20 to May 4, 1967. Although visits by me to research centres in Bombay and elsewhere had been proposed it soon appeared in discussions with Dr Mitra, Fisheries Development Adviser to Government of India, that the short time at my disposal would be best spent in consultations with him and his central staff and consequently I remained in New Delhi for the whole of my time in India. After initial briefing by Dr Mitra I occupied myself with reading Departmental papers and published reports, and in protracted discussions with Dr T.A. Mammen and Mr Kohli; the discussions were informative and animated and frequently became quite heated (which, in my view, was fortunate). Subsequently I resumed discussions with Dr Mitra. Since I have had extensive contact with Indian fisheries research, since 1947, I approached my task with some knowledge of personnel, geography and technical aspects and thus was reasonably well placed to profit from those discussions; anything of value in the observations reported here, and in the suggestions I make, owes much to those discussions; but, of course, any misapprehensions under which I may have laboured are to be attributed only to my inadequacies, not to theirs, and my collaborators are not to be held responsible for the proposals I make in this report, no matter how strenuously they strove to make me well informed on the matters I was considering.

The opportunity to renew direct contact with Indian fisheries research was very welcome to me and I am most grateful to the Government of India, and to Dr Mitra in particular, for it. I also wish to express my thanks to the Minister for External Affairs, Australia, Mr Paul Hasluck, for making the visit possible as part of the Colombo Plan.

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# INTRODUCTION

1. Although scientific work on fauna and flora in India has an admirable tradition, of ancient origin, maintained through activities such as of the Zoological Survey of India, and represented, for example, by Day's classical "Fishes of India", fisheries research in modern sense did not attract the attention of the Central Government of India until after World War II. In 1943 Dr Baini Prashad made recommendations, for the establishment of arrangements in Government of India for the conduct of fisheries research, which led directly to the creation of a number of institutions to carry out fundamental and applied research on fishery resources and on the industries engaged in the exploitation of those resources and in utilization of their products. In the twenty years since the establishment of these institutions their research workers have accumulated a formidable body of information on resources, products and industrial practices. The volumes of the Indian Journal of Fisheries and of the Journal of the Marine Biological Association of India, and of other Indian scientific publications, are witness to the industry of these workers.

2. Whilst the research situation was thus changing, important changes were also taking place in the fishery industries. Notable among these industrial changes was the development of mechanised fishing of the continental shelf resources, and of especial significance was the creation of a prawn fishing and processing industry to supply prawns to high-priced overseas markets. This development has brought technological, managerial and investment innovations which are having an important influence on the industry: the nurturing of these innovations, in public and private sectors, will be a significant element of the programme to promote the expansion of India's fisheries. Indubitably expansion of the fisheries should take place; that it can take place is manifest from what is already known of the resources; but to turn from these premises to a prognosis of the nature of the expansion and to the design of comprehensive plans, in public and private sectors, to achieve whatever developments might be possible, is to enter a complex of problems of considerable intricacy. Priorities must be set over a wide range of developmental possibilities; choices must be made between various types of boats, fishing gears and other equipment; discriminations of many kinds must be made with respect to courses of action, categories of technical competence, demands for finance, and so forth: in sum, there is a complex set of decisions to be made, for which both Government and industry must have access to a store of reliable information. This store however cannot be a museum - an array of fossilised fact; it must instead be living and growing, its vitality preserved through constant renewal by reconfirmation of its facts; fed by a constant flow of new data, it must grow and develop, transforming its descriptions and models in step with the changes taking place in the natural and industrial systems with which it is concerned. It is with this information store that the present report deals.

3. Government of India has included substantial schemes for fisheries in its Fourth Five Year Plan, and research has an important part in these. Apart from expenditure directly on research contemplated in the Plan, the design and management of development schemes will rely considerably on research for background and operational information. The Fisheries Development Adviser of Government of India (Dr G.N. Mitra), who has responsibilities in the formulation and conduct of these schemes, is very much alive to the role to be played by research in this programme, and is desirous of ensuring that the institutional arrangements for conduct of fisheries research (and for utilization of its results) should be made as effective as possible. For this reason he sought some outside assistance in reviewing the existing arrangements against the background of past research achievements and in the light of present needs. This move by Dr Mitra is to be understood as according with the principle that he who watches from the side-lines may be expected often to see what escapes the eyes of the players.

4. Dr Mitra's mandate to me was a fairly general one; to comment on the research needed for the development of India's fisheries; but his main concern was with a continuing resources survey*. Dr Mitra saw the CRS as a special sector of fisheries research distinguished by its strict concern with obtaining currently the information needed by Government and industry in developing and managing the industry. With this distinction Dr Mitra separated CRS activities from research activity directed at long range and fundamental enquiry.

5. Since this report is concerned chiefly with a CRS it is important that the nature of Dr Mitra's distinction, and its implications, should be quite clear to the reader; I therefore begin this report with a brief note on resources information and then consider the present situation of Indian fisheries and of research on them; this review material furnishes a background for a set of proposals for reorientation and acceleration of Indian research on marine fishery resources.

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*Generally I shall use the initials CRS for this term.

## RESOURCES INFORMATION

### The Nature and Uses of Resources Information

6. In the broadest sense, the information required with respect to each fisheries resource will relate to:

I. distribution, in time and space;
II. abundance and yield capacity (potential catch);
III. behaviour*.

Information on these matters will in the first place be quite generalized and will embrace the periodic (e.g. seasonal) changes that take place in these features. In the second place it will include some measure of irregular departures from average pattern - that is, it will, for example, give an indication of the frequency with which exceptional events (such as a fall to extremely low abundance) will occur. Finally, in its highest development it will furnish guides as to what is to be expected in particular places and at particular times - that is, it will be the basis to a system from which there can be prediction of particular events. In this phase is included fish-husbandry, which relies on an expectation of certain results as sequel to specified manipulation of the resource and its habitat.

7. This information will be used by industry:

(a) in the conduct of its operations within the established frame of knowledge;

(b) in extending and expanding its operations, so far as this may be possible;

(c) in securing the highest level of operational efficiency (productivity) consistent with the country's prevailing industrial norms; in this sense the information will be used inter alia to secure the greatest catch per unit effort, to prevent waste and to avoid loss.

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*The reader will find that the word "behaviour" is used in this report to refer both to the reactions of individual fish, of importance in fishing and, in a more theoretical sense, to the responses of whole populations to environmental variations.

8. The information will be used by Government:

(a) in planning development;

(b) in organizing and conducting its own work to promote and assist development; and

(c) in carrying out such work as may be necessary to ensure the conduct of the industry in conformity with national policy with respect to matters such as use of natural resources, and conditions of employment in primary industry. In part the Governmental use will be a dissemination of this information to industry as a means of promoting and directing development.

9. What I have designated as resources information consists of reports, on particular features of a resource population, of which Government and industry take note, and make use, for their several purposes. Such reports necessarily cannot constitute a complete account of the resource since they deal with only selected features and for the most part neglect what underlies and determines those features. Each of the features reported on is expressive of mechanisms and processes within the population generally, and in each individual of which the population is composed, and the operation of each process involves many interactions with features of the habitat occupied by the population. For the most part these internal processes, and the interactions, can be taken as given, but in particular cases resources information, as it is here designated, will include the data from observations of selected processes and interactions.

10. Resources information of broader scope will be necessary more especially for predictive purposes where, in principle, the observation of the behaviour of some determinative external system - for example, a current - affords a reliable and economic means of anticipating the behaviour of a resource population. At the same time it is to be borne in mind that it is their study of processes and interactions that enables research workers to construct their models of resource populations as systems, and then to identify the features to be observed for governmental and industrial purposes. It is this long way round, giving the short way home, that makes original research so effective.

11. In the concept of fisheries research from which I make my observations here, a CRS follows and is guided by original research. Location and identification of a resource opens the way to prospecting;

description of a life history, including features such as migrations, spawning places and times, permits better-informed observations on distribution and shifts in abundance; analysis of population structure and assessment of the dynamic significance of structural features, more especially of the significance of the association of structural changes with variations in the resource habitat including changes in fishing intensity, afford criteria for judging the meaning of changes in catches. Original research thus presses on with deeper and deeper penetration into a resource system, and as it goes identifies, for the benefit of CRS, particular features that can profitably be held under continued observation for the purposes of industrial operations.

12. The depth to which original research need go, for the purposes of management, depends upon the value of the resource, the variability of resource characteristics, the nature of the fishing operations, the ability of the industry to adjust its operations in response to resource information, and the economic gain to be got from such adjustment. It will be part of the CRS responsibility, in conjunction with economic research, to contribute to research strategy in this sense.

## Collection of Resources Information

13. Thus, the term "continuing survey" denotes an activity that differs from original creative research, although it must have much in common with original research and must be closely associated with it. It will be based on and guided by the results of original research; it will make observations and measurements similar to those made in original research, and will contribute data of which use will be made in original research; it may even turn up discoveries on its own. But in the main it will follow where original research has been before it.

14. Starting from an account of the resource constructed by research* a survey operation will collect, in systematic fashion, information on those attributes of

(1) the natural population of fish,

(2) the catch taken from it, and

(3) the fishing operations

that research has shown to be significant for the purposes described above.

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* (which generally will have made much use of information from industry)

15. The collection, compilation and analysis of this information will:

1. give a current view of the state of the resource population, within the bounds of the existing account of the population;

2. extend the bounds of that existing account (particularly, to begin with, in respect of distribution), and will add precision to various details of that account;

3. accumulate evidence on the departures from average pattern that may occur, and thus will contribute data from which research may extend and develop its account of the population;

4. provide, at times, a forecast of unusual events.

16. This description of the survey operation may seem to indicate essentially a monitoring of the exploitation of known resources within the range of existing fishing operations, and to exclude what is referred to as "exploration" and "prospecting". Since I do not intend a total exclusion I must show where and how exploration and prospecting may fall within this scheme.

17. Holt (1956) has given an admirable definition of these terms, proposing that the former be used to denote operations to obtain some information about quite unknown areas and that the latter be used to denote operations to obtain some quantitative measure of a particular resource in some area in which that resource is known to be present. Although the terms, of course, are only relative (one can explore in certain respects an area which in other respects is well known) they represent quite different spans of the reach from ignorance to knowledge, and hence they represent quite different sets of operations, conducted according to quite different strategies. Moreover they differ in principle and in detail from monitoring operations of the kind chiefly represented above, which generally constitute the bulk of a survey programme. But, since in exploratory operations the object of search is unknown (an exploration examines an unknown area to find out what is in it), the finding of an unsuspected object in a known area may give an appearance of "exploration" to even routine fishing operations; similarly, there can be a prospecting of an unexploited resource in an area in which there is already intensive fishing. Clearly, however, one does not "explore" a known area, except with very good reason, and one does not prospect an exploited resource.

18. In principle the sequence of evolution of understanding of an area, through research, is roughly as follows:

general exploration

characterization of fauna and flora

identification (taxonomic) of species

identification of communities

detailed account of life-histories of species

community dynamics

deep studies of ecology (including populations research), ethology, physiology of individual species.

This evolution, although it may draw on evidence from fishing, is in general independent of fishing itself, and fishing of an area (or of a particular species in an area) can start at any point in this sequence or, which has more often been the case, at a point some time before commencement of this sequence.

19. Since, by definition, survey work stands between original research (being based on it and contributing to it) and industrial operations, its terms, and its usefulness in any particular case, depend upon the point in the above sequence at which the research stands, and according to which the survey can be planned. The importance of this conclusion can be made clearer by reverting to the basic definition of survey, given earlier.

20. A survey is essentially the collecting of information (data) on attributes (of a system under study) which have been shown to be of critical significance for the purpose of maintaining a watch on the behaviour of the system. Compilation and analysis of the data lead to production of certain synoptic representations of the attributes and these "synoptics" are diagnostic of the state of the system (within the terms of the current research model of the system) according to rules for interpretation laid down by research workers. For example, a synoptic very widely employed in fisheries science is "catch per unit effort" (represented in symbols as c/g or c/f); this synoptic is taken to be a measure of the abundance of the stock from which the catch was taken; its usefulness for this purpose depends greatly on the reliability of the statistics of catch and effort and on the means of expressing the effort in standard units; the interpretation of changes in c/g is subject to a number of rules laid down in fisheries biology. The choice of synoptics and the rules for

obtaining them, as well as the diagnostic rules, are likely to be modified from time to time as accumulation of information leads to revision of the research model. We have noted above that survey will make important contributions toward such revision.

21. The array of information which, in the current state of the science, is to be assembled with respect to any resource species is represented in FAO's outline for a Species Synopsis (see Rosa 1965). It is to be remembered that the state of knowledge with respect to a particular resource species may be such that the rules for diagnostic appraisal of some or all of the synoptics, or even those for preparing the synoptics, may yet be lacking. Moreover, whilst the niches of this outline should generally be filled with synoptics, only some of these synoptics are of diagnostic value. Completion of an outline may be a research objective but for the Governmental and industrial purposes outlined above only a selected array of attributes need to be surveyed; a selection is set out in the Table at Paragraph 74.

## THE CURRENT SITUATION IN INDIA

22. From the foregoing discussion it will be clear that a CRS can properly be designed for a group of fisheries only on the basis of what is already known about the resources. The first step in planning a CRS thus should be a review and appraisal of accumulated knowledge. My time in India was too brief for me to be able to make such a review but in any case, in my opinion, the review should be made by those who have been engaged in the research and who will be responsible for the CRS and the further research that will be required. What I have done, instead, is to take a bird's-eye view of the status of the fisheries, in their main divisions, and of the salient features of the research results; from this view my suggestions are with respect to the strategy of CRS rather than to its tactics. A major element of that strategy will be a detailed review and appraisal for which my brief notes below are in no sense a substitute.

23. Oil sardine and Indian mackerel. The Indian fisheries for these species are notorious for their spectacular fluctuations; the prevailing view is that these fluctuations are caused by variations in accessibility of the stocks to the severely restricted fishing range of the gear in use at present, and that these variations in accessibility represent changes in the disposition of the migratory paths taken by the fish. It is thought that even maximum accessibility to existing gear brings only a proportion of the stocks under exploitation. From these views it is argued that a gain in average production

of some 15 lakh tons could be obtained if accessibility could be held constant at its level when maximum catch was taken, and that if the whole stock could be made accessible the average production might be carried beyond 100 lakh tons.

24. Whilst much is known of these species and many synoptics have been, or could be prepared from accumulated knowledge, their diagnosis is impossible in the absence of a measure of the accessibility of the stock and of its total magnitude. Survey can be planned as to catch and effort and as to the measuring of certain population characteristics, and this work certainly should be established, but the urgent need is for a research programme on distribution and abundance beyond the present fishing range.

25. Prawn. There is fairly sharp geographic distinction between the fisheries for Penaeid prawns (chiefly in Kerala and Mysore) and those for non-Penaeid prawns (chiefly in Maharashtra and Gujarat).

26. A graph of prawn production in the course of the past fifteen years shows that apart from a substantial increase between 1953 and 1956 the catch has been fairly stable at a level of about 0.8 lakh tons. For the non-Penaeid prawn areas there is perhaps a suggestion of an absolute decline in production since 1954. These appearances must be considered in the light of the greatly expanded overseas (chiefly US) market for shrimp, and the local response by way of mechanization of craft and establishment of processing plant; there is in this evidence an inescapable implication that the limit of production from these resources has been reached and perhaps passed, at least for the stocks now being exploited. It cannot be said that there are no more prawn grounds to be found; on the contrary, further prospecting of the continental shelf should be undertaken. However, close attention will undoubtedly be given to views, expressed by Menon, which suggest reasons for believing that serious changes may be taking place in the prawn habitat, and hence in the prawn stocks. In the result the conclusion seems to be that whilst prospecting is necessary, there is important work to do in monitoring the existing fishery.

27. Harpodon nehereus (Bombay Duck). A graph of the catch of this species since 1956 shows, if anything, a decline; at rough estimate this is in the order of 25% of 1957 catch. This evidence must be considered in the light of the fact that a large proportion of the mechanization of fishing boats has taken place in the states (Maharashtra and Gujarat) in which the bulk of the catch of this species is taken; at the same time, there are market and other matters to be taken into consideration, and no reliable diagnosis of this fishery can be made on the evidence presently available. It remains

possible that the fishery does not yet have full access to the stocks, and hence that some increase could still be got; in view of this possibility, some further prospecting for this species might be warranted; apart from this possibility, however, there is need for monitoring operations.

28. Demersal stocks. The amount of exploration and prospecting of the Indian continental shelf during this century has been considerable and the total knowledge of these resources is to be developed from the sum of those operations and analysis of data from them and from the intense inshore operations of country craft. Although there are several useful papers giving accounts of the exploratory and prospecting work, there has not yet been, so far as I can ascertain, a comprehensive compilation of all data. It seems to me that there can remain only little ground of which no measure whatsoever has been made, and that a study of accumulated data would permit fairly confident assessment of the yield characteristics of these resources in total, as distinct from assessments of particular species.

29. At its 12th Session (Honolulu, 1966) the Indo-Pacific Fisheries Council considered a paper by Tiews (1966) which argued that South-East Asian countries could expect each year to take, on the average, about 12.3 tons of demersal catch from each square nautical mile of continental shelf out to a depth of 50 m. Tiews calculated that at this rate India, with 53,000 square nautical miles of such shelf, could expect a sustained catch, from these resources, of about 650,000 tons. Tiews' thesis relied heavily on his experience with fishing in the Gulf of Thailand, but another paper before the Council (Isarankura and Kuhlmorgen-Hille, 1966) presenting more up-to-date information on the Thai fishery, gave evidence to suggest that Tiews' figure was placed too high as an estimate of sustainable yield. They reported that the catch rate had fallen from 1964 to 1965 and, as shown by research vessel operations, fell from 298 kg per hour in 1961 to 179 kg per hour in 1965. The Council itself concluded that a sustained catch rate of 12.3 tons per square nautical mile could not be expected, and that a more realistic figure might indeed be only 1/3 to 1/2 of Tiews' estimate. Even if Tiews' were the correct estimate, to increase Indian demersal continental shelf catch to 650,000 tons would not be of very great significance in the total Indian requirement from its fishery resources.

30. Zoogeographically there is much in common between the Indian continental shelf and the shelf of other South-East Asian countries and therefore a close study of results from other countries could be of considerable help to India. Particular attention should be

paid to the results from the Wadge Bank, which are very well documented (see Sivalingam and Medcof 1957, and Medcof 1963). The results on this Bank seem to have much in common with those on the Bombay grounds and with those in the Gulf of Thailand. The Indo-Pacific Fisheries Council has set up a Working Party to review evidence on the productivity of demersal stocks of its area and to assess the prospects of yields from them. In my view India could gain considerably from active participation in that Working Party; its participation would be an extension of the stock-taking proposed in Paragraphs 40-43 below. An important item of that work would be a comparison of productivity of Indian grounds with that of other grounds, especially of the Gulf of Thailand fisheries.

31. Assessment of the productivity of the established demersal grounds, and a monitoring of current operations, must obviously have an important place in the Indian fisheries programme. At the same time there must be a prospecting of inadequately known areas, notably between the Bombay and Cochin grounds on the west coast, and between Madras and Visakhapatnam on the east coast.

32. Pelagic stocks, continental shelf. The position with regard to these resources is even less certain than that of the demersal resources. Setting aside the sardine and mackerel resources, which have been dealt with separately and in any case are continental shelf resources only partially, the pelagic species of the shelf appear to yield only a minor part of the total marine catch. However, the exact status of a pelagic-shelf fishery is a little difficult to determine because of some uncertainty as to what are truly pelagic species; some of the catch taken by gears operated at the surface (especially by set nets operating in shallow waters) consists of species which are taken by demersal gears and are considered to be demersal. The conclusion that monitoring and further prospecting are needed, holds for this group, too.

33. General. Over the past ten years the average Indian marine fish catch has been in the order of 7 lakh tons. In the early '50s the catch was less than 6 lakh tons, but in 1957 it reached about 9 lakh tons. However, 1957 was the first year, in this period, in which the sardine fishery was successful, and in subsequent years it was chiefly better-than-average sardine catches that took the total beyond 6 lakh tons, and it appears that the other fisheries have remained more or less static over the period. Indeed, the statistical records show the marine catch other than of sardine and mackerel as relatively steady since 1950 oscillating about 5.2 lakh tons, and except for 1956, deviating by at most 15% and on the average by only about 7%.

34. The CMFRI's estimates of catch and effort show the catch per man hour by country craft to have increased somewhat since 1958, there having been, according to the Institute's figures, a substantial reduction in the effort expended whilst catch has increased. However, if the effect of the successful years of sardine fishing is removed from these figures, there is almost certainly no change in catch per unit effort from these data. Moreover, it is possible that real effort has been under-estimated, considering the degree of mechanization that has been achieved over the past 15 years, and more particularly over the past 10 years. A rough estimate from an examination of relative fishing power of mechanized as against non-mechanized craft suggests that the potential fishing power has been increased by perhaps 25%. It is difficult to believe that in the face of, inter alia, the national campaign for increased food production and the financial incentives offered by the export trade in prawns, the increased potential fishing power has been offset by what, from the CMFRI's figures, would amount to a decrease of more than 50% in the effort expended.

35. From the foregoing impressions I would represent the continental shelf prospects as follows:

| Resource | Prospective increase lakh tons |
|---|---|
| Sardine and mackerel | 9 |
| Prawn | 0 |
| Harpodon | 1 |
| Demersal | 3 |
| Pelagic | 3 |
| Total | 16 |

Added to the current catch of about 9 lakh tons this suggests a prospective catch of 25 lakh tons, from exploitation of the continental shelf resources. Some Indian researchers would probably place a significant figure (say 1 or 2) opposite Prawn, but clearly this would not greatly affect the result.

36. In the Report of the Working Group on Fisheries for the Fourth Five Year Plan, it is stated that "experts have estimated that India could produce 100 lakh tons of fish (85 lakhs marine and 15 lakhs inland)". If the prospect for the continental shelf fisheries is

25 lakhs, and if the estimate of 85 lakhs as total Indian marine production is well founded, a catch in the order of 60 lakh tons must be expected from offshore, beyond-the-continental-shelf resources.

37. The foregoing perspective, if valid, means that plans are required on the one hand for a continental shelf survey programme to assist the existing industry in efforts to achieve an increase in the order of 16 lakh tons, and on the other for a quite separate programme to guide and assist the creation of new fisheries in offshore waters to take a catch nearly two and a half times the total expected from those over the continental shelf. Moreover it means that most of the effort on the continental shelf should be directed at the sardine and mackerel resources.

38. Needless to say, none of the foregoing figures is offered as an authoritative estimate to be used for planning purposes. Although the figures have been arrived at by way of some logical argument, they have been reached after only superficial examination of only a small part of the evidence available, and they are given here to illustrate some lines of thought and to serve as a starting point for discussion.

## COURSES OF ACTION

39. The present situation of India's fisheries calls for simultaneous action along several fronts in fisheries science and the application of results from those activities. Basically such action should be directed toward expansion of production wherever that might be possible, and by whatever means. But, whilst certain of the opportunities for expansion are known, and some of the means are available, nevertheless much needs to be done to identify and appraise the opportunities for expansion and to create the climate for and means of seizing the opportunities. To neglect, in a developmental programme, the contribution that research can make, may be likened to the case of a wood-cutter who decides that he hasn't time to stop and sharpen his axe and so continues with it blunt. The same principle holds in the conduct of research: to continue blindly with the collection of descriptive information without periodic stock-taking, review of methods and re-examination of the directive models drawn from creative research carries a risk that the work is being continued with a blunted axe. The basic principle of the several suggestions offered below is that model-making research should be separated from routine observational tasks

so as to leave its practitioners free to make original contributions, and to undertake a more onerous and direct charge to sharpen the research and development axes.

40. My suggestions are set out in the following paragraphs under seven headings. They need to be considered separately under these headings although they point to a single, closely knit organization, represented in the diagram in the next section.

## 1. Stock-taking of Accumulated Knowledge

41. An immediate and intensive programme should be undertaken to draw together and assess the results of research on Indian fishery resources. Probably the resource species should be listed in order of importance and the list divided into two parts: the first containing those of greatest importance (say, each contributing more than 10% - by weight or value - to current catch), the second containing all other species; an early dead-line should be set for completion of the review of the first part of the list; review of the others could be deferred until after this dead-line, and could be programmed separately.

42. In general, the review can best be achieved through completion of a Species Synopsis for each species; the outline for this synopsis can provide the plan of work. The structure of the outline is such that the labour on each synopsis can be divided and can proceed on several lines simultaneously. Taxonomists can be working on Chapter 1 of the Synopsis (and contributing to Chapter 2, perhaps also to others) whilst fishery biologists are working on Chapters 2, 3 and 4 and CRS workers are engaged on Chapter 5.

43. However, there are certain items of the synopsis which have priority over others for present purposes; these are indicated in the table to these notes, and perhaps will impose a heavier load than the less important items; work on these items will draw heavily on the material to be got from Line of Action 2, below (Paragraph 44).

44. The immediate objective of this work should be the setting up of models (and, undoubtedly, there will at once be discovery of deficiencies in knowledge), and then the specification of synoptics and the formulation of diagnostic rules.

## 2. Compilation of Past Catch and Effort Data

45. All data drawn from exploratory, prospecting, research and industrial fishing operations should be systematically compiled and analysed. This work should be the responsibility of the unit concerned with collecting catch and effort statistics (Paragraphs 49-50); in fact, this will be a retrospective operation precisely within that unit's responsibility: it is given prominence here because of the urgency of the need for this analysis.

## 3. Stock Assessments

46. A new unit, to be known as the Stock Assessment Unit, should be created. The task of this unit would be to assess the yield capacity and current condition of each of the exploited resources. It would make use of current techniques in providing at any one time the best available assessments; its staff should however have freedom to undertake original research into these techniques. The staff should be biology graduates with experience in fisheries work who have gained mathematical and statistical qualifications; or conversely, mathematics graduates who have gained experience in fisheries research and a knowledge of biology. The unit should act as a bridge between the fishery biologists and other research staff on the one hand and the unit for catch and effort statistics on the other; it would make use of the models provided by research staff and of the catch and effort statistics; it would have primary responsibility for preparation each year of a report on the state of the stocks.

47. This unit will be operating with a model, provided by research, which will be under constant scrutiny by the unit itself and by research. The array of attributes to be measured and the synoptics to be prepared for any resource system will be subject to modification as understanding of the system develops. The diagnostic rules for interpretation of the values taken by the synoptics will also be subject to modification, but since their design is with a view to consumer use, they may be modified both because of development of understanding of the resource system and because of changes in the standards of accuracy required by the consumers, that is, by Government and industry. This dual modifiability of diagnostic rules will be more real in cases where the diagnostic rules are used predictively.

48. Close collaboration must be maintained between research and the Stock Assessment Unit to ensure that the model and its rules are kept up-to-date. In particular, research must be ready to move in to assist the Stock Assessment Unit in the event that behaviour of the resource system moves beyond the limits encompassed by the model.

## 4. Fishery Statistics Unit

49. Special attention should be given to development of the system for collection of catch and effort statistics and complementary data. For established fisheries this system can bring in a great deal more information per unit of expenditure than can a survey vessel - probably in the ratio of thousands to one! The programme should be the responsibility of special staff, throughout. The field staff should be organized into district or regional teams each under the direction of a supervisor who should have one or more staff to assist him in the collection, editing and quality control of the returns made by the field collectors of his team. Considering that this system must rely to a considerable extent on sampling methods, every means of cross-checking, through returns from processing plants, export agencies and the like, should be resorted to. Easy communication should be maintained between the district (or regional) supervisors and the central office.

50. Close liaison should be maintained between the unit responsible for this system and the research staff and Stock Assessment Unit. Operation of the system, however, should not be the responsibility of research staff. The administrative relationship in which these several units might stand is discussed in the next section (Paragraphs 64-80).

## 5. Dimensions of the Stocks of Oil Sardine and Indian Mackerel

51. It is obviously a matter of high priority to ascertain the dimensions of the stocks of these species and, if their magnitude should be great, to describe their distributional patterns in detail and to seek ways of exploiting them.

52. There appear to be four main possibilities:

(1) that the stocks are already fully exploited - which seems most unlikely,

(2) that annual catch could be maintained at about the level of the maxima reached in 1964 for the oil sardine and in 1960 for the mackerel, giving in total about 4 lakhs,

(3) that the annual catch might be, say, 4 or 5 times these maxima,

(4) that the stocks might be of the dimensions of the Peruvian anchovetta and permit an annual catch in the order of 100 lakh tons.

I believe that accumulated evidence should permit of a discrimination between on the one hand the possibilities 1 and 2, and on the other hand the possibilities 3 and 4; if the work in the first three Courses of Action (Paragraphs 41-50) should result in this discrimination and if it should point to the possibilities 3 and 4 then a further wider searching of existing evidence, and special field work, should be undertaken with the object of discriminating between 3 and 4. Obviously, if 4 is the case some heavy expenditures will be justified, which would not be justified if 3 were the case.

53. However, a recommendation can be made with some confidence that at the earliest opportunity work should be initiated in (a) tagging, (b) aerial searching, (c) surface searching with sonar and fishing gear; work along these lines will assist in establishing a proper view of these possibilities and is justifiable simply for the purpose of discriminating among them; if the possibilities 3 and 4 should prove to be the case, the work recommended here will be the beginning of the larger programme of the same kind that will be necessary.

54. In dealing with the problems of these resources (and with those of the resources discussed in the next item) reference should be made to the work of the ACMRR Working Party on Speedier Methods of Estimating the Abundance of Fish. This Working Party has reviewed these methods, is preparing a manual on them and has proposed training courses in them. Undoubtedly assistance could be got from the Working Party, and/or FAO. Reference should be made to the possibility that egg-and-larvae surveys might prove effective and economic.

## 6. Prospecting

55. Prospecting of the continental shelf with regard to both demersal and pelagic resources should be carried forward now on a systematic basis, drawing to the fullest extent on results from preceding lines of action, more especially of number 2; at the same time fullest advantage should be taken of the advances made in estimating stock abundance, referred to in Paragraph 54.

56. Rough summaries of the amount of ground already examined suggest that something more than half of the continental shelf has been visited, but the intensity of work has varied considerably between areas. Nevertheless, some tens of thousands of hours of fishing by various kinds of boats using a variety of gears, have

been recorded and undoubtedly these records contain material from which to establish, for the examined areas, accounts (often of a high degree of reliability) of the distribution of the resources. In the instances that accounts are of quantitative kind, with statistical characterization of shifts in density, it will be possible to plan the conduct of further prospecting in the sense of testing of hypotheses, sometimes with considerable economy. The detective force of the prospecting operations should also be greatly enhanced by reference to the research models; these should be able to nominate hypotheses for direct test. In simple terms, the result of this approach should be that every prospecting operation will be necessary, useful and highly informative; the reference to past results should indicate where and when to prospect, and in what pattern (frequency, timing, location) to carry out the prospecting operation; the average informational product of each prospecting operation should thereby be greatly increased so that, either a great deal more information can be got for a given allocation of funds, or, a designated array will be obtainable at substantially reduced cost. It follows that without a detailed summary of what has already been obtained, especially of the statistical characteristics of those results, it would be inadvisable for me to propose the details of a prospecting plan.

## 7. Collateral Research

57. A major theme of this note is that whilst certain elements of resources information can be systematically collected and put to effective use by Government and industry, the array of elements must be held subject to modification in the light of research results (see Paragraph 47). The array is represented in a set of synoptics subject to certain rules of diagnosis: some synoptics may be found to be relatively ineffective, new synoptics may be found, and the diagnostic rules will be under constant review (partly in the sense of acceptable order of accuracy). It is therefore appropriate to make some observations here on the range of research that might be undertaken in the expectation of increasing the power of the CRS and consequently of reducing its per unit cost.

58. Obviously there should be a strong programme in fisheries biology and at this stage the workers in this field should be engaged in the stock-taking proposed above and then in work directed toward developing and refining the models. However, at the earliest opportunity selected workers should be encouraged to embark on more original work in (a) populations ecology, (b) the general theory of model-making in ecology, with especial reference to exploited and cultivated populations. There are tremendous

opportunities today for ecologists, and especially for those who can bring to this work specialized qualifications in ethology, physiology, genetics and similar subjects.

59. Work in fisheries gear technology is required for the developmental programme and its results are needed for the CRS: at an elementary level there is work to be done in the standardization of the measurement of fishing effort, but with the advances now taking place in fish-searching and fish-catching equipment the research in gear technology rapidly becomes complicated in its connections on the one hand with electronics and on the other hand with behaviour research.

60. Interpretation of some of the information collected by the CRS will be subject to reference to technological and economic considerations. In countries where virtually total record of catch and effort can be got these considerations can be ignored for CRS purposes, but attention must be paid to the effect, for example, of market saturation, changing prices and so forth when catch and effort are measured by sampling. For this reason there should be consultation between the CRS and research workers in these fields.

61. Mention is made earlier (Paragraph 12) that the depth to which research should penetrate a resource system for industrial purposes depends on various matters which in sum mean the economic benefit to be got from modification of industrial practices through use of resources information. This is not to say that fundamental research untrammelled by such considerations should not be undertaken; on the contrary, it can only be of benefit to carry out such research. However, the allocation of funds for fundamental research is in principle made to persons and subjects in terms of prospects of originality whereas allocation for industrial purposes ought to be in terms of prospects of profitability. Therefore steps should be taken to initiate studies by economists, to which biologists, technologists and the CRS team should contribute, to assess the value of information, of various kinds and degrees of accuracy, in each of the major fisheries.

62. Leaving oceanography to the last is intentional: to emphasize its importance and, by isolating it and thus showing how separated fisheries and oceanography may become, to give further force to an argument that deliberate moves must be made to overcome this tendency to separate them. Whilst a fish population may be studied separately from its habitat, and represented largely as sets of statistics, no final understanding of its behaviour, and certainly no useful system

for prediction of that behaviour, will be attainable without an account of its habitat and of the relations between population and habitat. For this reason the prosecution of research in oceanography (physical, chemical and biological) should be accepted as an indispensable part of a marine fisheries programme.

63. However, there are three categories of oceanographic work. First* is the oceanography that provides what I call the "environmental frame" which, methodologically and in other respects, is exactly parallel with the work of meteorological bureaux and with the CRS itself. This kind of oceanography observes and records marine "climatic elements" and provides regular synoptic statements with respect to them. Next is the original creative research that provides general descriptions and models, and evolves basic theories; it has the same relations with the "environmental frame" activity as original fisheries biology has with the CRS. Last are the specializations (corresponding to agricultural meteorology) that make closely intimate studies of the association of particular oceanographic systems with particular fishery resources. I have nothing to say about the middle category but I would most strong recommend that steps be taken to develop at least the rudiments of the "environmental frame" programme.

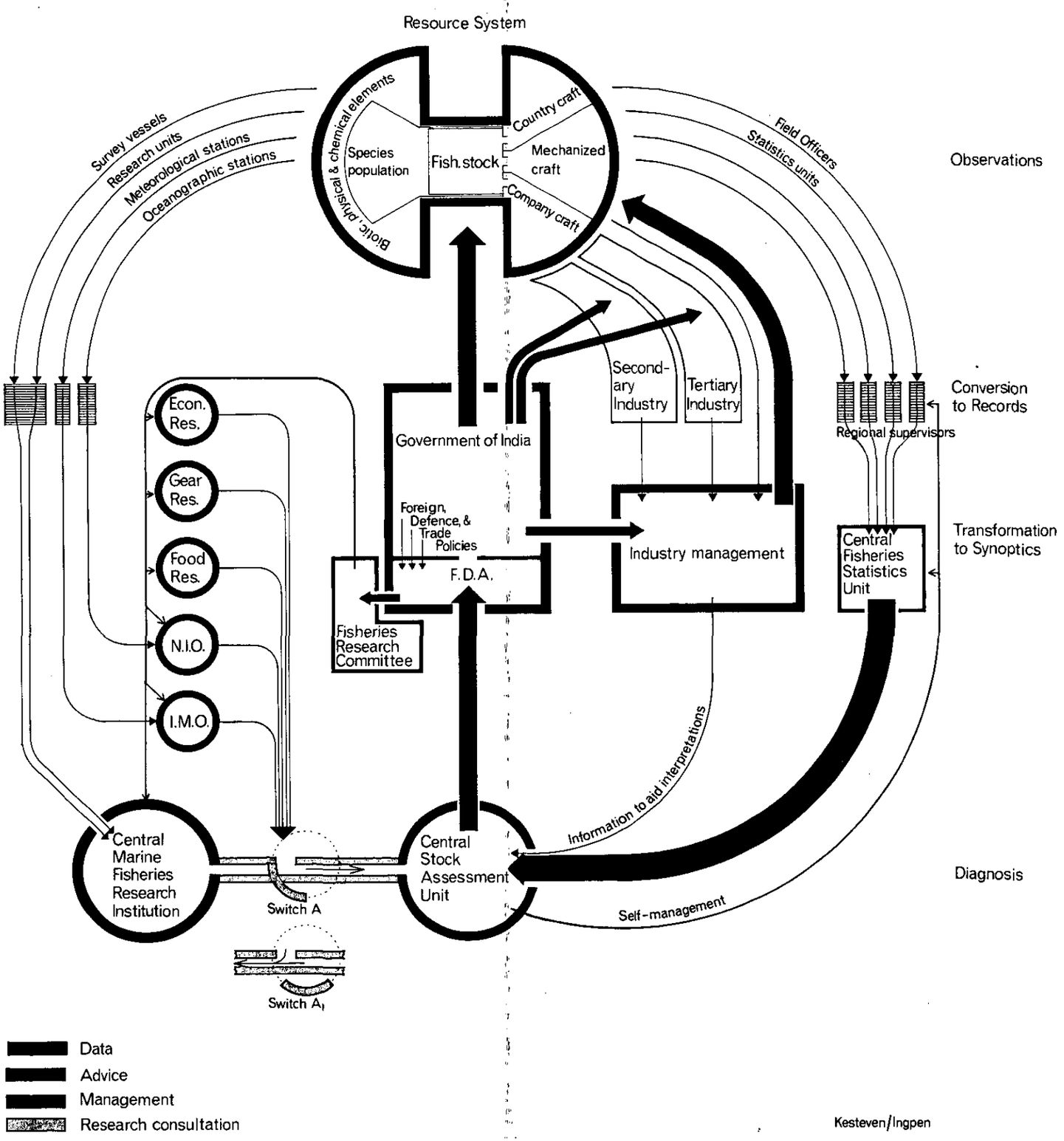
## ORGANIZATION, STAFF AND EQUIPMENT

64. The proposals of the preceding section are concerned with an informational system which would provide the Continuing Resources Survey proposed by Dr Mitra. They are represented in the diagram, of which detailed explanation follows. Some repetition of earlier material appears in this explanation, but probably this is advisable.

### Explanation of the Diagram

65. This diagram is a representation of informational relations between the primary sector (resources system) of a fishery and various research, management, and Governmental institutions. It is not intended to represent administrative structure although doubtless it will have implications in that sense. Other similar diagrams could be constructed to represent similar relations with respect to other sectors of the industry. The diagram has been drawn expressly with a view to the Indian situation, and although it does not presume to be entirely complete (in fact certain items are expressly omitted), it probably contains all elements that need at this stage to be

*The order in which these are mentioned is not intended to signify anything with respect to relative importance, or to precedence, historically or otherwise.


Resource System
Biotic, physical & chemical elements
Species population
Fish. stock
Country craft
Mechanized craft
Company craft
Survey vessels
Research units
Meteorological stations
Oceanographic stations
Field Officers
Statistics units
Observations
Econ. Res.
Gear Res.
Food Res.
N.I.O.
I.M.O.
Government of India
Second-ary Industry
Tertiary Industry
Regional supervisors
Conversion to Records
Foreign, Defence, & Trade Policies
F.D.A.
Industry management
Central Fisheries Statistics Unit
Transformation to Synoptics
Fisheries Research Committee
Central Marine Fisheries Research Institution
Switch A
Switch A1
Central Stock Assessment Unit
Information to aid interpretations
Self-management
Diagnosis
Data
Advice
Management
Research consultation
Kesteven/Ingpen

TABLE

POPULATION ATTRIBUTES AND SYNOPTICS OF CERTAIN OF THESE

| POPULATION CHARACTERISTICS | RESEARCH DESCRIPTION (ATTRIBUTES) | Synoptics |
|---|---|---|
| IDENTITY | Systematic name | |
| DISTRIBUTION (Accessibility) | Range | |
| | Bio-phase districts | |
| | Migration paths | |
| | " times | |
| | " determinants | |
| ABUNDANCE (Availability) | | |
| Reproduction | Fecundity | |
| | Age of first maturity | |
| | Spawning season | |
| Recruitment | $R = f(S)$ | $R_i$ |
| Growth | $K$, $L_\infty$, $t_o$ | |
| Population structure | Size composition | $\bar{l}_{c,i}$ $\bar{w}_{c,i}$ |
| | Age " | $\bar{t}_{c,i}$ |
| | Sex " | |
| Mortality | Total: Z | $Z_i$ |
| | Natural: M | $M_i$ |
| | Fishing: F | $F_i$ |
| Size and density | Population size, as biomass: P | $c_i/f_i \propto P$ |
| | as number: N | $c_i/f_i \propto N$ |
| | Population density: d | $c_i/f_i \propto d$ |
| BEHAVIOUR | Response to various stimuli | |
| EXPLOITATION | Yield curves: Y | $\bar{l}_c/L_\infty$, $E: \frac{F_i}{F_i+M_i}$, $M/K$ $E' = E_i/E$ op |
| | Selectivity | |
| | Standard effort | |

For definition of these symbols see Holt (1960). The synoptics are mean or other representative values for particular places and times as signified by the subscript "i".

considered. In particular it should be noted that the diagram carries no representation of Governmental institutions of the several States that have a seaboard; it presumes that appropriate arrangements will be made through the Fisheries Development Adviser (FDA) for contributions to the operation of the system by the State institutions.

66. The diagram is based on a concept of a resource system model constructed by a fisheries research institution and to be used by a Continuing Resources Survey (CRS).

67. The resource system is represented as a species population in its environment. The species population is surrounded by biotic, physical and chemical elements. One part of the species population, the fishable stock, is marked off, as subject to exploitation by the industry which itself in some sense shares the environment of the species population.

68. The CRS is represented essentially by the outer circuit, on the right-hand side of the diagram, from the field officers (at top right), who make observations through regional supervisors, a central fisheries statistics unit, to a central stock assessment unit.

69. The field officers of the statistics unit are engaged in making observations and measurements of certain attributes of the primary industry and its resources system. The set of attributes to be observed and the programme of observation (specification of time/space cells and of order of accuracy) are determined by the research institution's model. These field officers should be grouped into regional teams.

70. Each regional team should be managed by a regional supervisor who should have responsibility for directing the work of the field officers. It would be his responsibility to ensure that the field officers carried out their observational programme in accordance with the rules provided. With the assistance of suitable clerical staff the regional supervisor would receive the data sheets from the field officers, edit these and submit them to quality control, and make a conversion of them to suitable record form for transcription into computer operations.

71. The records would then pass from the regional supervisors to the central fisheries statistics unit which would be responsible for reduction of the data to suitable tabular form and for their transformation into designated synoptics. In this work the statistics

unit would make use of computer equipment.

72. The tabulated data and synoptics would then pass to the central stock assessment unit where the synoptics would be submitted to the diagnostic rules appropriate to the model furnished by the research institution. Diagnosis would take into consideration the information drawn directly from industry through industry management. It would also, and still in accordance with the diagnostic rules furnished, make use of information drawn from the research institutions shown on the left. The major contributor of such information would be the Central Marine Fisheries Research Institute transmitting the results of the operation of survey vessels and research units. The National Institute of Oceanography and the Indian Meteorological Office would furnish environmental information, whereas units concerned with economic research, gear research and food research would furnish information concerning the operation of the industry generally.

73. The switch A is intended to represent that the stock assessment unit would operate in routine fashion on these several sets of data within the terms of the model furnished by the research institution, but that in the event of the resource system behaving outside the predictive range of the model, the research institution would then be placed in relation with the stock assessment unit so as to permit of a review of the model. In such a novel situation the entire research apparatus would, with the stock assessment unit, make a review of all data and examine whether the schedule of attributes to be observed and the rules for observation should be modified in any way, and similarly whether modification should be made of the synoptics and of the diagnostic rules.

74. The attributes to be observed are identified by the research institution and the usefulness of the selected array of attributes and of the synoptics drawn from them depends very largely on the degree to which the institution's model has been developed. Initially under prospecting conditions the attributes are essentially presence or absence of various species. Later, catch and effort are the principal attributes. Still later, species, size and age composition of catch are critical attributes. The synoptics drawn from the data of these attributes are of the form $c/g$, $\bar{l}$ and $\bar{t}$. The diagnostic rules are those furnished by yield isopleth diagrams and similar schemes. The models that specify these attributes and synoptics are chiefly those of Beverton and Holt and of Schaeffer.

75. The stock assessment unit would report the results of its assessment to the Fisheries Development Adviser who, as part of the Government of India, would pass information and advice to industry management and to secondary and tertiary industry. Government of India also would, through the Fishery Development Adviser, take this information into consideration in its work in promoting any changes of the industry and in any management activity. Finally, the information from the stock assessment unit would be communicated to the research establishments through the Fisheries Research Committee. This channel of communication would serve in influencing the programme-forming and direction activities of these institutions. One other managerial line has to be noted; namely that the activities of the field staff, regional supervisors and the central fisheries statistics unit will be controlled by the central stock assessment unit in the light of evidence on the operation of the CRS.

## Some Administrative Implications of this Plan

76. The primary modification of existing arrangements proposed by this plan is the removal of statistical survey work from the Central Marine Fisheries Research Institute to a Central Fisheries Statistics Unit to be created and, I would suggest, located in New Delhi. This unit would operate with the use of computer equipment in tabulation and reduction of the data collected by field staff. Primarily the data would be the catch and effort statistics, but in my view the field staff of this unit should also be responsible for taking routine biological samples of the catch to provide data on its taxonomic, size, age and sex composition. This view of the duties of the field staff might call for some special training of those who are already engaged in these duties and perhaps for moves to raise the technical competence of the staff.

77. I attach considerable importance to the need to organize the field staff into regional teams and to place them under the control and supervision of regional supervisors. I am not in a position to suggest the number of regions into which the Indian coastline should be divided, but I believe that the number should be such that each supervisor would have an area over which he could expect to travel fairly regularly and through which he would be able to maintain close contact with the field staff.

78. In the diagram the Central Stock Assessment Unit is represented in a nodal position. Under some circumstances I believe it could be appropriate for such a unit to be physically housed with the research institution. However, in the Indian situation I believe that this unit also should be located in New Delhi in close association with the Fisheries Development Adviser on the one hand and with the Fisheries Statistics Unit on the other. The administrative advantages of this arrangement will be clear. However, arrangements would also have to be made to ensure a free and easily accomplished exchange between this unit and the staff of the Central Marine Fisheries Research Institute.

79. In my view the staff of the Stock Assessment Unit should be kept small. Probably it should be initiated with two people trained in stock assessment work and should be enlarged only in accordance with development of the work. Of course these trained people will need their assistants. I do not recommend that the Stock Assessment Unit should have administrative responsibility for the Statistics Unit, despite the close operational connection there will be between them.

## Prospecting and its Equipment

80. A line on the extreme left of the diagram from the Resource System to the Central Marine Fisheries Research Institute represents that the conduct of systematic prospecting operations as distinct from pilot and demonstration sea fishing, should best be located with, and made the responsibility of, the Central Marine Fisheries Research Institute. Such an arrangement in my view is desirable, and even necessary, because of the character of prospecting operations.

81. The objective, and hence the strategy and tactics, of prospecting differ from those of commercial fishing. A fisherman's sole objective is to make good catches and he uses all his experience and the evidence from his current operations to confine his fishing to areas in which he believes his chances are greatest of continuing to take catches. A prospector, on the other hand, seeks to maximize information, and he values information on the absence of fish equally with that on its presence, since it is undeniable that the distribution of any natural species is rarely, if ever, in regular pattern. Indeed, a prospector in fisheries may be more concerned to mark the places and times of minimal density than to identify those of maximum density, considering that in the developed fishery the fishermen themselves will concentrate on the latter.

82. The strategy of prospecting then will be to traverse the prospected grounds in such pattern, as to place and time, as will provide this information on the patterns of distribution of the stock being prospected. In carrying out this work use will be made of prior information and observations should be made of environmental factors that may be associated with, or determinative of, the characteristics of these patterns. The appeal to prior information and design of operations on it, the collection of evidence on environmental factors and the interpretation of evidence as it accumulates in the course of a prospecting operation are tasks for research workers.

83. For the mounting of an effective and reasonably economic prospecting operation, logistic support is an important matter. This support should relate both to the technical problems of operating vessels at sea and to the use of laboratory facilities and computer equipment in working up the material and data with least delay.

84. In preceding paragraphs relating to courses of action I have noted that prospecting is required for the demersal and for the pelagic resources of the continental shelf, quite apart from the searching requirements for the sardine and mackerel fisheries. For the pelagic resources much emphasis can be placed on the use of aerial spotting, and in this connection I would refer to the papers (Hynd (1963) and Hynd and Robins (1967)) in which Hynd proposes a methodology for estimating the number of searching units required in the air and at the surface. The use of the formula proposed by Hynd calls for reference to data which in fact are not available to me.

85. For the demersal resources the major determinant with regard to the number of survey units required will be information on the extent of ground that yet remains to be prospected. In next place will be the information (of which stock is yet to be taken) on the distribution and behaviour of the stocks on the grounds already being exploited. I illustrate the problem by assuming that about half, say 60,000 square nautical miles, of the continental shelf, still needs to be prospected. A trawler with 76 ft head-line Granton trawl will sweep approximately 0.1756 square nautical miles per hour towing at 3 knots. That is, it would have to tow for 5.69 hours to cover one square nautical mile. To cover the whole of 60,000 square miles only once without

overlap would require 341,400 hours of trawling. At 2,000 hours of trawling per year 171 trawlers for one year would be required to cover the entire area just once. But each sampling site should be covered in each season and by day and by night in each season, and the operations for statistical purposes ought to be replicated. This would mean multiplying the above number of trawler years by at least 2 x 2 x 2 = 8. However, as a sampling operation perhaps only 5% of the area need be covered, which means 171 x 8 x 0.05 = 68.4 trawler years, which is still a large figure. However, probably the essential information can be got by a very considerable reduction of this figure making use of the already accumulated information on the distribution of different species.

86. Perhaps of still greater importance in this matter is the role that can be played by methods of direct estimation of stock abundance, to which reference has been made earlier. These methods can greatly increase the accuracy of prospecting operations, and, by being much more rapid than prospecting with fishing gear, can draw closer to an instantaneous estimate of stock abundance. The nearer they can draw to instantaneous estimate, the less need there is for repetition of the survey to allow for seasonal or other effects. I therefore most strongly recommend that the Government's course of action should be to initiate enquiries about, and obtain assistance in, the speedier methods, simultaneously with carrying out the stock-taking recommended above.

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