Intergovernmental Oceanographic Commission

Workshop Report No. 44

IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities

Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986

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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
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. 22)
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, 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 Paris, 27 September - 1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish

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1. OPENING

Mr. Andrew Bakun, Chairman of the Guiding Group of Experts for the IOC-FAO Programme on Ocean Science in Relation to Living Resources (OSLR), called the Session to order at 9:00, 21 April 1986, at the Estacion "El Carmen", Instituto de Ciencias del Mar y Limnologia, UNAM, Ciudad del Carmen, Campeche, Mexico. He briefly reviewed the origin and evolving pattern of OSLR, the International Recruitment Programme (IREP) in particular, and how this developed into the need to organize the present Workshop on Recruitment in Tropical Coastal Demersal Communities. He emphasized the aim of the Workshop was to arrive at a limited number of concrete and viable multidisciplinary project proposals to be implemented under the TRODERP initiative. *

The Terms of Reference for the Workshop are given in Annex I.

Mrs. Mirna Wong, representative of the Instituto Nacional de la Pesca, Secretaria de Pesca, Mexico, welcomed the participants; referring to the Terms of Reference of the Workshop, she expressed her hopes that the specific research proposals resulting from the Workshop will benefit the management of the important tropical demersal resources of Mexico.

Dr. Agustin Ayala-Castanares, Director of the Instituto de Ciencias del Mar y Limnologia, UNAM, and President of the Mexican Commission for OSLR, elaborated on the significance of the programme and the TRODERP exercise in particular, both for IOC and Mexico. He recapitulated the development observed in the scientific programmes of IOC during its 25 years of existence, describing its evolution from supporting specific regional expeditions to that of major global programmes. He recalled that the next Joint Oceanographic Assembly (JOA) will be held in Acapulco, Mexico, tentatively in 1988. Then, Dr. Ayala-Castanares, on behalf of the Mexican Government, officially inaugurated the TRODERP Workshop.

The List of Participants is given in Annex II.

2. ADMINISTRATIVE ARRANGEMENTS

2.1 ELECTION OF THE CHAIRMAN AND DESIGNATION OF RAPPORTEURS

Dr. A. Yanez-Arancibia was proposed as Chairman for the Workshop. This proposal was unanimously seconded by the participants. Dr. D. Williams was proposed as English Rapporteur and Mr. J.C. Seijo and Mr. J.L. Rojas-Galaviz as Spanish Rapporteurs. These proposals were likewise unanimously supported by the participants.

The Chairman suggested the names of Drs. P. Rothlisberg, A. Bakun, D. Pauly and R. Livingston as Co-ordinators for the working groups proposed in the Provisional Programme for the Workshop (see Item 4 below). This suggestion was endorsed by the participants.

2.2 CONDUCT OF THE SESSION

Dr. F. Robles, Head of the IOC Ocean Sciences Unit and one of the Technical Secretaries for the Session, described the Provisional Programme for the Workshop. He also elaborated on the general terms of reference provided for the Workshop and expected end products.

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* A List of Acronyms is given in Annex V.

3. PRESENTATION OF CONTRIBUTIONS

The List of Contributed Papers appears in Annex III. These contributions, after editing by Drs. A. Yanez-Arancibia and D. Pauly, will be published as a Supplement to the present IOC Workshop Report no. 44.

4. PRELIMINARY CONSIDERATIONS

In order to focus the discussion, it was suggested that Workshop participants briefly separate into small working groups and address various aspects of tropical demersal recruitment along disciplinary or methodological lines; this initial exploration would then form a basis for cutting across these lines at a later stage of the Workshop's deliberations. It was initially suggested that four groups address the following topics: (i) biological processes controlling recruitment variation; (ii) physical processes controlling recruitment variation; (iii) methods for studying recruitment variation in tropical coastal demersal communities; (iv) methods for studying habitat variation (including habitat degradation).

Participants wishing to join in the working groups addressing biological and physical processes expressed the opinion that the interactions between the biological and the physical processes were vital points to be addressed in their deliberations. For this reason it was decided that both groups should convene together, at least initially, to consider whether the separation was appropriate. The consensus of the members was that these interactions were of such importance that attempting a separation along disciplinary lines would restrict the range of discussion, so that important topics would not be covered. The decision therefore was that the two themes would be addressed together by a single group. Each of the three resulting preliminary working groups offered an oral and written summary of their deliberations as follows. The composition of the groups is in Annex IV.

4.1 BIOLOGICAL AND PHYSICAL PROCESSES CONTROLLING RECRUITMENT VARIATION

The working group questioned the idea that there exist some basic differences in factors determining recruitment in the tropical and temperate regions. The consensus was that differences between habitats and taxa within the tropics were at least as great as those between the tropical and temperate zones. In addition, two generalizations were addressed that had been previously expressed with respect to "terms of reference" for the Workshop: (i) that there is a greater degree of separation between juvenile and adult habitats in the tropics compared to higher latitudes; and (ii) that biotic interactions in the tropics are relatively more important. The general validity of these two statements was also called into question. The consensus was that the basic processes determining recruitment were not highly different in the tropics from those found in other regions.

The group then assembled some example lists (Tables I and II, on pages 21 and 22) of biological and environmental processes as a basis for discussion. For convenience the lists were arranged in terms of time scales but it was noted that a corresponding range of space scales was also involved. After the lists were prepared, the participants noted that this arrangement was little different from one that might have been assembled for any region of the globe, except perhaps for some small extension of the time-scale ranges towards slightly higher frequencies. It was also noted that in terms of

large-scale ocean - atmosphere dynamics, the effect of the earth's rotation varies rapidly with respect to latitude in equatorial regions, resulting in large differences in dynamic balances and time scales of response in relatively short meridional distances. Certain dynamic responses (e.g., the time scale required for Ekman transport to constitute a valid description of the response of ocean surface drift to wind variations) become longer near the equator.

In the discussions that followed it was pointed out that strong longitudinal differences occurred in community structure, reproductive strategies and in other factors related to recruitment, in similar habitats at similar latitudes. The interaction of biogeographical factors with local adaptations was cited as a particularly interesting aspect of this type of geographic diversity. However, rather than being a source of difficulty and complexity, this degree of diversity was considered to offer excellent opportunity for application of the comparative scientific method.

It was felt that intra- and inter-regional comparative studies would be particularly useful and revealing if based on logical frameworks where, in at least some cases, the emphasis could be on the relative importance of various effects. Some examples suggested included relative importance of:

(i) physical processes versus biological processes;

(ii) larval processes versus post-settlement processes;

(iii) nearshore processes versus offshore processes (including coupling between the two);

(iv) estuarine-dependence versus non-utilization of estuaries (particularly with similar bottom type and availability of estuaries in each case);

(v) biogeographical factors versus local factors;

(vi) competition versus predation;

(vii) dispersal versus retention.

Other frameworks suggested for comparative studies included:

(i) reaction to perturbation;

(ii) spatial and temporal variation in reproductive dynamics;

(iii) temporal tuning of biology to environmental events.

The discussion revealed consensus on the particular importance of several of the foregoing suggestions. It was felt that in item (ii), the issue of whether the adult population dynamics is determined by post-settlement interactions (as has often been assumed for coral reef environments, but is now being questioned as results of scientific studies become available) or by recruitment variability (as is the case in most studied fish stocks) was one of great scientific importance and interest with respect to tropical demersal recruitment. The "union" of items (iii) and (vii), the general problem area of larval transport and

retention, reflecting the dual need of a species to maintain local populations while providing for colonization of distant habitats, was considered highly important to the recruitment of tropical demersal species problems in general and an ideal opportunity for enlisting the interest of physical oceanographers, in the context of OSLR, in a highly beneficial manner. Finally, the specific question of why in some areas (e.g., the Gulf of Mexico) there is overwhelming dependence on the use of estuarine environments in reproductive strategies, while in others (e.g., the Gulf of Guinea) there is an opposite tendency toward almost total non-use of available estuarine environments by fish populations which reach large biomasses, was considered to be an opportunity to apply the comparative scientific method with excellent prospects of gaining illuminating insights.

4.2 METHODS FOR STUDYING RECRUITMENT VARIATION IN TROPICAL COASTAL DEMERSAL COMMUNITIES

4.2.1 Definition of Recruitment

Essential to the evaluation of methods to be used in the study of recruitment in tropical demersal ecosystems was the development of an adequate working definition of this process. For the purposes of this discussion, a two-level definition was adopted, suitable for the description of recruitment to be exploited as well as to unexploited coastal tropical communities.

Firstly, it was recalled that most animal populations are characterized by a relatively high mortality rate early in the life cycle, which eventually declines to the lower and more predictable rates found in the adult population. The recruitment phase of the life cycle is that period of transition during which organisms begin to experience rates of mortality comparable to those of the adult forms. Larval and juvenile mortality may be reduced to varying degrees in live-bearing demersal species and others where an increased amount of parental care is present. In the case of larval broadcasters a precipitous rate of mortality during an early stage reduces the size of the larval population to a very small fraction of its initial value. Throughout this phase of exponential decay in survival it is impossible to predict accurately the change in biomass or numbers of the population with time. It is the more predictable mortality rate following recruitment which makes this phase interesting to population biologists and ecologists. Recruitment often follows a period of migration, and/or settlement to a benthonic existence. At whatever geographic location, depth, or stage in the life cycle, this primary definition of recruitment marks the age or size at which the transition to adult rates of mortality occurs.

Secondly, recruitment was considered as a change in size, form, food preference, habitat, and/or mobility, associated with the attainment of the adult way of life and a comparable level of autonomy, or susceptibility to fishing gear, competition, and predation. This transition is then specific to a particular phase in the life cycle, habitat, or gear type to which the organisms adapt or become vulnerable (see below).

In this context, there is the special case of derecruitment for stocks exploited in two or more stages of the life cycle, where organisms already constituting a part of an exploited juvenile stock migrate to other fishing grounds or grow to a size where they become

susceptible to methods of capture of a different fishery. Where organisms are short-lived and heavily exploited, and where the yield-per-recruit curve is flat-topped (see below on methods), catch and recruitment become proportional, but this is not the case for long-lived or less heavily fished populations. The key to this concept of recruitment is the identification of a unidirectional relationship which allows the prediction of the size of future adult stocks from a forward projection of recruitment patterns. The size of an egg or larval population is usually not an index of future stock size (and hence yields), but of the size of the parental stock.

Another additional necessary preface to the evaluation of methods for assessment of recruitment variation is the identification of the basic processes involved. The following processes of recruitment requiring methods of quantification and evaluation were outlined. First was the need to look at the timing, intensity, and spatial distribution of the recruitment flux (see e.g., Navaluna and Pauly, in the Supplement to this Report). Second, was the consideration of the timing and intensity of variables which may affect recruitment, such as the number and biomass of the parental stock, variable age at maturity, life-history strategies, survival rates, the occurrence of cannibalism, fecundity and differential egg viability with age. Other biotic variables of concern in the study of recruitment include varying food availability, predation (see Yañez-Arancibia et al., in the Supplement to this Report) and competition for limited resources. The importance of understanding abiotic mechanisms of retention and distribution of potential recruits is also evident, as is the need for the study of other abiotic factors that affect survival and ensure stock integrity (see Bakun and Boehlert in the Supplement to this Report). The group outlined the importance of addressing these critical aspects of recruitment and evaluating adequate methods for the assessment of their variation in tropical coastal demersal ecosystems.

4.2.2 Recruitment to Tropical Fisheries

The criteria traditionally applied to the evaluation of recruitment are also valid in the case of tropical fisheries. Nevertheless, the methods used traditionally may require specific adaptation to special characteristics of the tropical environment, including the existence of protracted periods of reproduction, high diversity, intense competition and predation pressures, and a high incidence of hermaphroditism and other complex life cycles. Consequently, the age or size at recruitment (t_r or l_r) will be a function of the characteristics of the fishery and its fishing gear.

The timing of the different events in the life cycle should be explicitly defined and separately evaluated. Critical periods should be described and represented in a formal manner in order to be incorporated into models of recruitment. For example, the evaluation of the reproductive process might need to take into account the existence of protracted spawning and to evaluate the relative importance of each spawning event.

4.2.3 Methods for the Estimation of Recruitment and Recruitment Fluctuation in Commercial Species

This topic may be split into two basic subheadings: (i) field-based approaches; and (ii) indirect methods of assessment. The

first group includes: monitoring of settlement in reef fishes using SCUBA diving census (see Williams, in the Supplement to this Report); sampling along beaches, in coastal lagoons (see Gracia and Soto, in the Supplement to this Report), etc.; periodic surveying, leading to catch-per-effort-based recruitment indices; market sampling of catch composition data and variants of the basic approaches. The second group includes virtual population analysis (cohort analysis) to obtain either annual recruitment, or estimates of recruitment in subannual units (i.e. months, when the ELEFAN III programme of Pope et al. (Ms) is used). It also includes various forms of seasonal recruitment patterns obtained through detailed analysis of length-frequency data (i.e., using the ELEFAN II programme; see Navaluna and Pauly, in the Supplement to this Report). Under the steady-rate assumption, estimates of recruitment can be obtained by the division of yield by yield-per-recruit, or of biomass by biomass-per-recruit (see Pauly, in Supplement to this Report).

Under certain limiting conditions, the annual catch from a stock can provide a suitable recruitment index. These conditions occur when: (i) the organisms in question have a flat or almost flat yield-per-recruit curve (i.e., the organisms in question must have a high natural mortality and a relatively short lifespan); (ii) fishing mortality producing the catch data used in the analysis remain high, such as in the case of penaeid shrimp. Another example is the oyster fishery on Crassostrea rhizophora along the tropical eastern Atlantic coast. However, it is recommended, whenever possible, to replace catch as a measure of recruitment with estimates of recruitment (R) obtained from R = annual catch/yield per recruit.

In the case of longer-lived species, such as many demersal fishes, size at recruitment can be defined for each type of fishing gear, monitoring relative abundance (CPUE) of this size and analysing its variation in time. A variant of this approach is to monitor overall mean size (which is usually reduced by the entry of recruits), or to use another index which reflects the relative abundance of small organisms in the stock (see Penchaszadeh et al., in the Supplement to this Report). In the case of lagoons and other coastal systems where internal fisheries exist, catch and catch-per-unit-effort (CPUE) data can be adequate indicators of recruitment fluctuation. In some species there may be a direct relationship between CPUE and recruitment. and spawning and recruitment may occur during the same yearly period. In other cases, diphasic data are needed in order to deduce the relationships.

There is a need for methods which define the timing and intensity of recruitment patterns. Studies of population dynamics are suggested as a key factor in the understanding of variation in recruitment. Identification of the principal cohorts, and monitoring of their survival and contribution to the biotic potential of the adult stock are critical to the quantification of variable recruitment. Differences should be noted between populations whose demography is governed by density-dependent and density-independent processes.

4.2.4 Life-history Considerations

The variables affecting recruitment which must be understood include the size, numbers, and mortality rates of organisms as a

function of age, sex-ratio or the proportion of reproductively mature females; and age/size-specific fecundity and egg viability. The methodology required to obtain such information includes catch and field sampling in order to determine size-frequency distributions and mortality rates, tagging experiments, and assessment of fecundity through laboratory and field work. The goal is to identify possible relationships between recruitment and other life-history phenomena in order to be able to predict the population responses to fishing pressure and environmental resistance in tropical ecosystems.

4.2.5 Methodological Considerations in Mathematical Modelling of Tropical Recruitment

Once estimates of recruitment have been obtained for different cases, or for any period of time considered sufficient, analysis of fluctuation of their spatial coherence and temporal structure may proceed, using standard statistical and mathematical methods (i.e., ANOVA, time-series analysis, etc.; see Williams, in the Supplement to this Report). Non-standard approaches to this analysis include the application of system-theory concerned with modelling of continuous dynamic processes. This involves: (i) the use of time-variant distributed delay functions to model time lags usually encountered in recruitment processes; and (ii) the generation of random variables with the appropriate probability density functions to represent the uncertainty of the recruitment processes. Additionally, the use of multivariate analyses is suggested to incorporate as many as possible of the relevant biotic and abiotic variables in recruitment functions.

4.3 METHODS FOR STUDYING HABITAT VARIATION

The following general issues were outlined:

(i) Definition of population processes involved in recruitment.

(ii) Knowledge of life-history aspects: spawning, larval stages, juveniles and fisher stock.

(iii) General habitat distribution (based on natural history).

(iv) Definition of critical habitats relative to life history stages.

(v) Effects of habitat changes (natural, man-made) on recruitment processes.

The term recruitment was interpreted to mean the addition of individuals to the next developmental stage of a given population. Normally, the division of stages would span several habitat uses by spawning stock, larvae, juveniles and adults. Habitat use during all life cycle stages is important to adult stock size and quality; however, one habitat may be more critical to recruitment success than another habitat.

The following generic issues were identified that are related to habitat and recruitment success:

(i) Of those habitats used, which are critical to the fishable stock?

(ii) What are the linkages between and among habitats?

(iii) How do habitat changes affect both habitat use and recruitment?

(iv) What aspects of the habitat-range limit and sustain the population?

Basic information on life history and habitat use need to be examined first, if not coincidentally, with experimental methods to test specific hypotheses associated with the recruitment process. As habitat and life history data become available, the following items should be addressed:

(i) Climatic effects

(ii) Food resources

(iii) Predator-prey interactions

(iv) Intra- and inter-specific competition

(v) Morphological, physiological and behavioral response to habitat changes

(vi) Genetic responses

(vii) Human effects (toxic waste, habitat alteration, over-fishing)

These methods are generally best applied by an interactive and multidisciplinary working group. Obviously, not all methodologies are appropriately applicable to all generic issues for all species.

5. MAIN TOPICS ADDRESSED

Following brief presentations of working groups, the Session was opened for discussion based upon the preliminary considerations. A discussion of the breadth of issues that should be further considered by the Workshop ensued. It was resolved that, while in particular cases it might be desirable to concentrate on processes determining larval survival, any study of factors influencing recruitment should consider all those stages of the life-cycle that might potentially affect recruitment to a fishery.

The Chairman then called for discussion of possible themes appropriate for IREP projects in recruitment of tropical demersal fisheries. Four broad themes emerged from the discussion:

(i) Comparative studies of recruitment in single species or taxa;

(ii) Recruitment in tropical demersal soft-bottom communities;

(iii) Comparative studies of recruitment in hard-bottom (reef) systems;

(iv) Recruitment studies using time series and/or cross-section data including environmental studies and development of methodology.

Working groups were set up to develop these themes in written form. The composition of the four working groups is given in Annex IV.

5.1 COMPARATIVE STUDIES OF RECRUITMENT IN SINGLE SPECIES OR TAXA

The objective of the working group (no. 1) was to identify species or small groups of species of wide interest and suggest how the comparative method could be used to investigate problems of recruitment.

The working group recognized two kinds of problems to which the comparative method might successfully be applied:

(i) to understand recruitment in a species for which a lack of understanding had, or was likely to have, significant economic or ecological importance; and

(ii) to understand a particular process or detail within the general problem of recruitment, however defined.

The working group thought that these two kinds of problems might be successfully resolved during studies of two kinds of species or groups of species:

(i) Single species, or very closely related groups of sibling species, having an unusually wide geographical range, especially where the range encompasses latitudinal and longitudinal differences.

(ii) Single species to be selected as regional examples of a single ecological type.

The working group was of the opinion that it would not be necessary for any taxon selected, within the above criteria, to be equally (or even approximately equally) abundant within the range of areas over which it was to be studied. Under such conditions the differences in abundance might indicate a response to changing environmental factors and be useful to the comparative method.

Though it was aware that selection of species groups in relation to the IREP Minimum Plan which had been carried out at the OSLR/IREP Workshop in Halifax (IOC Workshop Report no. 33), and that it had to some extent covered the same ground, the working group felt that it would be useful to examine possible candidates for study by the comparative method.

Species of Penaeus are widely distributed in the tropics and are of great economic importance there. However, in several cases, recruitment has not been understood as a process. The uncertainties include: reproductive seasons, larval migrations, and the use of coastal lagoons as nursery areas. Such uncertainties also exist for the recruitment of coastal demersal fish. The working group discussed the types of species for which comparative studies might elucidate the difficulties in understanding recruitment. The following families Sciaenidae, Gerridae, Lutjanidae, Carangidae, Ariidae and Pomadasyidae (among others) include species that might be suitable candidates for comparative studies: the working group wished to emphasize that these were listed only as examples, and as examples with which they were familiar. Some suitable genera, such as Cynoscion comprise species that are all rather similar, and the genus has a wide distribution in

all tropical oceans. Others, such as Selene were noted as being widely distributed along the eastern coast of the American continent, yet have similar representatives in the Gulf of Guinea. For some genera, such as Lutjanus, which are comprised of rather similar species morphologically, it might be necessary to examine the individual species ecology before they were selected for inclusion in a comparative study.

The working group recognized that this example list was not at all comprehensive and that, for the fish species they discussed, it was not yet possible to identify any cases where a simply stated problem (of ecological or of economic importance) awaited the application of the comparative method for its solution. They also recognized that there were many groups which their brief discussion did not touch on - the tropical rock-lobsters being a case in point and probably quite a strong candidate for inclusion in a comparative study.

As an example of the kind of study that could be performed usefully in suitable species of fish and invertebrates, the working group discussed one particular example as follows:

Penaeus merguiensis, the banana prawn, shows an apparent mis-match between its two peaks of spawning and peaks of postlarval recruitment in the Gulf of Carpenteria, Australia. Further, in some parts of the Gulf, juvenile emigration and adolescent recruitment are apparently controlled by the timing and amount of a single monsoonal rainfall. The species occurs widely in the Indo-Pacific and, through comparative studies over a wide range of hydro-meteorological regimes, the importance of environmental factors in controlling the timing and magnitude of recruitment and catch will be ascertained. These studies will have management implications for spawning stocks needing to be protected and/or if fishery yield is to be maximized. A somewhat similar problem may occur in Penaeus vannamei, of the eastern tropical Pacific from the Gulf of California to Peru. Off Mexico it also exhibits a dual spawning peak, one of which appears perhaps not to be correlated with the availability of an open lagoon mouth for the entry of larvae. Does such a condition occur everywhere within its range, and could differences explain the situation off Mexico?

The discussions led to two preliminary recommendations:

Recommendation 1 requesting that further examination be made of the possibility of investigating the relationship between tropical penaeid reproductive cycles and seasonal environmental cycles by the comparative method. This would require a preliminary canvassing of tropical prawn biologists as to the soundness of the suggestion; then, if a generally positive response was received, it would be necessary to convene a Prawn Recruitment Project (PREP) Workshop to define the problems with precision, and to reach agreement on an experimental programme that would be scientifically sound and logistically feasible.

Recommendation 2 requesting that several focal areas be identified for consideration for comparative studies of recruitment processes in fish and invertebrates, and that the first focal area be the western Atlantic continental shelf from the Gulf of Mexico south to Brazil. This region has two advantages: it contains an unusual degree

of habitat heterogeneity, and there are many fisheries and marine biological laboratories from end to end of the area to serve as loci for individual studies. The working group was of the opinion that a detailed discussion, probably in the form of an IREP Workshop, should serve to identify suitable species and problems as candidates from among which a selection of one could be made to form a Western Atlantic Recruitment Project (WARP). Like the penaeid proposal, such a Workshop would have the best chance of success if guided by a small group and with adequate possibilities for advance correspondence to select a preliminary listing of problems already identified as standing in the way of fishery management, and which might be solved by the application of the comparative method.

5.2 RECRUITMENT IN TROPICAL DEMERSAL SOFT BOTTOM COMMUNITIES

Working group no. 2 was assigned the task of developing project outlines on recruitment in tropical demersal soft-bottom communities. Five questions considered important to address and feasible to answer were developed. The suggested project outlines to address these questions vary geographically with methods applied to answer them, duration and effort. They are all concerned with factors limiting recruitment success and require sampling among several coastal areas. A separate paragraph for each question briefly outlines: (i) why the question is important; (ii) how to address the question; and (iii) the expected results.

Question 1: Which habitats are used and which are critical?

Tropical areas present a great diversity of habitats which are often, but not always, used as reproduction, feeding, and nursery grounds. The presence of estuaries and coastal lagoons is required for recruitment of numerous commercial species captured on the continental shelf. Coastal vegetation (sea grasses, mangroves, etc.) is considered particularly important, but there is great variety in type and amount amongst estuaries. This variety is determined in part by the physics of the intertidal zone, and affects the kind of fisheries through indirect or direct effect of these systems on juvenile recruitment. Not all estuarine habitats are equally critical to a species and not all coastal species are estuarine-dependent. But distinguishing between use and non-use, and between mere use and critical dependence, is not clearly accomplished for most coastal stocks.

It is recommended that comparative studies be undertaken in typical ecosystems such as the Gulf of Mexico to consider qualitative relationships of distribution, life history patterns, food resource use and competition in space and time. It is also recommended that the utilization of experimental, natural and man-made habitat changes could help to determine species habitat utilization.

These studies would evaluate the way in which these habitats are used and which ones are critical for tropical demersal species.

Question 2: Is recruitment food, space or predator limited?

Predation and competition for food and space are generally supposed to be factors of great importance in highly diverse tropical demersal communities. However, their quantitative role in tropical soft-bottom communities has never been assessed. Presumably they act

mainly on the freshly settled bottom stages of fish and invertebrates and on juveniles, and thus determine structure and productivity of the community at an early stage.

Traditional approaches like the study of gut contents are useful to determine the main trophic flows in a community (e.g., selection of prey from a wide choice), but they cannot clarify the mechanisms that structure demersal communities. Laboratory studies, on the other hand, while offering controlled conditions, greatly change the environmental framework and may simplify interactions to a degree that they no longer resemble those in the real world. The solution could be manipulation experiments in situ where species/numbers/size groups of predators can be removed from enclosures or cages, and where the impact of these predators (or of their removal) on recruits and juveniles of prey species can be assessed quantitatively. Similar experimental designs, always in different habitats and preferably over a wide geographical range, can be applied for perturbation manipulations (e.g., effects of oil and dispersants on the fauna) and for changing habitat complexity (e.g., adding and removing vegetation). The latter approach would also allow assessment of the role of space versus predation and competition for food.

The experiments need not be complex, but do require a thoughtful design and analysis, to avoid major artifacts, and then follow-up of the results. Techniques are available at most laboratories and can be supplemented with more sophisticated techniques available at laboratories that have formerly carried out these experiments. There are many suitable sites for this kind of studies in the Gulf of Mexico and throughout the tropics.

Question 3: What is the mechanism underlying the widespread relationship between fishery yield and river discharge?

Year-to-year and broad geographical differences in catches of estuarine-dependent tropical demersal fishes have been statistically related to river discharge in many areas. It is important to understand the mechanisms underlying this widespread relationship because of the impact of coastal development on river discharge quantity and quality. Several explanations for the relationship have been proposed and each implies very different management strategies. The following three are considered to be the most important: (i) high river discharge creates stronger reverse-flow bottom currents resulting in either more demersal larvae entering the estuary, or increased survival because the period of larval drift is shorter because of faster entry into the estuary; (ii) the freshwater discharge controls the amount of habitat suitable for a nursery area; and (iii) river discharge stimulates the productivity of nursery areas resulting in increased larval fish survival because of increased food availability. The determination of the relative importance of these three hypotheses requires a multidisciplinary approach.

Three general approaches can be used: (i) comparisons between several similar estuaries with different river-discharge characteristics, or different extents of nursery grounds and similar river discharge; (ii) between-year comparisons of a single estuary; or (iii) manipulation of sub-sections of the nursery ground.

Comparison of several estuaries in conjunction with manipulation of subsections may result in the most information in the shortest time. This study requires: (i) estuaries with river discharge; (ii) an estuarine-dependent fishery which has shown the river-discharge relationship; and (iii) fishery data for comparison of river discharge during the study of recruitment. Although there are many areas in the tropics that have these characteristics, the shrimp and sciaenid fisheries of the southern Gulf of Mexico are particularly well suited to this study. The reasons for this are: (i) the river-discharge/fish-yield relationship is well established; (ii) historical background of river discharge and fishery data is available; (iii) fish-catch data are available; (iv) a wide range of estuaries with different river discharge and nursery areas can be found within a relatively small geographical range; and (v) there are several marine research stations located on or near suitable study sites. It is recognized that there may be other suitable areas. This area is recommended because the participants are more familiar with it.

The following experiments are suggested to test the three general approaches mentioned above:

(i) Hydrodynamic transport measurement of larval and juvenile abundances on a transect from the shelf to within the estuary at different depths; simultaneous measurement of water currents in the estuarine mouth, offshore, and at the nursery grounds; application of a three dimensional hydrodynamic model to estimate larval transport and development of stratified bottom flow; use of otoliths to determine whether the length of larval drift period decreases with increased river flow.

(ii) Amount of suitable nursery habitat, based on physico-chemical characteristics using satellite imagery of sediment plume or temperature and water-quality measurements (salinity, temperature, nutrients) to determine extent of habitat changes.

(iii) Stimulation of productivity of nursery habitats through: (a) measuring productivity of habitat related to nutrient input from river discharge; (b) estimating mortality and growth of larvae and juveniles using length-frequency distributions or otoliths; (c) adding nutrients to nursery areas (i.e., fertilizing an open sea-grass bed) and measuring fish abundance, growth, and mortality.

It is recognized that a complete study in several locations would be a large-scale project. However, many parts are based on relatively simple measurements which could yield valuable information if measured by themselves. In this manner, limited projects in a variety of locations could contribute to the overall goals of the project. The results from these studies can be coupled with information on recruitment from the fishery data to produce a multi-dimensional model which will replace the single-factor model relating fishery yield to river discharge.

Question 4: Are tropical juveniles highly food selective and are food resources stable?

Question 4 addresses how well juveniles adapt to changing conditions in the tropics. First, tropical species may not have capacity to adapt to changing food resources as well evolved as

temperate species, since the tropics are relatively more stable. Second, demersal food resource communities likewise may not have the ability to recover from stresses with which they did not evolve (dredging, land-use changes, eutrophication, pollution). If high food selectivity of the predator and low recovery rates of the prey (the benthos) occur together, then recruitment is surely affected and small changes in habitat will have a disproportionately large impact. These ideas have not been scientifically tested but are commonly suggested to occur in the tropics.

The suggested methods to address the question include both traditional and more sophisticated approaches (e.g., the use of "virgin" substrate for the study of colonization and succession) and should be applied in several estuaries over a wide range of latitude, tidal range, and sediment type.

Question 5: What is the effect of bottom trawling and by-catch on recruitment?

Tropical soft-bottom communities are disturbed by bottom trawling gear. This implies the loss of pre-recruits to the fishable stocks, as well as physical disturbances to the fish habitat. The loss of pre-recruits has been widely discussed. The mortality of juveniles due to the by-catch can be assessed and compared to natural mortality.

The impact of discharged by-catch also poses questions about its impact on the ecology of soft-bottom communities. The latter could mean: changes in the food availability of some species, alteration of the predator-prey interactions and the relocation of nutrients from the biomass of benthic organisms.

Bottom-trawl fishing is intensive over many tropical shallow-water communities and may act as a driving force to control recruitment of juveniles into the fishable stocks. If this is the case, the assessment of the magnitude of this process on a comparative basis could help set priorities in the management options of the fishery in order to predict fishery yields. These studies should be undertaken in a fishing ground heavily subject to bottom trawling, where there would be evidence of pre-recruit mortality due to fishing activity.

The five questions are ranked below in order of their overall significance to understanding recruitment in soft-bottom demersal communities (1 = high, 3 = low). Having high significance does not necessarily imply that the question can be answered. They have therefore also been ranked in terms of scientific feasibility (1 = highly feasible, 3 = possible but not easy) and in terms of the scale of the study. Funding levels are not addressed since they are beyond the scope of this study.

QUESTION AND RANK		IMPORTANCE	FEASIBILITY	SCALE
1. Habitat use	a *	2	2	medium-large
	b	1	2	
	all	1		
2. Food/predator	a	1-2	2	
	b	1	1	many localities
	all	1		
3. River discharge	a	2	1	
	b	2	1	
	c	1	2	ecosystem
	d	1	1	
	e	2	1	
	all	1		
4. Food choice	a	1	2	
	b	3	1	many localities
	all	2		
5. By-catch	a	2	1	
	b	2	2-3	many localities
	c	3	2	
	all	2	2	

* For sub-items, see Table III on page 23.

5.3 COMPARATIVE STUDIES OF RECRUITMENT IN HARD BOTTOM (REEF) SYSTEMS

Working group no. 3 addressed the issues before it under the following headings:

(i) Objective

Although many studies have been conducted on coral-reef and island ecosystems, few studies have comprehensively covered long-term variability in physical or biotic factors. In particular, variability in recruitment or year-class strength of tropical islands has not been described, but to refer to what is known, a recent paper by Munro and Williams (1985), cited in William's paper in the Supplement to this Report, summarizes much of the available information. The working group recommended studies of multispecies recruitment variability in tropical reef, bank, and island ecosystems, especially those in fauna associated with hard bottoms. The aim is to stress comparative studies that may be conducted in a variety of such areas. It was decided to express the proposed project in the light of physical and biological factors considered by the relevant preliminary working group reports and within the framework of OSLR/IREP objectives, and, to this end, stress the role of retention mechanisms and their variability in the recruitment of reef, bank, and island ecosystems.

(ii) Proposed Research Project

The following project considers mechanisms of recruitment by addressing two major issues recommended by the sessional working group on Biological and Physical Processes. The first

of these issues is the recommendation that, in recruitment, distinction should be made between the effects of pre- and post-settlement phenomena. The second is that the linkages of nearshore and offshore processes should be addressed. The project has been accordingly divided into categories based on pre- and post-settlement approaches with the linkages considered within each section.

a) Pre-settlement Studies

The first step in the proposed study is to develop conceptual but site-specific models of physical retention mechanisms pertinent to the island or bank system to be considered. The types of retention mechanisms might include eddies, Taylor columns, or other topographically trapped hydrodynamic structures as discussed in Bakun's paper in the Supplement to this Report. Within each specific model, the different retention mechanisms should be evaluated as a function of the following:

- latitude
- ocean current flow and eddy fields
- island or bank size, geomorphology, and local bathymetry
- vertical stratification
- tidal factors
- seasonal variability

The goal of this exercise is to predict the spatial and temporal stability of potential retention mechanisms for each system to be studied.

The second step in the project would be to initiate field sampling to address physical and biological factors in the offshore and nearshore environments. The physical study should be carefully designed by physical oceanographers to test the predictions of the conceptual model and should concentrate on mesoscale phenomena in the bank or island regions. The group did not recommend specific work in this study other than stressing the full application of remote sensing, including thermal imagery, ocean-colour imagery, and, wnen available, satellite altimetry, to allow larger-scale applications of results of this study to other systems.

Biological sampling for pre-settlement stages should proceed concurrently with the physical sampling. The goal of the sampling should be to evaluate the use of potential retention mechanisms by larvae. Studies of the distribution of early larvae should be conducted on a horizontal basis only as necessary to delineate distribution around the bank or island and the onshore- offshore pattern. Special attention and effort should be paid to vertical distribution pattern of larvae in the region where larvae are retained or where the potential retention mechanisms would be suspected to maintain the larvae. Further sampling for late pre-recruit stages should also be conducted using available gear, including large midwater trawls or light traps for larval forms. As with the larval sampling, this should be done to assess the temporal and spatial distribution relative to retention mechanisms and relative to later onshore recruitment. A second purpose of this sampling would be to capture and rear late-stage larvae

for taxonomic purposes. Many unidentified forms will transform rapidly if placed in a tank and these stages may then be identified.

Information on pre-settlement stages may also be gained from post-settlement stages via daily growth increments. Recruitment marks as used by Victor and others (cited by Boehler in the Supplement to this Report) can allow determination of the length of larval life. From this the relationship of the length of larval life in different island or bank systems to the temporal stability of retention mechanisms can be learned.

Further sampling in the offshore habitat would involve other biological factors. Studies of larval prey and predators, while not recommended as an integral part of this study, could be considered here. Preliminary work associated with the above-mentioned plankton sampling could help to answer the questions "do retention mechanisms enhance productivity and thereby larval prey density?" and, conversely, "do retention mechanisms aggregate predators of larval fishes?". This knowledge could not only lead to the design of future studies on larval prey and predators, but also could provide hypotheses for alternate causes of interannual fluctuations in recruitment strength.

Questions concerning reproductive strategy can also be addressed, namely, about the placement of reproductive products. Johannes hypothesized that adults of some species spawn in locations and seasons that maximize the probability that eggs and larvae are placed in eddies or other retention mechanisms. The proposed study could test this hypothesis.

b) Post-settlement Studies

Several components of sampling of recruits onshore would be directly related to the pre-settlement sampling described above and in fact should be temporarily associated with that sampling. First, on a spatial basis, recruitment should be studied to assess the locations where new recruits settle and the relationship with the distribution patterns of early and late larvae and with potential retention mechanisms. The manner in which recruits are redistributed on the island or reef system during early development should be studied, paying particular attention to movement to other habitats, including sand flats, seagrass beds, and other reef areas besides those where the initial recruitment occurs. Such studies could increase our understanding of the patterns of community structure and adult distribution. On a temporal basis, timing of recruitment should be studied relative to spawning, location and intensity of the retention mechanism, length of larval life, and seasonality. Further, if the experiment were conducted over several years, the cohorts could be followed and, after an appropriate time, sampled to assess age structure and thereby show the relationship between recruitment strength to the reef and ultimate year-class strength. This latter approach could allow the importance of post-settlement mortality to be determined.

The above work should take advantage of the multispecies nature of tropical fish communities by studying the assemblage of species with pelagic eggs and larvae. Differences clearly exist between species and the distributional differences noted may allow inferences about the behaviours used in population maintenance to be made. Particular attention, however, should be paid to those species with sufficient abundance in the pelagic environment to allow conclusions to be drawn regarding use of retention areas. In the case of this work, such species may serve as models of a variety fishes with pelagic eggs and larvae.

Two other areas concerning interannual variability in recruitment strength of commercially important species deserve mention. The working group discussed the fact that few data of this kind exist for tropical ecosystems. It was suggested that an artificial time series could be developed by intensively sampling a fish species which is relatively long-lived and also which may be aged. Sufficient samples should be taken to determine the age at first recruitment and the population age structure. This would allow estimates of year-class strength for a given population, and such data could be compared with other islands or populations to consider coherence in the strong or weak year classes. This approach would allow valid comparisons between islands. This line of investigation could be continued through large-scale regional studies on commercially important species with broad geographic distributions. This work, as proposed in Group I, could not only serve a temporal function (initiating a time series), but could also serve an important spatial function, namely that of showing coherence or lack thereof in recruitment strength among regions or islands. The spatial component of this work could be used to evaluate the existence of local retention mechanisms as proposed in Bakun (in the Supplement to this Report). The group pointed out spiny and rock lobsters as examples of widespread species where such an approach could be tested. It was also suggested that common methodology be developed to maximize the comparability of results.

(iii) Conclusions

The work recommended above is obviously large in scale and intensity; it is therefore unlikely that the full project could be carried out at many locations. It is suggested, however, that many components of the project are useful by themselves. Thus, conducting portions of the research in a variety of locations to provide a comparative approach is encouraged. Remote sensing, for example, could be used to examine a wide range of areas simultaneously. In this manner, limited projects utilizing regional expertise will help to achieve the overall goals of the project.

5.4 RECRUITMENT STUDIES USING TIME SERIES AND/OR CROSS-SECTION DATA INCLUDING ENVIRONMENTAL STUDIES AND DEVELOPMENT OF METHODOLOGY

The working group no. 4 considered this topic under the following headings:

(i) Necessary Conditions for this Project

a) Involvement of an important multispecies fishery based on shrimp and incidental fish species; the project should also include recruitment interactions between the coastal and offshore environments.

b) Availability of a data base on catch composition, stock structure and environmental factors.

c) On-going research in countries involved, with a stated interest in international and interinstitutional (within country) co-operation, including sharing of data.

d) Willingness to commit resources to substantive modelling efforts including:

- application of existing models with their corresponding software; and

- development of new approaches for model building dealing with recruitment processes.

(ii) Project Setting

The working group felt that regions such as IOCARIBE, WESTPAC or the central eastern Pacific, may constitute an appropriate setting to implement such a project, involving a number of countries and institutions within these regions, dealing with tropical fishery recruitment problems.

(iii) Technical and Logistical Requirements

A number of major technical and logistical requirements need to be taken into account in order to make this international effort operational. Among them, the working group identified the following:

a) It will be required to set up a group to identify:

- Standard methods for data retrieval and analysis; and appropriate software to deal with data management and modelling;

- Procedures for analysing data stemming from different research groups; hardware selection and the corresponding operating system are needed to handle different data bases and modelling efforts.

b) It was recognized that interface information would need to be defined in order to enable the linking of information produced by different groups.

c) A research group and/or agency is needed to co-ordinate the project as a whole.

(iv) Expected Results

The working group discussed a number of goals to be achieved as a result of this international research effort. The following were identified:

a) To predict recruitment to the shrimp and associated fish stock under different biological and environmental conditions such that optimal exploitation strategies can be designed.

b) To enhance national capabilities to conduct comprehensive research programmes.

c) To identify implementable conservation strategies for coastal ecosystems important for the recruitment of tropical demersal communities.

d) To foster knowledge transfer among participating individuals and institutions.

(v) Recommendations

The working group recommended that, during the IOC Symposium on Marine Science in the Western Pacific (Townsville, Australia, 1-6 December 1986), a group of interested scientists consider the possibility of further developing the project proposal outlined above and consider its implementation in this region.

The working group recommended that the IOC Sub-Commission for IOCARIBE, at its Second Session (Havana, Cuba, 8-13 December 1986), take the necessary action to further develop the project proposal outlined above and consider its implementation in this region.

6. WORKSHOP RECOMMENDATIONS

6.1 SUMMARY RECOMMENDATIONS OF WORKING GROUPS

Working group no. 1:

That comparative studies of recruitment of single species or taxa be developed as follows:

(i) consideration of the feasibility of a programme to examine the relationship between environmental cycles and reproductive and recruitment dynamics of tropical penaeids should be pursued in some appropriate forum.

(ii) several focal areas should be identified as appropriate for comparative studies of recruitment processes; it is suggested that the first focal area should be the western Atlantic coast from the Gulf of Mexico to northern Brazil.

Working group no. 2:

Studies of recruitment of soft-bottom communities should be formulated from among the following:

(i) comparative studies of use or non-use of estuaries by similar species complexes.

(ii) studies of food or predator limitation of recruitment.

(iii) studies of the relationship of river discharge to yield.

(iv) studies of juvenile food specificity.

(v) studies of the effects of gear and by-catch on recruitment.

Working group no. 3:

Comparative recruitment studies in hard-bottom (reef) systems should be developed, concentrating on effects of physical retention mechanisms on the pre-settlement stage and the significance of these effects on reef-population dynamics.

Working group no. 4:

Recruitment studies using available time series of data and/or cross-section data appear to offer a useful and cost-effective approach.

Consideration of the development and implementation of this approach should be recommended to appropriate subsidiary bodies of the IOC Sub-Commission for IOCARIBE, and the IOC Programme Group for the Western Pacific.

6.2 GENERAL RECOMMENDATIONS

(i) Incorporation of the broadest spectrum of marine science specialties be pursued in IREP projects on tropical demersal systems.

(ii) A substantial Training, Education and Mutual Assistance (TEMA) component should be incorporated in all IREP projects addressing tropical demersal systems. This should include standardization of methods among and within regions.

7. CLOSURE

In closing the Session, the Chairman of the Workshop, the IOC Senior Assistant Secretary and the Chairman of the Guiding Group of Experts on the OSLR Programme commended the excellent facilities and hospitality provided by the Instituto de Ciencias del Mar y Limnologia (UNAM) and its Estacion "El Carmen", as well as by the Instituto Nacional de la Pesca - Secretaria de Pesca, for the fruitful development of the meeting. Mention was made, in particular, of the enthusiastic support provided by the two Spanish Rapporteurs, the English Rapporteur and many other young scientists from the Estacion "El Carmen", ICML/UNAM-Mexico City and the Instituto Nacional de la Pesca. The active participation of all attendees, contributors and observers alike, especially the co-ordinators of the different working groups, was highly commended

The Workshop was closed at 15.35 on 25 April 1986.

Table I. Biological Processes

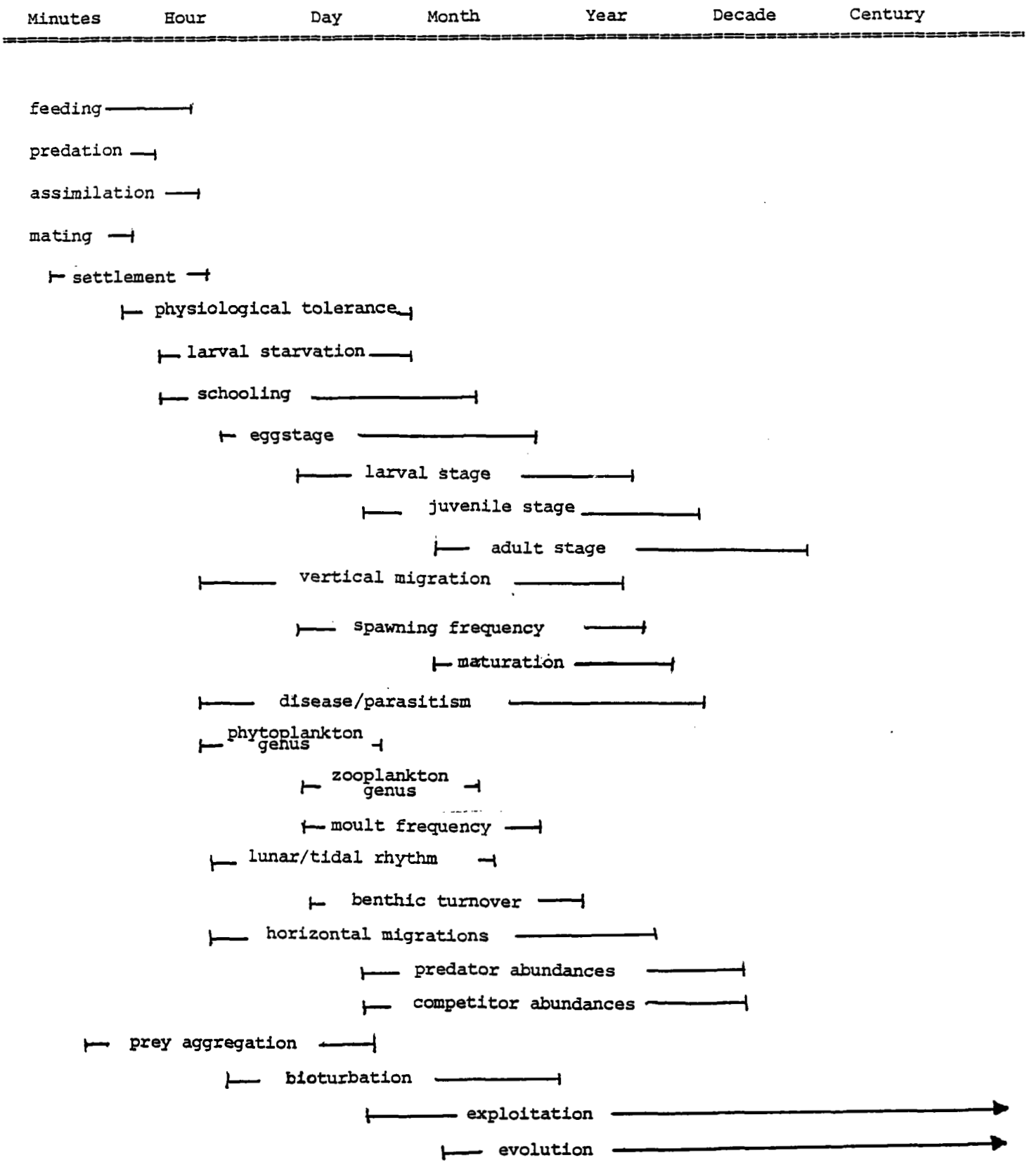
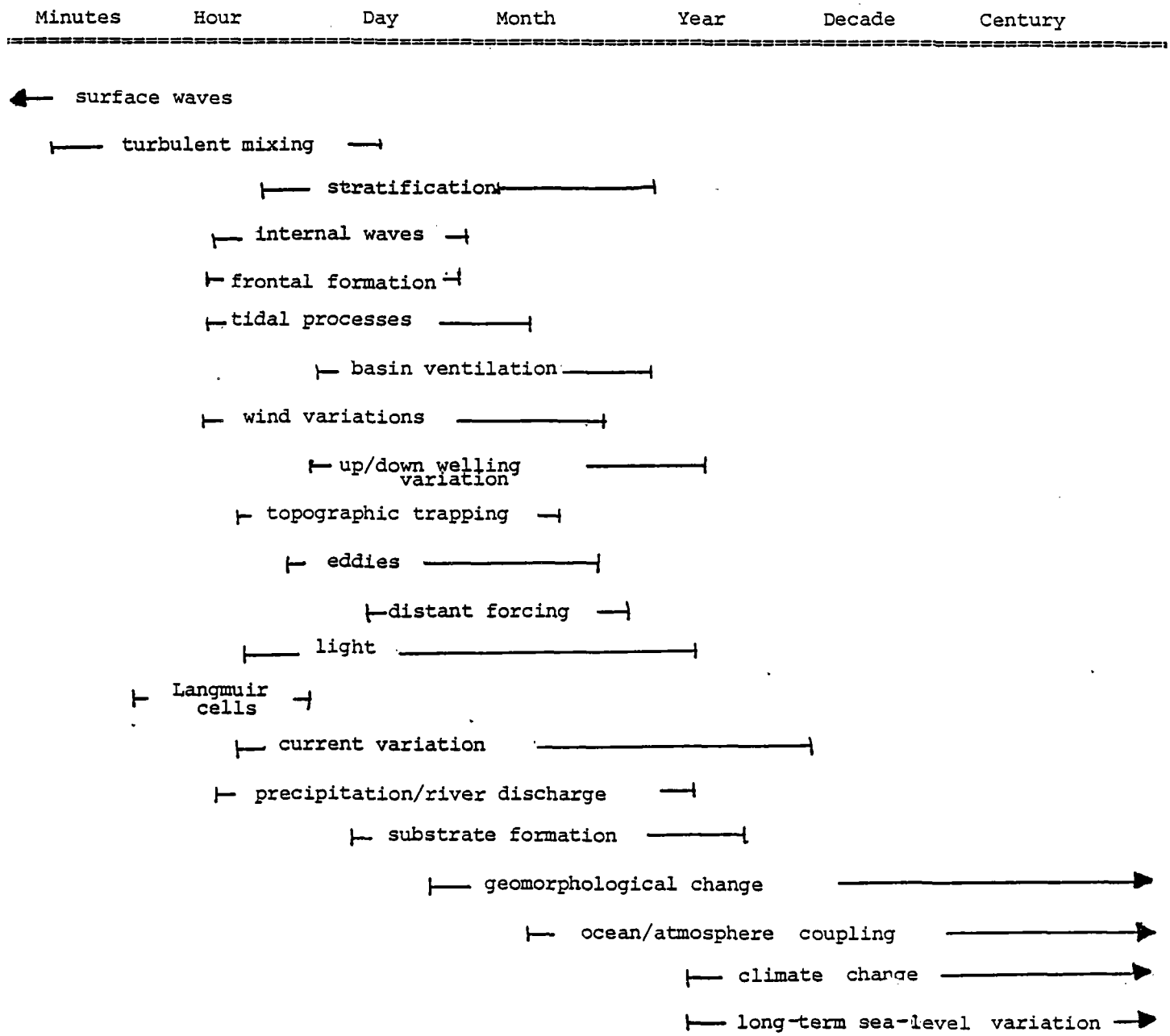


Table II. Environmental Processes



Environmental properties

Temperature
Salinity
Oxygen
Nutrients
Turbidity
Coastal configuration
Substrate type
Vegetation

Table III

QUESTION/hypothesis (in order of importance)	APPROACH
1. Which habitats are used and which are critical?	
a) Of those species using estuaries, how does recruitment occur?	i) Comparative: qualitative and quantitative distribution, life history patterns, food resource use and competition studies.
b) Of the species not using estuaries, how does recruitment occur?	ii) Experimental: using natural and man-made habitat changes to determine species response in habitat use/non-use; experimental manipulations of habitat through substrate changes, vegetation alterations, etc.
2. Is recruitment food, space or predator limited?	i) Predator-prey exclosure/inclosure experiment in different habitats.
a) What is the quantitative significance of predation/ competition on early stages of fish and vertebrates?	ii) Gut content analysis in different habitats.
b) What is the role of vegetative structure on predation and is it more important than food resources?	iii) Chemical analysis for food use (e.g. multiple isotopic analysis, fatty acid, and antibody studies).
	iv) perturbation manipulation: add detritus, remove/add structure, artificial substrates.
3. What is the mechanism underlying the widespread relationship between fisheries yield and river discharge ?	i) Study all hypotheses simultaneously in one coastal area for three years.
a) Increased primary production.	ii) Compare similar river systems for one year in one region.
b) Increased available habitat.	iii) Use captains' log books to discern catch location changes.
c) Dynamic distribution of larvae/juveniles due to transport changes.	iv) Larval hydrodynamic transport + larval abundance - shelf to estuary.
d) Mortality due to predator interactions.	v) Map extent of nursery grounds.
e) Catchability.	vi) Measure productivity in response to nutrient addition.
	vii) Compare estuarine conditions to recruitment.
4. Are tropical juveniles very food selective and are food resources stable?	i) Laboratory studies on food selection.
	ii) Stomach content in conjunction with natural food resources.
a) If tropical juveniles are more food specific, then what are the effects of changes in food resources on recruitment?	iii) Benthic recovery experiments / Sequence and rates / for food resources used by juveniles/larvae (artificial substratres; field studies along stress gradients).
b) Do food resources in the tropics recover more quickly from stress?	iv) Geographic comparisons of similar taxa (e.g. food use of croakers around the Gulf of Mexico).
5. What is the effect of bottom trawling and by-catch on recruitment?	i) Gear effect studies on benthic food organisms and the physical, chemical and biology of the benthos.
a) Mortality of juveniles is what amount and what percent of total mortality?	ii) Model biomass by-catch effects.
b) What is the effect of gear perturbation on nursery ground quality?	iii) Measure by-catch mortality.
c) What are the impacts of by-catch disposal on the physical and community structure of nursery spawning grounds?	iv) Site-specific study of by-catch disposal.

ANNEX I

TERMS OF REFERENCE FOR THE WORKSHOP

(i) To evaluate reported cases of biotic interactions suggesting a "biotic control" of recruitment in tropical coastal demersal communities.

(ii) To evaluate environmental factors suggesting a "physical control" of recruitment in these communities.

(iii) To evaluate the role of "man-made perturbation" of the coastal environment in recruitment of tropical coastal demersal resources.

(iv) To examine in detail length-based methods that have recently become available as to their suitability to estimate vital statistics in tropical demersal communities, with emphasis on recruitment-related information.

(v) To suggest cost-effective ways by which juveniles can be sampled quantitatively in the inshore habitat (i.e., marshes, lagoon estuarine environment, sea-grass beds, mangroves). To test whether the critical features of SARP-type components (daily age distribution of juveniles, batch fecundity and spawning frequency) are applicable to tropical coastal demersal fish.

(vi) To identify analogues for comparative studies in tropical coastal demersal communities (i.e., identification of areas with comparable communities throughout the intertropical belt).

ANNEX II

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ANNEX III

LIST OF CONTRIBUTED PAPERS

General Concepts

PAULY, D. Towards appropriate concepts and methodologies for the study of recruitment in tropical demersal communities.

Hacia conceptos apropiados y metodologías para el estudio de reclutamiento en comunidades demersales tropicales

BAKUN, A. Local retention of pelagic larvae in tropical demersal reef/bank systems: the role of vertically structured hydrodynamic processes.

Retención local de larvas pelágicas en sistemas de arrecifes/bancos demersales tropicales: el papel de los procesos hidrodinámicos verticalmente estructurados.

BOEHLERT, G.W.
An approach to recruitment research in insular ecosystems.

Sugerencias para investigar el reclutamiento en ecosistemas de islas.

DEEGAN, L. Coastal fishery habitat requirements.

Requerimientos de habitat de pesquerías costeras.

SOBERON-CHAVEZ, G., A. YAÑEZ-ARANCIBIA, P. SANCHEZ-GIL, J.W: DAY Jr. y L.A. DEEGAN
Relaciones entre características físicas y biológicas y reclutamiento en ecosistemas costeros tropicales.

Relationships between physical and biological characteristics and recruitment in tropical coastal ecosystems

YAÑEZ-ARANCIBIA, A.L. LARA-DOMINGUEZ, A. AGUIRRE LEON and S. DIAZ RUIZ

Feeding ecology of tropical estuarine fishes in relation to recruitment processes.

Ecología de los hábitos alimentarios de peces estuarinos tropicales y su relación con procesos de reclutamiento.

CHAVEZ, E. y F. ARREGUIN

Un método alternativo para la evaluación de poblaciones pesqueras (Sólo resúmen).

An alternative method for stock assessment (Abstract only).

Area - Specific Studies

ALVAREZ-LEON, R.	Aspectos sobre el Reclutamiento de los recursos demersales en las costas colombianas. Aspects of the recruitment of demersal resources off the Colombian coasts.
BAISRE, J.A.	Consideraciones sobre la estrategia reproductora y el reclutamiento en poblaciones de recursos pesqueros tropicales. Considerations on reproductive strategies and recruitment in populations of tropical fishery resources.
CAMPOS, J.	Reclutamiento en recursos demersales de importancia comercial en Costa Rica: estudios preliminares. Recruitment to demersal resources of economic importance in Costa Rica: preliminary studies.
CHAO, N.L.	Lagoa dos Patos as a nursery ground for shore fishes off Southern Brazil. Laguna dos Patos como área de crianza para peces costeros del Sur de Brasil.
LIVINGSTON, R.J.	Ecological processes of recruitment in coastal epibenthic macrobiota. Procesos ecológicos de reclutamiento en macrobiota epibéntica costera.
NAVALUNA, N.A. and D. PAULY	Seasonality in the recruitment of Philippine fishes as related to monsoon wind patterns. Estacionalidad en el reclutamiento de peces de Filipinas relacionado al patrón de vientos monsones.
NOVOA, D.F. y F. CERVIGON	Resultados de los muestreos de fondo en el área del delta del Orinoco. Results of bottom sampling in the estuarine zone of the Orinoco delta.
PENCHASZADEH, P.E., J.J. SALAYA, R. MOLINET y O. DEFEO	Aspectos del reclutamiento en comunidades demersales en Golfo Triste, Venezuela. Aspects of the recruitment to the demersal communities of Gulf Triste, Venezuela.

SANCHEZ-GIL, P. y A. YAÑEZ-ARANCIBIA

Discusión sobre relaciones de reclutamiento de los peces marinos dominantes del sur del Golfo de México en sistemas lagunares-estuarinos.

A discussion of the factors affecting recruitment of dominant marine fishes from the southern Gulf of Mexico in lagoon-estuarine systems.

WILLIAMS, D. McB.

Spatial and temporal scales of processes determining recruitment of fishes on the Great Barrier Reef: a preliminary analysis.

Escalas espaciales y temporales de procesos que determinan el reclutamiento de peces en la Gran Barrera de Arrecifes de Coral: un análisis preliminar.

Studies on Selected Species (Groups)

ROTHLISBERG, P., D. STAPLES and B.J. HILL

Recruitment of penaeid prawns in tropical Australia.

Reclutamiento de camarones peneidos en Australia tropical.

MACIAS-REGALADO, E.

Procesos de reclutamiento en camarones peneidos del Pacífico mexicano.

Recruitment processes in penaeid shrimps from the Pacific Coast of Mexico.

GRACIA, A. y L.A. SOTO

Condiciones de reclutamiento de las poblaciones de camarones peneidos en un sistema lagunar-marino tropical: Laguna de Términos y Banco de Campeche.

Aspects of the recruitment of the population of penaeid shrimps in a tropical lagoon-marine system: Terminos Lagoon and Campeche Bank.

TURNER, R.E.

Relationships between coastal wetland, climate and shrimp yields.

Relaciones entre pantanos costeros, clima y capturas de camarones.

PAULY, D. and J. INGLES

The relationships between shrimp yields and intertidal vegetation (mangroves) area: a reassessment.

Las relaciones entre capturas de camarones y áreas de vegetación intermareal (manglares): un nuevo enfoque.

D'CROZ, L., J. del ROSARIO y R. HOLNESS

Contribución de nutrientes de un manglar de la Bahia de Panamá. (sólo resumen).

Nutrient contribution by a mangrove in Panama Bay (Abstract only).

LARA-DOMINGUEZ, A. L. y A. YAÑEZ-ARANCIBIA	Reclutamiento en bagres marinos tropicales. Recruitment in tropical sea catfish.
MUSICK, J.A.	Seasonal recruitment of subtropical sharks off Chesapeake Bight, USA. Reclutamiento estacional de tiburones subtropicales en la Bahía de Chesapeake, EUA.

ANNEX IV

WORKING GROUPS

1. Comparative Studies of Recruitment of Single Species or Taxa

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2. Recruitment in Tropical Demersal Soft Bottom Communities

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3. Comparative Studies of Recruitment in Hard Bootom (Reef) Systems

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4. Recruitment Studies using Time Series and/or Cross Section Data including Environmental Studies and Development of Methodology

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ANNEX V

LIST OF ACRONYMS

ANOVA	Analysis of Variance
CPUE	Catch per unit effort
FAO	Food and Agriculture Organization of the United Nations
ICML	Instituto de Ciencias del Mar y Limnologia
IOC	Intergovernmental Oceanographic Commission
IOCARIBE	IOC Sub-Commission for the Caribbean and Adjacent Regions
IREP	International Recruitment Experiment
JOA	Joint Oceanographic Assembly
OSLR	Ocean Science and Living Resources
PREP	Prawn Recruitment Project
SCUBA	Self-contained Underwater Breathing Appratus
TEMA	Training, Education and Mutual Assistance in the Marine Sciences
TRODERP	Tropical Demersal Recruitment Project
UNAM	Instituto de Ciencias del Mar y Limnologia, Mexico
WARP	Western Atlantic Recruitment Project
WESTPAC	IOC Programme Group for the Western Pacific

No.	Title	Publishing Body	Languages
32 Suppl.	Papers submitted to the 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 Paris, 27 September-1 October 1982	IOC, Unesco Place de Fontenoy Paris, France	English
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife, 12-17 December 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36	IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36 Suppl.	Papers submitted to the IOC-FAO Workshop on Inproved Uses of Research Vessels Lisbon, 28 May-2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37	IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40	IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29-31 July 1985 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) Dakar, Senegal, 28 October - 1 November 1985 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
42	IOC/UNEP Intercalibration Workshop on Dissolved/Dispersed Hydrocarbons in Seawater Bermuda, USA, 3-14 December 1984 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean Venice, Italy, 23-25 October 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
44	IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English