Intergovernmental Oceanographic Commission
Workshop Report No. 33

Workshop on the IREP Component of the IOC Programme on Ocean Science in relation to Living Resources (OSLR)

Halifax, Nova Scotia, 26-30 September 1983

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2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock)
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6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock) Russian
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian

No.	Title	Publishing Body	Languages
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian Arabic
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (superseded by IOC Technical Series No. 20)
26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
29	WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco Place de Fontenoy, 75700 Paris, France	English (out of stock) Spanish
31	Third International Workshop on Marine Geoscience Heidelberg, Federal Republic of Germany, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
32	UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
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1. INTRODUCTION

1.1 THE IMPORTANCE OF RECRUITMENT AND ITS SCIENTIFIC CHALLENGE

The consensus of scientific opinion is that the processes governing recruitment to fish populations should be the main focus of OSLR, at least for the time being. We start with a brief explanation of "recruitment" in this context, why it is so important, and the scientific challenge presented by it.

By "recruitment" is meant the replenishment each year of young fish (or shellfish) to the adult or the fished stock. Recruitment is therefore the essential process on which continuity of the stock from one generation to the next depends.

It is typical of most fish that they spawn vast numbers of eggs, of which only a minute proportion survive to become recruits. During the early stages of the life-history the young fish are very small and vulnerable to adverse conditions - particularly to predators and shortage of the right kind of food. As a consequence, the number of annual recruits typically fluctuates very greatly, up to a hundred-fold in extreme cases, which has a corresponding effect on the size of the fished stock and the success of the fishery.

Even more profound are the consequences of systematic trends, upwards or downwards, in recruitment due to climatic events, and the prolonged failure of recruitment due to excessive depletion of the parent stock. A combination of such circumstances has led to the collapse during the last thirty years of some of the world's greatest fisheries, not all of which have recovered even though fishing ceased.

From the turn of the century, when the great Norwegian fisheries scientist Johann Hjort first suggested that shortage of food at a critical stage in the early life-history was the key factor determining recruitment, the search for an understanding of the recruitment process has continued. Although some valuable clues are emerging it has to be admitted that the mechanisms are still largely obscure.

The reasons for this are not far to seek. It is extremely difficult to measure accurately at sea, on the necessary scales of time and space, what is happening in the early life of fish. Success or failure of recruitment, which may not be manifest unless the fish are several years old, can be due to a variety of causes. Although biological factors such as food, predators and diseases are always important, their effect is mediated through the physical and chemical conditions in the sea at the time. Currents, turbulence, stratification and wind stress are all significant. Thus, upwelling regions, although potentially highly productive, are also unstable and liable to generate extreme variation and systematic trends in recruitment, as instanced by the disappearance of the California sardine and the collapse of the Peruvian anchovy due to the El Niño phenomenon.

The prize, in terms of the gain of useful knowledge, from a better understanding of the processes of recruitment, is therefore great, but the scientific challenge is formidable, both in concept and logistics. The problems go to the heart not only of physical and biological oceanographic science but of many ancillary disciplines such as fish physiology, nutrition and behaviour.

It might be thought that, in such circumstances, a high degree of international co-operation would have developed to tackle problems which are of universal significance in the utilization of living marine resources. In fact, this has not happened hitherto, to any marked extent. The reason is no doubt partly because the relatively few research centres that in the past have had the necessary capability to mount major sea programmes of research on the early life stages of fish are widely scattered - on each side of the Atlantic and in the North and South Pacific. It may also have been the realisation - and this is certainly the view of the Workshop - that techniques and equipment have not yet been developed and standardized to the point at which a large multinational programme could be justified.

On the other hand, it is just in such circumstances that there is everything to be gained from establishing close and regular communication between the many researchers and research groups whose endeavours can throw light on one or other aspect of the general problem of recruitment. Such an initiative is highly appropriate and timely for IOC, with the help of the regional bodies (notably ICES and CPPS) and institutes who have experience in this field or who wish to begin programmes of research on recruitment. This, in fact, is one of the recommendations of the Workshop (see section 5) which comprise the first set of requirements and objectives for IREP - the International Recruitment Project.

1.2 THE WORKSHOP

Two main approaches to research on recruitment processes were identified by the Workshop, namely:

(a) direct investigation of events during the early life-history of fish. This involves measurement of mortality rates and condition of eggs larvae and, if possible, juveniles, in relation to environmental conditions and the eventual number of recruits.

(b) investigation of the relationship between recruitment (i.e. year-class strength) and environmental factors. In this case the causal mechanisms are inferred from a matrix of cross-comparison and correlations in time and space between the same and different species.

In addition, the Workshop agreed that the results obtained from each of those approaches would be greatly enhanced by experimental and field research on the various biological mechanisms that influence spawning success and survival of the young stages. Many aspects of this ancillary research are not unduly demanding on facilities; if planned and carried out as part of a wider programme, many relatively small projects could contribute to the general advance of relevant knowledge in this field.

Regarding time scales relevant to fisheries management problems, three kinds of variability patterns which can be associated to recruitment changes were recognized, in general terms. These correspond to the three "streams" of the World Climate Programme; namely, seasonal variability, interannual changes and long-term (decennial) trends. Perturbations observed vertically and horizontally in the ocean, mainly due to variations observed in the respective thermal gradients, can be interpreted by reference to these three time scales.

The Workshop was attended by twenty-five marine science specialists (biologists, physicists and ecologists) from twelve different countries. The list of participants is given in Annex I.

During the first two days seven invited lectures were offered on topics addressed to the recruitment problem. The summaries of these presentations are given in Annex IV.

Subsequently, separated working parties were established to examine in detail the approaches dealing with direct investigations of events during the early life-history of fish (Working Party I on Direct Observations, Mr. S.A. Akenhead, rapporteur) and investigations of the relationship between recruitment and environmental factors (Working Party II on Inferential Approaches, Dr. D. Pauly, rapporteur).

The Bedford Institute of Oceanography hosted the meeting, the facilities of which were much appreciated by all participants.

The Halifax Workshop had been preceded by earlier meetings and discussions, notably that of SCOR/ACMRR Working Group 67 and an informal meeting held in conjunction with the FAO Conference on Changes in Abundance of Neritic Fish Stocks held in San José, Costa Rica, in April 1983. Details are given in Annex II.

2. DIRECT OBSERVATIONS RELATED TO EARLY LIFE-HISTORY (SURVEYS AND STUDIES)

The objective of these studies is to conduct surveys with sufficient precision to detect correlation with biotic and abiotic environmental variables and, secondarily, to investigate the causal mechanisms involved. The target level of precision depends on value judgements of the space and time-scales of likely environmental factors in relation to the distributions of the stock in question. The smaller the relative scale the higher the resolution required unless, as an alternative option, one accepts a lower level of resolution with the intention of seeking to detect only the most extreme variations in recruitment, etc.

Sequential estimates of the absolute abundance of eggs and larvae and thence estimates of mortality can be provided with total census methods. The level of resolution is determined by, inter alia, the time intervals between samples and the sampling errors, including age determination of eggs, and especially the larvae. Typically the heterogeneity of the distributions and the sources of error prevent the identification of within season cohorts, and mortality estimates therefore relate to the gross egg production and larvae output throughout the season as the basis of correlation with other variables. The approach therefore aggregates the variations of mortality, and environmental variables.

The daily ring method permits accurate assignment of age, in days, to a sample of larvae and juveniles. It is used in association with estimates of daily egg production to estimate relative mortality between the daily cohorts present in a sample. The estimates of relative mortality are extended throughout the season by phasing surveys to ensure overlap of identified cohorts in successive surveys. This estimation of relative mortality itself assumes that egg production is constant at the average level determined on the appropriate previous cruise and applicable for the duration of that cruise. The scale of resolution of such a survey can therefore be the starting date of the initial survey of egg production and the date of a subsequent larval sample. Estimates of actual mortality required for between year comparisons depend on later independent estimates of recruitment versus the surveyed egg production.

The daily ring method therefore provides (e.g. by comparing abundances of cohorts of late larvae and early juveniles with that of some cohorts when they were in the egg and/or early larval stage) increased resolution in relative mortality for within-season correlation with other variables at the expense of timely estimates of actual mortality between seasons. The within-season resolution is dependent on the frequency of surveys, and depending on logistic circumstances, could have a time scale of resolution larger than the period of the life history when crucial events take place. It will, however, be shorter than the total season estimates of the census method and has the advantage of not requiring a total census of the larval population.

The daily ring method will therefore facilitate the identification of causal mechanisms but is perhaps less robust than the total census in determining the net effect of these mechanisms on an annual recruitment. With both methods the level of resolution decreases as the spatial and temporal heterogeneity of both the spawning population and the biotic and abiotic environment increases (because it becomes progressively more difficult to associate the absolute or relative mortalities with a specific egg production in a particular area characterized by an environmental variation).

Further improvements will be obtained in circumstances where it is possible to conduct a serial total census of an aged population within the duration of the pelagic phase that can be sampled, assuming, as seems reasonable on present evidence, that the crucial events determining recruitment do take place in that period of the life history.

The Workshop gave particular attention to the Egg Production Method (EPM), which is suitable for the estimation of spawning biomass of species with pelagic eggs. This method has been applied successfully to the northeastern and southeastern Pacific anchovy and is being developed for sardine species in the sardine-anchovy complexes of both regions. The Workshop estimates it would be rewarding to aim at extending the daily ring and related early life-history methods to other species groups combining the eastern Pacific approach (mainly developed at La Jolla) with existing experience in the North Sea (e.g. on flatfish in Lowestoft and on cod in Bergen). Nevertheless, preparatory work on the validity of the daily ring method for these (and other) species would be required before a cost-effective field programme could be mounted.

The Workshop reviewed current hypotheses which relate recruitment success to the effect of seasonal and interannual variability of environmental conditions in the upper oceanic layers. These hypotheses postulate that recruitment variability is mainly determined by environmental changes that mediate the availability of food and the presence of predators within spawning seasons. The problem to a given species would be to inject the spawning products into suitable "windows" in this variable environment so as to maximize reproductive success. The existence of these reproductive strategies is increasingly confirmed by early life history research, particularly in pelagic species. The following table presents some field and laboratory approaches to Predation, Starvation and Environmental measurements.

	Predation	Starvation	Environment
FIELD	1. Estimates of predator abundances. 2. Coincidences in time and space of larvae and predators.	1. Determination of vertical distribution of eggs and larvae 2. Studies of species composition in larval stomachs and in the water column. 3. Analysis of larvae for incidence of starvation. 4. Estimation of growth rates of larvae from otoliths.	1. Meteorology 2. Geostrophy 3. Ekman transport 4. Wind-induced turbulence 5. Currents
LABORATORY	3. Study of predation rates as a function of larval nutrition 4. Determination whether predators are opportunistic or obligate feeders	5. Determination of feeding threshold 6. Studies of food and temperature effects on on growth 7. Quantification of effect of temperature on egg development	

In Annex V, expanded considerations on measurements are listed for data collection related to IREP.

The Workshop listed the following criteria for selecting species or group of species suitable for early life-history studies of this type:

a) Information on the life history, adult biology, spawning area and stock population dynamics should be known.

b) Fish should be of commercial importance.

c) The geographical dimensions of the population habitat should be known.

d) A fishery with adequate sampling and statistics must exist.

e) An on-going fisheries research programme should be in progress.

f) There should be discreet stocks.

g) Fish must be amenable to daily ring technique.

h) Population should be highly variable.

i) An infrastructure should be available (e.g. ship, oceanographic equipment, etc.).

In general, it was agreed that studies should concentrate on the most critical factors likely to control growth and survival of fish eggs and larvae in the ocean.

In this context, an IREP MINIMUM PLAN was proposed for those countries which have limited resources but wish to participate in recruitment research at a certain level. The work at this level should pinpoint at what time in the spawning season recruitment takes place. Other information resulting from this approach will include estimates of stock biomass, mortality rates of eggs and early larvae, the distribution of spawners, and inter-annual variability of these parameters.

Juvenile random sampling is required for age determination by the otolith method to compare relative survival with larval production.

Detailed requirements for this IREP MINIMUM PLAN should include:

a) A quantitative larval survey and egg production method biomass survey.

b) Juvenile sampling sufficient for otolith aging.

c) Oceanogramhic measurements and monitoring (e.g. temperature, salinity, geostrophy, etc.).

d) Meteorological observations (especially winds) from shore and ships at sea.

e) Birth data analysis of juveniles.

f) A quantitative analysis of year-class strength from fisheries statistics.

In the columns that follow, a species group criteria is attempted for the IREP MINIMUM PLAN including (when appropriate) some geographical representation. Comments made by the participants to the Workshop as regards their applicability to the IREP MINIMUM PLAN concept, are included.

SPECIES GROUP	BORDERING COUNTRIES	COMMENTS BY WORKSHOP PARTICIPANTS
Sardine-Anchovy	Perú, Chile, Ecuador Mexico, USA, Japan, Australia, Brazil, Argentina, South Africa, Namibia, Gulf of Guinea, Senegal, Portugal, Spain, Morocco, Oman, India	- usually part of an upwelling system; - their suitability for recruitment studies has been demonstrated only in the Eastern Pacific; - the egg-production biomass survey technique has been developed for some of the species; - of particular value to many developing countries.
Sprats	ICES countries	- very similar to the anchovy and sardine, but fished by developed countries; - to be encouraged because of technology fall-out appropriate to the anchovy/sardine studies.
Herring and Capelin	ICES countries	- daily growth studies have been done; - problems in surveys of eggs are anticipated; - early larvae surveys may be more appropriate.
Mackerels (Scomber)	ICES countries, Japan, countries bordering warm temperate upwelling regions	- daily aging studies have been done; - Northwest Atlantic mackerel have stock definition problems. Northeast Atlantic mackerel have a large spawning range with a cline in spawning time; - Japanese mackerel stocks are much better defined and may be suitable for IREP studies.
Jack Mackerels (Carangidae)		- the plethora of similar species makes fisheries stations unreliable, and egg and larval identification a major problem; - Stocks tend to be dispersed offshore with poor biological knowledge; - not recommended.
Gadoids	ICES countries, Chile New Zealand, Argentina, South Africa, Namibia, and many others	- late larvae and early juveniles are particularly hard to sample; - there are several NE Atlantic surveys for cod, facilitated by the pelagic habits to the Norwegian coast;

SPECIES GROUP	BORDERING COUNTRIES	COMMENTS BY WORKSHOP PARTICIPANTS
Gadoids (Contd.)		- daily aging studies have been done on cod; - hakes are partial spawners, and nearly ubiquitous in coastal ecosystems. Their appearance in convergent and divergent, temperature and tropical systems makes them ideal for comparisons; - hake adult fisheries statistics are problematic due to aging difficulties and species identification in catch data.
Sea Rockfishes, Redfish		- identification of larvae and adults is very difficult in some areas; - slow growth and low mortality rates may be useful in some comparative work. Daily aging has been established; - not recommended.
Salmon	ICES countries	- _Oncorhyncus_ dominates North Pacific area, and is marine in first year of life; - daily aging studies gave good results; - research recommendations left to other international scientific fora.
Invertebrates	All developed and developing countries	- there are long data series available for many of them; - in the majority of cases of shellfishes, distribution and abundance is well known and their local nature facilitates sampling; - data from mariculture is particularly valuable, but awareness of the need for recruitment studies by mariculturists is lacking; - the pelagic cephalopods of the NW Atlantic have been aged by daily rings in statoliths; - Penaid shrimps and crabs have had important recruitment studies done; - in some cases of inshore species, recruitment variability may be affected by alteration in environments, such as by pollution;

SPECIES GROUP	BORDERING COUNTRIES	COMMENTS BY WORKHSOP PARTICIPANTS
Invertebrates (Contd.)		- there is probably no fundamental difference in the pelagic mechanisms of recruitment of invertebrates and vertebrates; - each year recruitment is the fishable stock for many species, making IREP particularly valuable.

Peruvian and Chilean scientists attending the Workshop were particularly interested in pursuing the IREP MINIMUM PLAN because of its precise basic orientation towards applied fishery problems, especially as regards the need for forecasting recruitment of anchovies and sardines. They recalled in this context Recommendation El Niño-III.2 (February 1983) and Resolution 22 of the CPPS countries (July 1983) which call for co-ordination with the OSLR Programme. The Workshop recommended that a SARP (Sardine-Anchovy Recruitment Project) be developed as a pilot programme of IREP for the Eastern Pacific region.

It is anticipated that the Eastern Pacific SARP experience will benefit other nations in the short run by establishing useful comparisons with studies elsewhere, provided the daily ring method can be properly validated for similar species in other regions.

IOC and FAO were requested to concentrate their efforts to implement this SARP project in the context of IREP/OSLR, including the necessary TEMA components. As regards teaching and training in the Egg Production Method, a manual in English is under preparation in the Southwest Fisheries Center, La Jolla, California, and a manual in Spanish is being printed by the Cooperative Peruvian-German Fisheries Project. A regional training course on this method for Latin-American countries, is planned by IOC for 1985, in co-ordination with the cooperative Peruvian-German Fisheries Project.

The resources available to countries interested in SARP-related studies are not currently sufficient to mount such programmes. It should be recognized that no real progress can be made in these recruitment investigations (which require ships, personnel and laboratories) without additional funding.

3. INFERENTIAL APPROACHES

Field work and experimental programmes are costly and difficult. Although these represent the classical scientific approach, it is possible that certain indirect, or inferential approaches may yield limited but useful results and involve much smaller resource outlay. These approaches involve data for which the observational investment generally will already have been made; they thus tend to be highly cost-effective and are therefore a useful complement to direct approaches.

In the following we will propose a number of methods which can be applied to study recruitment-related problems in a variety of marine ecosystems. At the same time, using cross-sectional empirical relationships among various methods, will tend to eliminate spurious correlations. These methods are generally applied by single or small groups of investigators and are suitable for use in developing countries. Also, these approaches have a valuable training aspect in that they expose the investigators concerned to a broad range of scientific methods and fosters interpretative skills. The need for a link-up of these indirect methods to the more direct approaches discussed previously, is emphasized.

The inferential approaches to be discussed in this report have been split into six groups as follows:

(i) Studies of Adult Reproductive Potential

(ii) Comparison of Ecosystems and Life Histories

(iii) Studies of Changes in Catch Composition

(iv) Length-Based Approaches

(v) Use of Growth Rings Information

(vi) Use of Sediment Records.

(i) <u>Adult Reproductive Potential</u>

Comparisons of the reproductive potential of adult species can be conducted within and between different ecosystems. Such comparisons can be conducted to test the ramification of hypotheses already in the literature, or to generate new hypotheses. The most interesting hypotheses of this type are those linking the reproductive features of adult fish with environmental variableslikely to influence the survival and development of early life history stages including juveniles, such as for example studies on the links between egg sizes (and hence larval sizes) and offshort transport phenomena. Another interesting aspect of the comparison of reproductive activities of fishes involves the study of seasonal rhythm of gonadal activities. Comparative studies can involve <u>within</u> and between species comparisons; between species comparisons can involve comparisons between different types of fish (pelagic vs demersal, omnivore vs piscivores, slow growing vs fast growing, etc.). In this context, it must be emphasized that a large number of life history and reproductive studies already have been or are presently being conducted throughout the world, including the tropics, and that these studies provide a rich material from which inferences can be drawn or through which hypotheses can be tested.

(ii) <u>Comparison of Ecosystems and Life Histories</u>

When available data in similar ecosystems are arranged in a comparative manner (seasonally and geographically) it is sometimes possible, by comparison with the seasonality and general features of the reproductive habits, to draw inferences on the common mechanisms regulating reproductive success. Natural selection implies that observed reproductive habits represent successful accomodation to the most crucial environmental effects. Thus, patterns of correspondence are indicative of causal process. Comparison of time series relationships among similar systems, under an assumption of analogy can be used to test hypotheses and increase statistical confidence. For example, disruptions of onshore transport of fish larvae is a prominent current hypothesis for recruitment fluctuations in coral reef systems. By comparison, seasonality of recruitment in various examples of island systems which may be oriented differently in relation to seasonal transport mechanisms, it may be possible to recognize the dominant mechanisms involved and to thereby specify their formulation in empirical studies and experimental design.

(iii) Changes in Catch Composition

Changes in the species composition of ecosystems (exploited or not) are generally thought to represent changes in the recruitment success of the various species involved. The inference drawn from changes in species composition thus allow for inferences on the recruitment process. Under exploitation, species succession will have certain features which should match the major life history features and vital characteristics of the animals involved, e.g. it is generally perceived that under exploitation low-fecundity, slow-growing, large animals are replaced by high-fecundity, fast-growing, small animals. One group of hypotheses that can be tested by studying changes in species composition are those related to the persistence of size composition spectra and the replacement of species inhabiting certain ranges in those spectra by other species fitting into the gaps that removal has created. For generalization to emerge, however, it will be necessary to document many more exploited ecosystems than have been documented hitherto. When such exploited ecosystems and their exploitation history are documented, care must be given to the problems associated with the appropriate aggregation level. Thus, it might be that size groupings, or groupings according to trophic levels can replace the usual species groupings, although it must be realized that groupings above the species level will make species replacement process invisible and hence inferences on the species specific recruitment process impossible. Moreover it seems appropriate to monitor not only commercially important species, but also such species that are representative of the "trash" fish that often increase when commercially exploited species decline under exploitation.

Major environmental variables should also be considered when studying changes in catch composition, as the changes may reflect responses to changed environmental conditions, rather than be caused by exploitation and biological interaction. Separating such different effects indeed requires great care.

(iv) Length-Based Approaches

Length-structured approaches to the study of population and their use for inferences on recruitment appear to be promising, particularly in view of the wide availability of length-frequency data in many species throughout the world which also go back in time, and thus can be compared with time series of environmental data. It is felt therefore that approaches to developing and validating various length-structured models should be encouraged.

(v) Growth Rings Information

Age structured methods obviously can and should be used wherever possible to draw inferences on recruitment. However, in the particular context of the indirect inferences discussed here, the major strength of age-structured methods seems to lie in the support they can give to the length-structured method for which data are more widely available.

(vi) Use of Sediment Records

The application of methods such as dendrochcenology and the study of paleosediments associated to revisions of historical documents (when available), is particularly applicable to investigations of long-time scale fluctuations in fisheries populations. One classical example where these methods have been applied, are the studies and comparisons of fish-scales presence in sediments in the California and Peru current systems. For this particular case, these studies have shown that long-time changes in the abundance of clupeid-scombroid ensembles can be detected regularly during the last ten thousand years and may be a normal feature in these types of ecosystems.

Data needed to draw inferences on the recruitment of fish as influenced by environmental variables are often not accessible though existing in large amount. Therefore,an effort should be conducted wherever possible to retrieve and organize such data and to infer form them, in combination with estimates of recruitment and other data, as much as possible. For instance, fluctuations of atmosphere wind conditions are involved in several prominent hypothesized mechanisms for environmental regulation of reproductive success. Therefore, time series continuity of some form of wind data is an important requirement for most IREP research activities.

Attached is a table indicating environmental measurements of particular importance for inferential (indirect) approaches. In each case a careful analysis of the available knowledge of the particular physical/biological system in relation to hypothesized mechanisms will be necessary to assign priorities for specific experimental efforts. For example, in certain systems reference to fresh water inflows will be important, while in others (e.g. subtropical upwelling systems) they will be unimportant.

	Indirect estimates
Type of Observations	Wind observation at coastal stations Large scales analyzed winds Fresh-water run-off Satellite images Coastal (island) sea level observations
Type of Information	Ekman transport on large scale Wind induced turbulence on large scale Anomalies in the current pattern (some indications)

The compiling effort, which may be national and/or regional, should involve attempts to catalogue environmental data sources of various kinds (e.g. daily wind records in meteorological offices, tide gauge readings in hydrographic services, etc.) as well as to compile, standardize and publish at least some of the actual records, e.g. as appendices in the technical reports where partial analyses are presented. Such efforts would considerably benefit from support provided by the IOC services, the Unesco Division of Marine Sciences, the IOC/SCOR CCCO and the Unesco International Hydrological Programme (IHP).

The Workshop identified five general areas in which the inferential methods presented above can be applied:

(a) Shelves and banks (both tropical and temperate)

(b) Reefs (including coral reefs)

(c) Upwellings (Eastern Boundary Currents and elsewhere)

(d) The Open Ocean

(e) Lagoons, estuaries and areas of inter-tidal vegetation.

4. SUPPORTIVE EXPERIMENTAL WORK

Early studies on recruitment concentrated upon "stock-and-recruitment" early feeding of larvae, and describing the effects of various oceanic variables upon recruitment. It is fair to say that despite all of these studies there is little predictive understanding of the mechanisms that cause fluctuations in recruitment.

We realize that the problem is very complex. It may involve all life history stages, the density-dependent factors affecting these stages, and the influence of other biological and physical variables. The problem is made even more complex since it is likely that the nature and combination of causal mechanisms which affect recruitment changes from year to year.

The fact that causal mechanisms and their changing nature are not well understood means that time series of recruitment and of any particular environmental variable or set of environmental variables may not necessarily lend new insights into the recruitment process.

New approaches need to be tried. These approaches need to "short cut" the complexity. It would seem that an efficient approach for dealing with the compexity is to emphasize experiments aimed at studying causes which are as close as possible to the effects and to use these studies to develop a new theoretical approach to the problem of recruitment.

Examples of such experimental studies should include studying the nutritional requirements of larvae, the effects of predation upon larvae, and the effect of physical variables upon predation, larvae and larval nutrition.

In addition to the scientific quality of this programme, the results are intended to benefit the developing countries. It should be realized (a) that developing an improved theory of recruitment is a long-term proposition (b) that there are other approaches using standard stock assessment techniques to estimate recruitment in addition than estimating the abundance of very small fish; and (c) that some of the research whilst not having short-term fishery management benefits, can be of considerable benefit to the developing countries because of the training opportunities that are afforded. In this context, it should be considered that experimental work is nevertheless rather restricted to those countries which have already well established/adequate laboratories. Establishment and maintenance of laboratories is, in general, a progressive and costly process. As far as developing countries are concerned, the available resources would be better spent in the immediate future on field work.

5. GENERAL REMARKS

The review made by the Workshop on the present state of knowledge in the problem of recruitment and its variability, indicates that an integration of experimental and field studies is being initiated which can be projected towards the formulation of comprehensive models of reproductive strategies evolved to maximize the recruitment process.

The Workshop concluded that IREP represents a particular good case for co-operative and interdisciplinary research towards this aim in terms of cost-sharing logistics, liaison between developed and developing countries, data processing and exchange and corresponding TEMA components.

In this connection, it should be taken into account that although the Workshop was as specific as possible in examining and formulating its proposals, further definition and implementation of IREP components will require consultation within the OSLR Guiding Group of Experts. To attain this goal, it would be essential for the Guiding Group of Experts to seek the co-operation of relevant working groups of SCOR, IABO, regional organizations (such as ICES and CPPS) and regional subsidiary bodies of IOC and FAO, including interested national institutions.

Also in recognition of the high costs involved in the sorting, and identification of fish eggs and larvae, and their planktonic prey and predators, and being cognizant of recent technological advances to deal with this particular problem, it was considered that it would be useful to convene a specific workshop in this area aimed at covering the following objectives: (a) to review the capabilities of new systems available or under development for the collection, sorting, and identification of fish eggs and larvae; (b) to evaluate the potential application of these systems in support of IREP studies; and (c) to identify modifications to the most promising systems for operation in developing countries.

6. WORKSHOP CONCLUSIONS AND RECOMMENDATIONS

Conclusion 1

To obtain a better understanding of the processes governing the recruitment to stocks of fish and shellfish is of fundamental importance. Attainment of this objective presents formidable problems, scientifically and logistically, requiring for their solution a wide range of research, at sea and ashore, on a long-term basis.

Conclusion 2

To attempt a worldwide comparative exercise at this juncture would be premature, although it could be a future objective. There is, however, a strong case for co-operative endeavour between countries, enabling complementary research to be undertaken on the same or different species groups in various environmental systems in different parts of the workd, the results forming part of an overall co-ordinated programme (IREP).

Recommendation 1

To this end, regular communication and contact needs to be established between researchers and research groups actively engaged in recruitment studies. It is accordingly recommended that IOC should seek the co-operation and participation of regional organizations (notably ICES, CPPS and IOC and FAO regional subsidiary bodies) and research centres as appropriate, with a view to establishing or extending such communication.

Recommendation 2

Concerning direct investigations of the Early Life History (ELH), it is recommended that the existing co-operation between oceanographic laboratories on the west coast of North America and marine research institutions on the west coast of South America about recruitment research of the anchovy/sardine complex, for which the daily ring method is best established, should continue and be extended as the Sardine-Anchovy Recruitment Programme (SARP). It is hoped that experience and results of this programme, and the evolution of the IREP Minimum Plan (see section 2), can be disseminated to other interested regions through the network envisaged under Recommendation 1.

Recommendation 3

Because of the great potential value of the daily otolith ring technique in enabling the age of individual fish larvae to be ascertained, it is recommended that experience with this technique should be pooled and plans made to extend tests on its reliability on sardines and anchovies in regions other than California and Perú, and on other species.

Recommendation 4

The measurement of total egg production is a powerful technique in its own right for estimating stock biomass, as well as being the first stage in an ELH survey. It is recommended that research on adult conditions, fecundity, and egg viability be given greater emphasis.

Recommendation 5

Considerable potential exists for development of techniques and sampling gear for efficient survey of fish eggs, larvae and juveniles. It is recommended that experience in this field of gear technology be pooled, with a view to developing a suite of improved and calibrated sampling methods and equipment for general use.

Recommendation 6

In view of the importance of certain oceanographic conditions, particularly transport and mixing, in determining recruitment success, it is recommended that emphasis be given to a closer identification of the particular conditions that are most significant in this connection, for various species and environments.

Recommendation 7

For the indirect (inferential) approach, the main need is to make available the wealth of relevant data normally peripheral to the marine field. Of particular importance are climatic and meteorological data (e.g. from the CCCO programme) and river run-off (from the IHP of Unesco). It is recommended that IOC could perform a valuable service by organizing symposia and visits of scientists actively engaged in this field of research and by facilitating the exchange of data and products through its existing ocean services systems.

Recommendation 8

Planning of research and interpretation of results from both direct and indirect investigations can be greatly helped by experimental and field work on the physiology, behaviour and feeding of fish larvae, and on the role of predators. It is recommended that a further analysis be made by a small group of specialists of the most profitable lines of research in this field and the facilities required, in relation to various species and areas.

Recommendation 9

A number of the research areas covered by the above recommendations, together with related techniques - such as identification of fish larvae - would make appropriate topics for TEMA support, and it is recommended that these opportunities should be developed in conjunction with the TEMA Working Committee.

ANNEX I

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ANNEX II

THE OCEAN SCIENCE IN RELATION TO LIVING RESOURCES PROGRAMME OF IOC

The Intergovernmental Oceanographic Commission (IOC), through a study of the Future Role and Functions of the Commission, identified a clear need to expand basic research in marine resources, particularly ocean sciences as they apply to fisheries, and to improve and expand the capabilities of developing countries in these fields. Accordingly, at its 11th Assembly (15 October - 3 November 1979), the Commission passed Resolution XI-17 on Ocean Sciences in Relation to Living Resources (OSLR). The purpose of this resolution was to promote development of plans for major oceanographic studies of the physical-ecological interactions of importance to fishery resource-related problems for submission to the Twelfth Assembly in 1982. As a contribution to the OSLR Programme, FAO organized a Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fishes, held in Lima, 20 April - 5 May 1980. Concurrently, a small group of scientists involved in research on multispecies and climate-environment physical processes related to fisheries problems, was jointly convened with FAO in Rome (14-17 October 1980), to review updated thinking on how to start the formulation of the OSLR Programme. The group identified research requirements which concentrated on questions of recruitment and predation, mentioning four major systems of interest to developing countries (upwelling systems, coral reefs, tropical demersal fisheries and the open oceans).

Resolution XI-17 also asked "the Advisory Committee on Marine Resources Research (ACMRR) of FAO and the Scientific Committee on Oceanic Research (SCOR) to develop a comprehensive scientific programme plan for OSLR and project proposal for research projects."

SCOR and ACMRR responded to the IOC request by forming Working Group 67, on "Oceanography, Marine Ecology and Living Resources".

The SCOR/ACMRR Working Group 67 arrived to the following main recommendations:

(i) That a set of experiments collectively called the International Recruitment Experiment (IREX) be proposed to investigate the relationships between environmental variability and fluctuations f living resources.

(ii) That a separate working group be set up to determine the feasibility of IREX application to high diversity ecosystems.

(iii) That the Committee on Climatic Changes and the Ocean (CCCO) support the IREX activities through the Time Series Group of the Biology Panel.

The above scientific exercises were followed by a number of regional and national consultations, notably among them a series of nationally sponsored workshops in the USA and the UK and regional consultations in the framework of the CPPS countries (Colombia, Chile, Ecuador and Perú).

The concept of OSLR as a long-term programme of marine research was formally adopted (Resolution XII-1) at the Twelfth Assembly of IOC in Paris, 3-19 November 1982. It was endorsed that a central aim within this general programme should be to promote co-ordinated regional research projects aimed at elucidating the factors (physical, chemical and biological) determining the recruitment to fish populations, having regard to the variability of commercial fish stocks. In this context, the recommendations of the SCOR/ACMRR Working Group 67 were re-formulated and the corresponding component denominated the International Recruitment Project (IREP).

The text of the IOC Resolution XII-1 is enclosed in Annex III. The Resolution invites the FAO to co-sponsor the Programme and provides for the establishment of a standing Guiding Group of Experts for OSLR. It accepted also with appreciation the offer made during the Assembly by Canada to host a Workshop on the future planning of the IREP component of OSLR.

The main task of the Halifax Workshop was to formulate a set of objectives and a strategy for practical research projects, or group of projects, to implement IREP. In addition to the background material provided by the consultations organized before the Twelfth Assembly of IOC, certain criteria to guide the Workshop were derived from an informal meeting held on April 23, 1983, during the course of the FAO Expert Consultation to examine changes in abundance and species composition of Neritic Fish Stocks, San José, Costa Rica (18-29 April 1983).

Relevant reports and papers of these consultations were made available for the Halifax Workshop (see Annex VI).

It should be noted also that in pursuance of Resolution XII-I, IABO sponsored in co-operation with the Unesco Division of Marine Sciences a meeting on High Diversity Marine Ecosystems (Roscoff, 6-9 September 1983) the report of which was made available for the Workshop and is enclosed in Annex VII.

ANNEX III

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of Unesco)

Twelfth Session of the Assembly
Paris, 3-20 November 1982

Resolution XII-1

OCEAN SCIENCE IN RELATION TO LIVING RESOURCES (OSLR)

The Intergovernmental Oceanographic Commission,

A

Recalling Resolution XI-17 approving the development by the Commission of a Programme of Ocean Science in Relation to Living Resources (OSLR),

Expresses its appreciation to SCOR and ACMRR for the report of their joint Working Group No. 67 (document IOC-XII/8 Annex 1a) which was submitted to the Assembly in response to the Commission's request for advice on this programme;

Adopts OSLR as a new scientific programme of the Commission.

B

Agreeing with the SCOR view that the first major objective of the Commission's OSLR Programme should be to gain a better understanding of the effect of environmental conditions on recruitment of fish stocks, this being one of the central and long-standing, but still largely unresolved, problems in marine science in relation to living resources,

Noting that progress towards this objective would be of direct assistance to Member States in their task of achieving the best management of fish resources and in support of FAO activities to that effect,

Acknowledging that the multi-disciplinary research involved is particularly demanding logistically and calls for the concerted application of a wide range of scientific skills, together with the necessary facilities, at sea and ashore, on a long-term basis,

Agreeing also with the conclusion of SCOR/ACMRR Working Group No. 67 that a promising approach would therefore be to develop an international programme comprising a network of investigations into the relevant aspect of the quantitative ecology of selected fish species, co-ordinated in space and time and using similar techniques (hereafter called the International Recruitment Project, IREP),

Noting also that one possible form that this programme could take is that described in the report of the SCOR/ACMRR Working Group No. 67 as IREX (International Recruitment Experiment),

Being aware that much consultation and detailed planning will be required before such an international programme can be undertaken,

Invites the FAO to co-sponsor the OSLR Programme and the International Recruitment Project in particular;

Establishes a Guiding Group of Experts on the OSLR Programme, with the terms of reference contained in the annex attached to this resolution;

Requests the group to report on progress to the Executive Council at its Seventeenth Session;

Accepts with appreciation the offer from Canada to host a workshop on the future planning of the IREP;

Accepts also with appreciation the offer from the Unesco Division of Marine Sciences to sponsor a working group to examine the special problems of high-diversity ecosystems in the context of the OSLR Programme.

Annex to Resolution XII-1

TERMS OF REFERENCE OF THE GUIDING GROUP OF EXPERTS ON THE PROGRAMME OF OCEAN SCIENCE IN RELATION TO LIVING RESOURCES (OSLR)

1. To plan further the development of the OSLR Programme, and in particular the International Recruitment Project (IREP), along the lines of the IREX proposal or in other ways, paying particular attention to methodology, techniques and logistics.

2. To provide scientific and technical advice to the IOC regional subsidiary bodies involved in the implementation of regional components of the OSLR Programme.

3. To seek the co-operation of SCOR, IABO, appropriate regional bodies (ICES, CPPS and regional fishery bodies of FAO, in particular) and national institutions.

4. To liaise with IOC subsidiary bodies (e.g. Joint SCOR/IOC CCCO, Working Committee for IGOSS and Working Committee on IODE) that might be able to assist in one or other aspects of the OSLR Programme, particularly IREP.

5. To co-operate with the Unesco Division of Marine Sciences on the special problems of high-diversity ecosystems in the context of OSLR.

6. To consider how best to ensure the participation of developing countries, in the OSLR Programme, by including TEMA components therein.

ANNEX IV

SUMMARIES OF INVITED LECTURES

A. Bakun	"Specific problems of research and monitoring"
M. Berman and K. Sherman	"A prototype system for rapid processing of zooplankton-ichthyoplankton samples"
L.M. Dickie, K. Frank, T. Lambert and S.R. Kerr	"Recent perspectives on causes of recruitment variability"
D.J. Garrod	"Logistical problems in the measurement of recruitment characteristics"
T.D. Iles	"Stock and recruitment and ecological theory"
D. Pauly	"Studying the recruitment variability in tropical fishes: a brief review of the available methodology"
H. Santander and I. Tsukayama	"The anchoveta and sardine and some events associated to the recruitment"

SPECIFIC PROBLEMS OF RESEARCH AND MONITORING

A. Bakun, Pacific Environmental Group,
National Marine Fisheries Service, Monterey

Our understanding of the mechanisms regulating recruitment is not well developed. The processes involved are difficult to observe directly. Empirical efforts are hampered by short series of annual data points; however new techniques for reading daily otolith rings and some new length-frequency methods yield multiple within-year data points.

The range of time and space scales involved is very broad. Effects of short-scale environmental events tend to cascade to longer scales as a result of biological reactions. Annual recruitment estimates are generally auto-correlated, leading to reduction in available degrees of freedom. In this situation of limited degrees of freedom and multiple possible mechanisms which may interact on a variety of scales, highly significant correlations of recruitment with any single environmental variable is not to be expected. Dealing with weak relationships and possibilities for numerous spurious correlations is a major challenge.

A search for useful unifying principles is recommended. These may add confidence to weak relationships and will aid in limiting the choice of explanatory variables in order to avoid spurious empirical models. For example, an assumption of analogous mechanisms acting in the cases of similar species in similarly-operating environmental systems allows interregional comparative studies to be a powerful inferential method. Note that even if the assumption of analogues is not strictly correct, it still provides a basis for systematizing experience and may be preferable to separate and unrelated "hindcast" explanations of each separate set of circumstances. Natural selection implies successful accommodation to the most crucial environmental factors limiting reproductive success. Thus, consistent patterns in seasonality and geography in reproductive habits and environmental processes are empirical evidence of causality. The identification of factors regulating reproductive success over the period in which the observed reprodutive habits were developed provides a basis for assuming that the same factors may presently be regulating recruitment variations. Likewise, empirical time series models may be subjected to inter-regional comparison as a judge of their validity.

A careful evaluation of the physical and biological system, using the available information, is an important prerequisite for any investigation. This may indicate logical choices of processes to receive research attention and of variables to be included in empirical studies. Where possible, inferences should be checked and improved by suitable field and laboratory experiments.

The reaction of adult populations to environmental anomalies is a crucial problem area. Whether they merely follow environmental gradients to suitable reproductive sites, or tend to attempt to reproduce in consistent geographical locations is a serious question when attempts are made to predict consequences (of the present El Niño on the South-American sardine population, for example).

The only variable which can be controlled by human action is the stock size. Thus illuminating aspects of the dependence of recruitment on stock size should be a major goal of any recruitment research.

A PROTOTYPE SYSTEM FOR RAPID PROCESSING OF ZOOPLANKTON-ICHTHYOPLANKTON SAMPLES

M. Berman and K. Sherman, National Marine
Fisheries Service Laboratory, Narragansett,
Rhode Island

In recent years several approaches have been attempted to reduce the time and effort required to process ichthyoplankton samples including electronic gate-counters, holography, and photoelectric counters. The system described uses pattern recognition of digital images from a television camera. The technique identifies the organisms to major taxonomic groups, as well as countint and measuring them.

The automated system is made up of major components. The sample, contained in a modified Bogorov chamber, is mounted on an automated translation stage. It is viewed by an optical assembly made up of a television camera and a dissecting microscope. The shape of the Bogorov chamber is programmed into the stage controller, so the whole sample is moved under the field of view of the microscope, one field at a time. The video signal is sent to a frame grabber which integrates the video data stream into a complete image (one television screen of data), the frame grabber then digitizes the image by recording the brightness of each point on a 256 X 256 array. Finally it converts the image to a binary array by comparing each point to a threshold intensity; points brighter than the threshold are recorded as one's, those less bright as zeros. The output of the frame grabber, a string of over 65,000 bits is sent to an Eclipse computer network where the measurement of each object is made. At present, the system can separate the following 8 taxonomic groups with 90 % accuracy: fish eggs, fish larvae, copepods, chaetognaths, decapod larvae, pteropods, euphausiids, and amphipods.

In recognition of the high costs in time and money expended in the collection, sorting, and identification of fish eggs, larvae, and their planktonic prey and predators, and being cognizant of recent technological advances in several countries to deal with the problem, it would be useful to convene a workshop to:

1. Review the capabilities of new systems available or under development for the collection, sorting, and identification of fish eggs, larvae, and their planktonic prey and predators.

2. Evaluate the potential application of candidate systems in support of IREP studies.

3. Identify modifications to the most promising systems for operation in developing countries

4. Include a detailed description of these systems in the Report.

5. Report the results to the next meeting of the OSLR Guiding Group of Experts.

RECENT PERSPECTIVES ON CAUSES OF RECRUITMENT VARIABILITY

L. M. Dickie, K. Frank, T. Lambert and S.R. Kerr,
Marine Ecology Laboratory, Bedford Institute of Oceanography,
Dartmouth, Nova Scotia

A review of the literature since the ICES Symposium on Fish Stocks and Recruitment reveals a consensus that there is as yet no basis for a single ecological theory of the relation of recruitment to adult stock size. For management, the main consequence of this realization is that there is no adequate substitute for data-rich empirical information for each important fishery. Without a general theory the requirement for more and better empirical data must increase wherever an attempt is made at more precise management.

The prospects for useful results from experiments are, however, better than ever before. Knowledge of recruitment mechanisms has developed a new appreciation of the types of factors which can account for recruitment variability. In particular, models now exist which indicate the conditions under which food supply may create the time-lagged density-dependent effects necessary to explain the observed variability. These models suggest the kinds of observations and experiments that are required to verify the existence of the mechanisms and test the relative power of their effects, especially among certain pelagic (e.g., anchovy and herring) and demersal (e.g., haddock and cod) population systems. The experiments that will be needed consist of a combination of fine-scale field studies and laboratory tests, and appear to include verification among fish, of genetic mechanisms that have, as yet, only been observed among marine molluscs. Such experiments will be needed as part of any overall assessment of the relative importance of food supply, depredation and disease in relation to physical factors in the ultimate definition of the "carrying capacity" of the environment.

LOGISTICAL PROBLEMS IN THE MEASUREMENT OF RECRUITMENT CHARACTERISTICS

D. J. Garrod, Fisheries Laboratory, Lowestoft

The presentation reviewed characteristics of the mortality in the early life history of selected north-east Atlantic stocks judged from conventional time series data on spawning stock size and year class strength. Evidence was presented to suggest that in fish having pelagic eggs and larvae, there are similarities in fecundity per gram female; the density of spawning products, and the magnitude of mortality and its variation with stock size do not exclude the possibility that the apparently wide range of stock-specific stock and recruitment relationships depend on a general mechanism.

Generality would be a significant advantage to the interpretation of results from the proposed IREX programme, but the same evidence also illustrates the high level of precision required to detect biologically significant variations in mortality in the early life history.

The paper then composed the logistical implications of a coarse field programme conducted over a number of years at a level of precision sufficient only to detect extreme variations in mortality, with those of intensive studies to achieve the enhanced precision required to quantify causal relationships. These were illustrated by reference to surveys of both types conducted by the Lowestoft Laboratory, together with their costs in order to provide a background for judgement on the funding implications of programme proposals.

STOCK AND RECRUITMENT AND ECOLOGICAL THEORY

T.D. Iles, St. Andrews Biological Station, New Brunswick

Theories are necessary on the grounds of economy of intellectual effort and of use of material resources in research.

An examination of the theoretical basis of stock and recruitment begins with that of the impact ecology made on the development of the "New Synthesis" ..., the impact was negligible.

Much the same can be said for the significance of fisheries biology in the development of ecological theory and of marine fishes in fisheries biology. The necessary conclusion is that marine studies generally have not been influential in the development of biological theory.

An examination of biological theory itself reveals a diminishing concensus. For example in ecology there is current controversy about the significance of competition that, for example, throws doubt on its application, in physiological terms, to life history theory.

Even in evolutionary theory, recent years have seen the development of a persistent and increasing questioning of fundamental aspects of Neo-Darwinism. This goes as far as to question the importance of Natural Selection as the main evolutionary force.

Since so many theories are being questioned, it is necessary to critically analyze the theoretical basis of extant stock/recruitment methods for their biological and logical content and to test for consistency and plausibility.

This is done for the Beverton & Holt model to show that a consistent biological approach was achieved, but in a mathematical framework designed to lead to an <u>expected</u> result. This was also an <u>acceptable</u> result in the context of the Beverton & Holt Yield/Recruit model.

Ricker attempted a more comprehensive theory based on "reproduction curves" (not year-classes) and involving increasing dominance of early life-history stages by the adults as adult stocks increased to produce "dome-shaped" curves. However, between 1954, when the theory was put forward, and 1975, when it was again reviewed by Ricker, much of the theoretical argument was lost.

It is concluded that "theory" has been replaced by curve-fitting in the study of stock and recruitment and that an attempt to build up a biological theory for stock and recruitment is long overdue. One was in fact initiated by Iles at the 1970 Aarhus Symposium but it was largely overlooked. An attempt to establish it as an alternative to other models is being made, based on both its biological basis and diagnostic power.

STUDYING THE RECRUITMENT VARIABILITY IN TROPICAL FISHES: A BRIEF REVIEW OF THE AVAILABLE METHODOLOGY

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The type of living resources and the data base on these resources were characterized in general terms, and the features discussed in detail which are related to recruitment processes and their study.

Lack of time was identified as a major constraint. More precisely, the problem is (a) lack of time to study thoroughly all the species that are relevant; (b) lack of time series of recruitment indices long enough for successful application of standard correlation methods and (c) a general tendency for biological events, in tropical waters to occur within a compressed time scale. This compressed time scale requires a scaling down of all time-related components of the methodology generally used for recruitment studies (this scaling-down may not be always possible to perform, however).

Data which are widely available in tropical countries, for which longer time-series are often accessible (in the appropriate time scale) are (a) length-frequency data from commercial fish stocks and (b) meteorological information (particularly wind data). Other type of data usable for inferences on recruitment processes are generally unavailable, and/or hard to generate.

Methods have been developed in recent years which allow inference on recruitment variability of tropical fishes. Such methods are best represented by (a) the ELEFAN (Electronic LEngth Frequency ANalysis) suite of microcomputer programmes for the detailed, objective analysis of length-frequency data, as developed by the author and his associates and (b) the "wind"-based comparative method of A. Bakun and co-workers at the Pacific Environmental Group (NMFS, NOAA, Monterey), which itself has its theoretical basis in the work of R. Lasker and associates at the Southwest Fisheries Center (NMFS, La Jolla).

When no detailed catch data are available, the integration of the approaches mentioned above involves the following steps:

i) estimation of growth parameters (including those describing seasonal growth oscillations) from the length-frequency data using ELEFAN I;

ii) derivation of so-called "recruitment patterns" using ELEFAN II (this process involves the projection onto the time axis of the available length frequency data by means of the growth parameters derived in (i), thus making subannual or annual recruitment "pulses" visible, quantifiable and amenable to further analysis and

iii) interpretation of the combined recruitment pulses of group of species by means of plots of turbulence on Eckman transport, as proposed by Bakun and co-workers in the narrower context of single species in upwelling ecosystems.

When monthly catch data are available for a period for which matching length frequency data are also available, conversion to monthly catch-at-length data can be easily performed; such data can then be used with the ELEFAN III programme to run age-structures Virtual Population Analyses, which yields estimates of absolute monthly recruitment.

Such estimates of monthly recruitment can be used (after accounting for seasonality) for deriving standard stock-recruitment relationships or for such approaches as spectral or multivariate analysis. ELEFAN III and the monthly recruitment estimates in general thus allow for the application to the recruitment problem of extremely powerful methods; such methods had earlier not been available for recruitment studies because of the lack of sufficient degrees of freedom (the "one-point-per-year" problem).

It is this last aspect of the methodology proposed here which seems the most promising.

THE ANCHOVETA AND SARDINE AND SOME EVENTS ASSOCIATED TO THE RECRUITMENT

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One of the most impressive causes in the collapse of an important fishery that can be attributed to successive failures of recruitment, is that of the Peruvian anchovy Engraulis ringens.

In the sixties its biomass fluctuated between 13 and 22 million tons annually and the annual average catch during this period was 7.8 million tons. From 1972 to 1981, the intensive fishing effort applied during mainly the four previous years and the drastic environmental anomaly of El Niño 1972, contributed to the abrupt decrease of this population which dropped to less than half of its average in the previous decade.

The present "El Niño" 1983, has weakened the stock even further. It was observed a gradual decrease in body weight since 1982, which reached 30 % in March 1983 (IMARPE, 1983). The spawning index determined during the peak of the spawning period, showed a certain agreement with the stock sizes. After 1968 it began to decline (Santander y Flores, 1983). With the exception of 1978 when a relative increase in the spawning was recorded, it was continuously decreasing up to 1983, when no spawning was observed in the main spawning area. In the decade 1961 to 1971, when the environmental conditions did not show large changes and the adult biomass was relatively high, the recruitment indices of the anchovy were very stable and fluctuated only by a factor of 3.

The recruitment failure in 1972 is attributed to an extreme exploitation rate, mainly done in 1970 and 1971. It was accelerated by the adverse environmental conditions of the severe "El Niño" 1972. Recruitment varied by a factor of 18 from 1972 to 1981. Although other pelagic species (such as sardine, jack mackerel and mackerel) have increased, the total biomass of these three species is lower than the previous level of the anchovy. It represents a major change in the species dominance complex in the pelagic ecosystem of the Peruvian sea (Tsukayama, 1983).

Numerous mechanisms can affect the success of the recruitment. In this context, the importance of the contribution of Csirke (1980) is the incorporation of the environmental effects in the Ricker model.

Ware and Tsukayama (1981) suggested that recruitment is determined by a mechanism (stock-dependent), where egg production decrease at high stock levels and to another process (density-dependent) in which the survival of the larval stages is a function of the size of the year class and of the environment.

Tsukayama and Alvarez (1981) proposed, as a compensatory mechanism associated with the recruitment of anchovy, the decreasing in the fraction of the adult stock which is actively involved in spawning at high stock levels during periods of high temperature.

The distribution changes for anchovy and sardine in different stages of their life and the more frequent co-occurrence in eggs and larvae stages of both species, lead to an interaction demonstrated by the predation on eggs and larvae (Santander, et al. 1983). Santander and Flores (1983) suggested that the mortality of eggs and/or larvae of anchovy on the last years, should be higher than previous years, because the associated reduction observed in the areal distribution of larvae, compared to the relatively larger extension of the spawning. An increased interaction between the two sepcies, the gradual decrease in the anchovy spawning stock and changes in the reproduction process due to changes in the environment will affect the recruitment. In 1972 will begin a sudden expansion of the sardine stock influenced, as mentioned, by the decline of the anchovy stock and by environmental changes. This turned later on into significant increases in the stock of sardine up to 1982. In the period 1978 to 1981 the biomass values fluctuated around 3.0 million tons. In March-May 1983, the values were estimated to be around 4.8 million tons (IMARPE, 1983). The environmental conditions caused by "El Niño" 1972, 1976 and 1982 seemed to have a positive effect on the sardine spawning. Conversely, on the period between 1980-1982, the spawning indices suggested that the sardine stock was decreasing. The Peruvian system shows a large scale change in the dominance of species, between anchovy and sardine. Future models need to incorporate mechanisms of interaction and strategies developed by both species during their life stages, when they have to face varying conditions.

Table 1. Annual biomass, Spawning Index, Recruitmen Index and Landings of anchoveta along Peruvian coast during 1961-1982.

Year	Mean Annual Biomass (Millions Metric Tons)	Spawning Index	Recruitment Index	Landings (Millions Metric Tons)
1961	-		332	4.6
62	-		237	6.3
63	13.4		183	6.4
64	14.7		403	8.9
65	18.6	148	193	7.2
66	18.5	3013	439	8.5
67	22.0	5769	383	9.8
68	16.8	1595	338	10.3
69	14.2	1204	377	9.0
1970	16.0	725	553	12.3
71	13.4	537	539	10.3
72	6.6	206	52	4.4
73	4.9	239	160	1.8
74	5.4	1134	180	3.6
75	6.8	933	160	3.1
76	8.3	498	392	3.9
77	3.0	488	22	0.7
78	3.9	1322	224	1.2
79	3.4	399	62	1.3
1980	1.8	479	62	0.6
81	3.0	384	50	1.2
82		213		1.7
83		0		

Source of data:
(1) Tsukayama, 1983 (In press)
(2) Santander, 1983 (In press)
(3) Instituto del Mar del Perú - Area Monitoraje de Anchoveta
(4) Tsukayama, 1983 (In press)

Table 2. Annual biomass, Spawning Index and Landings of sardina along the Peruvian coast during 1960-1983.

YEAR	(1) Mean Annual Biomass (Millions Metric Tons)	(2) Spawning Index	(3) Landings (Thousands Metric Tons)
1960	-	-	3
61	-	-	3
62	-	-	3
63	-	-	2
64	-	-	10
65	-	0	7
66	-	0	2
67	-	0	2
68	-	0	2
69	-	0	1
1970	-	0	0.4
71	-	0	6
72	-	5	6
73	-	0	132
74	-	25	73
75	-	87	63
76	-	268	175
77	1.8 a)	254	871
78	3.7 a)	399	1244
79	3.0 b)	1551	1675
1980	3.0 c)	570	1480
81	3.0 - 3.7 d)	183	1163
82	-	429	1512
83	4.8 e)		

Source of data: (1) a) Jordán *et al.*, 1978
b) IMARPE, 1979
c) Jordán *et al.*, 1980
d) IMARPE, 1981
e) IMARPE, 1983
(2) Santander, 1983 (In press)
(3) Tsukayama, 1983 (In press)

ANNEX V

DATA COLLECTION FOR IREP

The following considerations should be taken into account:

a) Environmental Measurements:

Simple CTD (+ chlorophyll fluorescence) systems can be attached to most samplers. The new undulating instruments provide high speed wide-scale environmental measurements with a fine spatial scale of discrimination. New internal solid-state recording CTD's eliminate costly slip-ring winches and multi-conductor sea-cables, making them appropriate for hi-tech studies in low-tech environments.

b) Environmental Monitoring:

The utility of sea surface temperature and sea level monitoring cannot be overestimated. These shore-based technologies are inexpensive and represent a fundamental investment. The availability of routine meteorological observations is assumed.

c) Developing Technologies:

Physical oceanographic technology is being revolutionalized by micro-computers. The elimination of moving parts in moored current meters, thermistor chains, and CTD's has increased their reliability and lowered costs. The interpretation of bottom pressure records provides indices of advection that are valuable for biological programmes. Bottom pressure recorders are probably an appropriate tool for developing countries, although their placement and interpretation require scientific advice of the highest caliber. A shopping list of biological oceanographic research tools will include in time a wide variety of particle counters, in-situ fluorometers, photographic systems, hi-frequency hydro-acoustics, etc. The perils of sophisticated equipment in field programmes are therefore not to be underestimated.

The following table summarizes environmental direct measurements phased in increasing effort and complexity for different types of observations and information required.

ENVIRONMENTAL DATA FOR IREP

	DIRECT MEASUREMENTS (INCREASING EFFORT AND COMPLEXITY)		
TYPE OF OBSERVATIONS	Temperature/Salinity (discrete depths) Wind observations at research vessels The whole distribution area surveyed by an open grid	CTD type instruments (continuous with depth): a) whole area with open grid b) sub-area fine-scale in time and space	Current measurement in fixed position Drifting buoys positioned by satellite Direct measurements of turbulence and vertical processes (vertical velocity - dye experiments, etc.) More sophisticated satellite products
TYPE OF INFORMATION	Water mass distribution, current pattern and vertical structure in relation to variation in the windfield and fresh water outflow	More details. More continuity of coverage Fine scale observation should be carried out synoptically with biological observations.	Still more details on time and space Variability of current pattern, vertical structure and the causes of variability

The Workshop considered, regarding tools for recruitment research, that studies of the past have been limited by the instrumentation available. Prototype instruments are in routine use now but are generally unavailable to fishery scientists interested in studying recruitment processes at scales only accessible to the newer equipment. For example, new versions of the undulator and Longhurst-Hardy Plankton Recorder (LHPR) are now being used. The in-situ fluorometer is another. The application of these new technologies to recruitment research within IREP framework is encouraged, particularly in the context of co-operative research between developed and developing member states.

The following plankton sampling systems in relation to recruitment studies can be listed:

Eggs: Many simple ring nets, Bongos, Clarke-Bumpus, Calvet, Gulf type, etc. samplers can give quantitative estimates and can be used from small vessels. Often the smaller sized nets are the more appropriate samplers to be used. UNDULATOR sampling offers high-speed advantages and potential of wide-scale environmental monitoring of spawning variables over the fish grounds.

"Larvae" $<\sim$ 15 mm:

Most nets for egg sampling will also sample larvae adequately. Larger nets are generally more efficient due to the lower density and escape activity of the larvae

Post-Larvae $>\sim$ 15 mm:

Few reliable systems are available. Neuston nets, plankton seines and traps offer some potential. A reliable estimate of population numbers cannot be obtained from available techniques.

Microplankton

Most simple plankton nets can be fitted with fine mesh to collect microplankton (of size range taken by larval fish). However, studies of larval feeding require fine-scale vertical discrimination of distribution patterns and vertical distribution sampling systems are needed.

Vertical distribution:

Several methods are available. Simple opening-closing nets (e.g. Bongo, Clarke-Bumpus) and multiple depth tows of simple plankton nets can give some information on depth distribution. More sophisticated systems include LHPR type samplers and pump systems; both of these methods allow microplankton to be sampled concurrently. Larger net systems such as Bioness or Rectangular Midwater Trawl (RMT) type samplers can be used for larger larvae. Vertical distribution samplers generally require larger vessels ($>\sim$ 25 m in length).

ANNEX VI

LIST OF DOCUMENTS DISTRIBUTED AT THE WORKSHOP

Document Code	Title
IOC/OSLR ad hoc-I/2	Objectives and Suggested Guidelines
IOC Workshop Report No. 28	Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fishes (Lima, 20 April - 5 May 1980)
IOC/INF-438	Meeting of Experts on Ocean Sciences in Relation to Living Resources (OSLR) (FAO Headquarters, Rome, 14-17 October 1980)
IOC-XII/8 Annex 1a	Proposal on a Programme of Ocean Science in Relation to Living Resources (Report of the SCOR/ACMRR Working Group 67 to the Twelfth Session of the IOC Assembly, Paris, 3-20 November 1982)
	Fish Ecology III - A foundation for REX, a Recruitment Experiment (University of Miami, RSMAS and NOAA Coop. Inst. for Mar. and Atm. Studies, B.J. Rothschild, C.G.H. Rooth (Convenors), Miami, 6-10 September 1982).
	Environmental Studies and Monitoring (Working Group 3, Draft), FAO Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Stocks, San José, April 18-29 1983)
	Physics and fish populations: Shelf Sea Fronts and Fisheries (by J. Hunter and G.D. Sharp, FAO Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Stocks, San José, April 18-29 1983)
	Comparative Climatology of Selected Environmental Processes in Relation to Eastern Boundary Current Pelagic Fish Reproduction (by R.A. Parrish, A. Bakun, D.M. Husby and C.S. Nelson, FAO Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Stocks, San José, April 18-29 1983)
	Monsoon-induced seasonality in the recruitment of Philippines fishes (by D. Pauly and N.A. Navaluna, FAO Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Stocks, San José, April 18-29 1983)

	Vertical distribution of larvae of mackerel (Scomber scombrus) and microplankton, with some conclusions on feeding conditions and survey methods (by S.H. Coombs, J.A. Lindley and C.A. Fosh, FAO Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Stocks, San José, April 18-29 1983)
IOC/INF-529	Scientific Inputs to Fishery Management: International Implications (by A. Longhurst for submission to the FAO World Conference on Fish. Man. and Dev., at the request of the Secretary of the IOC)
	Report of the IABO/Unesco ad hoc Meeting on High Diversity Marine Ecosystems (Roscoff, 6-9 September 1983) (see Annex VII)
	Automated Sizing, Counting, and Identification of Zooplankton by Pattern Recognition (by H.P. Jeffries, M.S. Berman, A.D. Poularikas, C. Katsinis, I. Melas, K. Sherman and L. Bivins)
	Computer-processing of Zooplankton Samples (by H.P. Jeffries, K. Sherman, R. Maurer and C. Katsinis, Estuarine Perspectives: 303-316)
	A Prototype System for Rapid Processing of Zooplankton-Ichthyoplankton Samples (by M. Berman and K. Sherman)
IOC-WMO-CPPS/El Niño-III/3	Recommendation El Niño-III.2. Co-ordination between the ERFEN and the OSLR Programmes

ANNEX VII

INTERNATIONAL ASSOCIATION FOR BIOLOGICAL OCEANOGRAPHY

REPORT OF THE IABO/UNESCO AD HOC MEETING ON HIGH DIVERSITY MARINE ECOSYSTEMS

Marine Station of Roscoff, France
6 - 9 September 1983

I. INTRODUCTION

The Member States of the Intergovernmental Oceanographic Commission (IOC), at the Eleventh Session of the Assembly, adopted Resolution XI-17 "Ocean Sciences in Relation to Living Resources" (OSLR). The resolution states that IOC has decided to plan a major program "on Oceanographic studies of the marine ecological conditions in relation to fish stocks". The Scientific Committee on Oceanic Research (SCOR) and the Advisory Committee on Marine Resources Reseach (ACMRR) responded to IOC request by forming Working Group 67, "Oceanography, Marine Ecology and Living Resources". The WG 67 concluded in its final Report for IOC (SCOR Proc., vol. 18, 1982) with the following recommendations:

1. A set of experiments collectively called the International Recruitment Experiment (IREX) is proposed to investigate the relationships between environmental variability and fluctuations of living resources.
2. It is recommended that a separate working group be set up to determine the feasability of IREX application to high diversity ecosystems.
3. It is recommended that the Committee on Climate Changes and the Ocean (CCCO) support the IREX activities through the Time Series Study Group of the Biology Panel.

The Report of WG 67 emphasized the variable recruitment found in fish stocks as mediated by environmental variability. The working Group 67 has proposed in IREX a set of comprehensive but united experiments on a number of selected fish stocks, found in low diversity ecosystems, mostly in the medium and high latitudes.

The Twelfth Assembly of IOC (Nov. 1982), in its resolution XII-1, adopted the concept of OSLR as a long-term Scientific Program. The resolution recommends the establishment of a standing guiding group of experts for OSLR and the organization of a workshop on the planning of an International Recruitment Project (IREP), to be held at the Bedford Institute of Oceanography, Halifax, Canada (September 26-30, 1983)

Furthermore, following the same resolution XII-1 of IOC (Nov. 1982), the International Association for Biological Oceanography (IABO), responded to the Unesco Division of Marine Sciences and IOC, by organizing an ad hoc Meeting of experts "to examine the special problems of high-diversity ecosystems in the context of the OSLR Program".

The Meeting was held at the Marine Station of Roscoff, France, from 6 to 9 September 1983.

The Meeting took as its point of departure Recommendation 2 of SCOR/ACMRR Working Group 67 (see SCOR Proceedings 1982, Vol. 18, pp.57-67). The second recommendation of WG 67 applies to the multispecies fisheries and asks for a separate study to establish wether the same hypotheses apply in high diversity marine ecosystems, where it is felt by some that inter-specific relations may be of greater importance than environmental variation.

The Meeting recognized that there exists for low diversity ecosystems a body of knowledge about the general functioning of these systems, against which it is possible to start planning an experimental approach to the solution of a key problem, namely the "recruitment problem". Conversely, we do not have the same body of knowledge concerning high diversity ecosystems.

After detailed consideration of the feasibility of an IREX application to high diversity ecosystems, the Meeting concluded that an experimental approach to the single problem of recruitment is not appropriate at the present time. Instead, it recommended a program emphasizing an experimental approach to the biological oceanography of high diversity marine ecosystems in order to provide a basic understanding of their functioning.

II. REVIEW OF PRESENT UNDERSTANDING

1. The Roscoff Meeting accepted the Working group 67 operational definition of high diversity ecosystems based on the number of species in the fishery and the statement that these ecosystems have unique biological characteristics.

The Meeting noted, however, that diversity is a subjective notion which depends on both the method of sampling and the sample size. This comment applies equally to the fish community and to other parts of the ecosystem. Further, a high diversity fishery does not always imply a highly diverse ecosystem. For example, high diversity in a fish community may be generated either by evolution of many niches during a long period of stability (coral reefs) or by mixing of several adjacent communities (some estuaries, bays and lagoons) over shorter time intervals. The implication for management of these two types of high diversity fisheries are quite different.

2. Ecosystems supporting highly diverse fish communities are conventionally represented as having some combination of the following properties:

2.1. The ratio of total primary production : total biomass of the community is low. This is achieved by intensive recycling of nutrients, so that the ratio of recycled nutrients to new nutrients is high.

2.2. A high proportion of K-selected species characterized by a slow growth, long life histories, territoriality etc.

2.3. Lack of strong seasonality.

2.4. Relatively constant biomass, especially in the benthic communities, leading to the concept of robustness of these high diversity systems.

Furthermore, examination of ecological theory (cybernetical approach and ecological niche approach) indicates that at present there is no adequate model of community dynamics, particularly in highly diverse marine ecosystems and their supporting multispecies fisheries and/or nurseries, in the medium and low latitudes.

III. ASSESSMENT OF THE NEED FOR FURTHER WORK

It was apparent to the Meeting that the concept of diversity in marine ecosystems must be more rigorously defined as a spectral quantity in terms of time and space, and that the properties listed in II.2 are based on assumptions which are largely unsupported by data. We suggest that a program of field observations and experiments is needed to enhance our understanding of high diversity marine ecosystems.

Such a program might include :

a - Comparative field studies, in a number of locations, of : nutrient dynamics ; biomass and production at different trophic levels ; metabolic activity and pathways of energy flow ; spectra of species diversity as they change with different regimes of sampling and perturbation, recognizing that such spectra reflect the pattern of ecosystem structure and function.

b - Investigation of large scale variability in high diversity ecosystems by means of remote sensing imagery, notably coastal zone color scanner (CZCS)-type measurements, and palaeoecological techniques.

c - The direct participation of physical and chemical oceanographers is a condition for success in the program in both **a** and **b**.

d - Experimental studies, using controlled ecosystems, controlled perturbations and manipulations (physical or biological), as well as more conventional laboratory approaches. Such experiments might include controlled stocking and recruitment, nutrient enrichment, pollution, or exploitation.

e - Studies of the special role of species interactions such as symbiosis, commensalism, parasitism, toxicology etc.

On the management side, there will be a need to consider the implications of the research results in the context of resource use and conservation. The new data base generated by the proposed studies is expected to lead to a deeper understanding of the properties of these high diversity ecosystems, on the basis of which new exploitation strategies can be developed.

The Meeting noted that there are various international scientific activities which are increasing our understanding of different aspects of high diversity marine ecosystems.

However, it was noted that none were oriented specifically to understanding the ecosystem basis of multispecies fisheries. It was suggested that the contacts already established through these activities would provide a framework for responding to Recommendation 5, below.

IV. RECOMMENDATIONS.

The Meeting recommends to IABO the formation of a Working Group, jointly with SCOR entitled : **"High Diversity Marine Ecosystems and their living resources"** , with the following terms of reference :

1. To develop improved concepts and models of high diversity marine ecosystems in the medium and low latitudes, with particular reference to those supporting tropical multispecies fisheries.

2. To suggest specific field observations in contrasting environments and controlled ecosystems experiments which would contribute to a better understanding of these ecosystems and the proper management of associated fisheries. Consideration should be given to both pilot projects and full scale programs.

3. To identify specific research problems requiring satellite data and service components of climate-related ocean science studies to identify key oceanographic processes that influence distribution and abundance in highly diversified biota.

4. To advise IOC, Unesco and FAO within the context of the OSLR Programme and the IREP exercise.

5. To propose ways and means of establishing relevant cooperative research activities between interested institutions.

The Meeting also recommends that IABO proceeds immediately to identify institutions and scientists interested in participating in cooperative research activities on high diversity marine ecosystems experiment (HIDIMEEX).

ANNEX VIII

LIST OR ACRONYMS

ACMRR	Advisory Committee on Marine Resources Research (of FAO)
CCCO	Committee on Climatic Changes and the Ocean (IOC/SCOR)
CPPS	Comisión Permanente del Pacífico Sur (Colombia, Chile, Ecuador, Perú)
ERFEN	Estudio Regional del Fenómeno "El Niño" (of CPPS)
FAO	Food and Agriculture Organization of the United Nations
IABO	International Association for Biological Oceanography
ICES	International Council for the Exploration of the Sea
IGOSS	Integrated Global Ocean Services System (IOC/WMO)
IHP	International Hydrological Programme (Unesco)
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data Exchange (IOC)
IREP	International Recruitment Project (IOC)
IREX	International Recruitment Experiment
OSLR	Ocean Science in Relation to Living Resources (IOC)
SCOR	Scientific Committee on Oceanic Research
TEMA	Training, Education and Mutual Assistance in the marine sciences (IOC)
Unesco	United Nations Educational, Scientific and Cultural Organization
WMO	World Meteorological Organization