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ANNEX VIII

WORKING GROUP 67

OCEANOGRAPHY, MARINE ECOLOGY AND LIVING RESOURCES

Report prepared for the IOC

SUMMARY AND 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 feasibility 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.

BACKGROUND

Marine fisheries have changed dramatically in recent years. World fish landings increased from 19 million tons in 1950 to 61 million tons in 1980, and the expected rate of growth of the world population indicates that there will be continuous pressure to increase fish catches. Technological improvements and innovations in fishing gear, fish finding and capture techniques, fishing vessels, and fish processing equipment have greatly increased the ability to catch fish throughout the ocean. While overfishing was an actual or potential problem in merely a few limited areas a couple of decades ago, the capabilities for increased harvesting now exist on a broad enough scale for over-exploitation to be an actual or potential problem virtually anywhere in the world ocean.

Even where this is not a problem, exploited stocks are under heavier fishing pressure than ever before. Management techniques must be applied now or in the near future in most fisheries to conserve the resources and maximize the economic and societal benefits. Proper management requires a foundation of research on both the fish and on the ocean environment in which they live. Where regulation is not yet a prime concern, there is usually a need for fisheries development programmes to make use of the available living resources. Unfortunately, neither the capability to conduct research in living resources and other ocean sciences nor the scientific infrastructure to do it has kept pace with the ability to catch fish.

On the other hand, the authority and responsibility of coastal states over fisheries and other marine resources have changed dramatically, particularly in the last decade, as a result of extended jurisdiction by coastal states and advances made in the Third United Nations Conference on the Law of the Sea. Until a few decades ago most coastal states asserted authority over fisheries in only a narrow band along their coasts, generally three to twelve nautical miles. Limited authority over fisheries was exercised through a few international fisheries commissions in areas beyond this narrow band in only a few regions where a strong scientific capability existed to support the regulatory efforts. Now, however, most coastal states have extended their fisheries authority two hundred miles out from their coasts. Thus, the area for which coastal states are responsible for management, conservation and development has increased tremendously, encompassing most of the world's prime fishing grounds. While extended jurisdiction over most of the world's fishing areas is now recognized, so too is the need for a better understanding of what goes on in those areas. This is illustrated by the obligations as well as the rights set out in the Law of the Sea treaty regarding the exclusive economic zone. There is now a clear need, as well as a clear obligation, for coastal nations to pay close attention to the interactions within their extended economic zones of climate, ocean variability, the activities of society and variability of living resources.

Nations have responded to this situation through various national, bilateral, and multilateral approaches to expanding and improving the basic and applied fisheries and other ocean science infrastructure. For example, the Food and Agriculture Organization of the United Nations (FAO) has launched an Exclusive Economic Zone (EEZ) Programme to assist developing countries in exercising their new responsibilities for fisheries in their expanded zones, particularly the applied aspects of fisheries development and conservation. At the same time, the Intergovernmental Oceanographic Commission (IOC), through a study of the Future Role and Functions of the Commission, identified a clear need, inter alia, to expand basic research in marine resources, particularly ocean sciences as they apply to fisheries, and to improve and expand the infrastructure of developing countries in these fields. Such an expanded effort in basic research would provide the foundation necessary for conservation and development of fisheries. Consequently, the Member States of the IOC at the Eleventh Session of the Assembly adopted Resolution XI-17 "Ocean Sciences in Relation to Living Resources" (OSLR). A copy of the resolution is given in Appendix 1. Resolution XI-17 states that IOC has decided to plan a major program "on Oceanographic studies of the marine ecological conditions in relation to fish stocks" and asks 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 and project proposals for research projects".

SCOR and ACMRR responded to the IOC request by forming Working Group 67, "Oceanography, Marine Ecology and Living Resources", with the following Terms of Reference:

1. Assess present understanding of the mechanisms through which variability in the physical-chemical marine environment affects the biological productivity of the ocean and the abundance and distribution of living marine resources.
2. Based on this assessment, identify promising directions and possible priorities for relevant research.
3. Consider appropriate regional research projects and related activities that are of interest and benefit to countries of these regions.
4. Provide advice for the Intergovernmental Oceanographic Commission on the above aspects of their Resolution XI-17 "Ocean Sciences in Relation to Living Resources".

WG 67 agrees with the SCOR Executive Committee that a particularly critical time has arrived because both society and exploited stocks are now more sensitive to ocean variability. The major reason is fishing itself; the more we fish, the more we depend on our fishing, and the more society is affected by fish stock variation. On the other hand, living resources are also likely to become more sensitive to ocean variability when they are under heavy exploitation. Thus, the more we fish a stock, the more vulnerable it is at times when environmental conditions are poor. Expansion of harvest of food from the sea, or even the maintenance of the present level of harvest, requires a much improved understanding of the relationship between ocean variability and stock variability. It would be clearly beneficial to all Member States of IOC if it were possible to draw for their own management needs on an intercomparison of various fisheries research programmes and to be able to extrapolate the research results from one area of the ocean to another.

ASSESSMENT OF THE PRESENT UNDERSTANDING

The first Term of Reference of WG 67 was: "assess the present understanding of the mechanisms through which variability in the physical-chemical marine environment affects the biological productivity of the ocean and the abundance and distribution of living marine resources".

WG 67 reviewed the available literature and noted that the vast majority of work related to effects of environmental variability on living resources is concerned with relatively low diversity ecosystems where ten or fewer species make up 90% of the biomass, as distinct from high diversity ecosystems where 100 or more species make up the bulk of the biomass. Several excellent synthesis papers have been written in regard to the former and we recognize the quality and merit of these assessments. One of the most recent is IOC Workshop Report 28, the report of an FAO-organized workshop held in 1980 entitled "Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Species". WG 67 found the review, edited by Gary Sharp, to be particularly thorough and up-to-date for pelagic species. (A list of references is given in Appendix 2). An earlier synthesis we used is "Marine Ecosystems and Fisheries Oceanography" edited by Parsons, Jansson, Longhurst and Saetersdal which contains papers from four symposia of the 1976 Joint Oceanographic Assembly. We also acknowledge two books that are valuable syntheses; "Early Life History of Marine Fish, The Egg Stage", by Hempel and "Marine Fish Larvae" edited by Lasker.

WG 67 had available the IOC draft report on OSLR entitled "Meeting of Experts on Ocean Sciences in Relation to Living Resources (OSLR)," IOC/INF-438. In addition to the original and revised report we had comments by 22 marine scientists who reviewed the report and a summary of these comments. WG 67 feels that the revised report of the "Meeting of Experts on Ocean Sciences in Relation to Living Resources" (OSLR) stands on its own as a contribution to OSLR.

WG 67 discussed at great length the syntheses given in the papers mentioned above, and we note two aspects that emerge from an analysis of this literature. One is that there is evidence that year class and stock variations appear to be caused by environmental variability. It starts with Hjort's work early in the century and includes some excellent long time series such as the Soviet work by Elizarov on variations in temperature and year class yield of commercial species in the North Atlantic and Barents Sea. The phenomenon we seek to understand is clearly real, but what are the causal mechanisms? The volumes edited by Sharp, Lasker, Hempel, Parsons, Jansson, Longhurst and Saetersdal present hypotheses that relate the food or physical conditions at the critical early stage of a fish's life history to the success of a particular year class.

The second aspect is that it is not yet certain which of the environmental variables are most important in causing stock variability. There are a number of hypotheses available in the documents mentioned in the previous paragraph. Clearly, the next logical step is the testing of hypotheses. In the past, however, there were a number of obstacles to these tests, e.g. the lack of certain technology for sampling and analysis, the fact that the collection of fishery data has not been universal, and that the basic information on fish larvae which can be used in such tests has only become available in the last decade. WG 67 believes that oceanography, marine ecology, and fisheries research now have reached a stage in technical advancements, fishery sampling, time series collections, and the understanding of larval biology that allows us to test hypotheses which relate ocean variability to the abundance of living marine resources.

IREX, A PROPOSED FRAMEWORK FOR OSLR EXPERIMENTS

The second Term of Reference asks WG 67 to "identify promising directions and possible priorities for relevant research". We note here that variability in the physical-chemical marine environment is not the only factor affecting the abundance and distribution of living marine resources: variations in fishing effort and biological interactions can cause significant changes in stock abundance and recruitment.

However, in response to IOC Resolution XI-17, WG 67 proceeded on the conviction that it would be beneficial to consider an experimental framework in which fishing effort and biological interactions can be treated as external parameters and a significant part of the variation in recruitment is treated as a function of environmental variables. We believe that there is sufficient evidence from well studied species to support this approach; i.e., we are confident that environmental variability is responsible for a significant part of the observed variations in recruitment (for these species) and that it is possible to account for the effects of fishing effort and biological interactions. Our response to the second Term of Reference is therefore a proposal for a set of experiments, collectively called the International Recruitment Experiment (IREX).

The first step in the design of such an experiment is to identify the environmental variables which are likely to account for most of the biological variability. Five independent variables: temperature (T), turbulence (Tu), transport (Tr), food (F) and predation (P) are suggested. Biological responses are known to be related to population density in certain species and where this is the case the number of independent variables would be increased to six. Eight biological variables (BV) can be identified as dependent on these five environmental variables: fecundity or egg production, egg survival, larval growth, larval survival, juvenile growth, juvenile survival, adult growth and adult survival. Figure 1 (Sette, 1943) shows the interrelations that exist between environment and recruitment.

We propose a large-scale, multinational experiment based on the assumption that the functional dependence of biological responses on the environment can be expressed with the above five or six variables as shown below:

$$BV_i = f_i(T, Tu, Tr, F, P) + g_i \text{ (external parameters)} + \text{sampling error}$$

and that these functional relationships are the same for a given species group. A species group in this context is defined as closely related stocks which occur in geographically separated, but environmentally similar regions. There is evidence for some species groups to support the hypothesis, although it is admittedly limited. The great advantage of our hypothesis is that data points can be collected for different stocks simultaneously, so that the number of data points necessary for a test would become available in considerably shorter time than would be required for one stock. This makes a multinational research effort both warranted and manageable.

Based on this reasoning, WG 67 suggests comparative experiments to be done at many places around the world on a few species or species groups. A common suite of fisheries biology, marine ecology and oceanographic data should be collected simultaneously in each location participating in the OSLR effort. Two aspects of the experiment need careful consideration and judgement by fisheries experts of the participating Member States: 1) What species group should be studied? and 2) How broad should the definition of this species group be?

There are species groups for which the assumption underlying the experiment appear to be reasonable. At this writing (April 1982), the best candidates for species groups on which IREX can be conducted seem to be: anchovy, sardine, sardinella, hake, cod, haddock, mackerel, horse mackerel, herring, penaeid shrimp, and spiny lobster. Basic work on the feeding biology, distribution and population fluctuation is available for these species from a number of places in the world. A foundation of time series data is also available which can be used as complementary information in the comparative experiment. A variety of other species seem to be amenable to similar international, multi-site experiments; but for these species groups basic biological data may not yet be sufficient to design such an experiment. Clearly the background work is at different stages for different species groups and for many groups the major need at this time is further laboratory and descriptive work. These investigations will need to be done before an appropriate experiment can be designed.

The essence of the IREX experimental design is that ocean variability and biological response to that variability occurring at one location would be compared experiences different environmental conditions. The organizing element of the experiments is the species group rather than the geographic area. The species groups form a number of parallel elements in the OSLR effort; for example, an anchovy experiment might have 10 locations participating, while a cod experiment might have 15 locations participating. We believe that such an OSLR experiment can test hypotheses that relate variability in fish abundance to variability in the ocean as given in Figure 2.

The success of a complex exercise such as IREX is not entirely dependent on a hypothesis being true; there is the possibility that a hypothesis will not hold and the experiments would then confirm this sobering fact. This potentiality should not deter the scientific community from embarking on the proposed experiments. Even if as a result of the experiments a hypothesis is rejected, the information collected will not be less than the information that would have been collected in the uncoordinated fashion of the past, and we cannot see at present an alternative hypothesis that could be tested within the framework of a manageable multinational effort.

The set of measure

<u>Biological Variables</u>

1. Fecundity by:
    a) sampling spawning females
    b) determining modal number of yolked eggs

   Egg production by:
    a) plankton sampling
    b) aging and staging of eggs
    c) determined from adult fecundity and biomass

2. Egg survival by:
    a) plankton sampling
    b) at intervals count, age and stage eggs

3. Larval growth by:
    a) determining daily rings on otoliths
    b) measure larvae
    c) relate age to length

4. Larval survival by:
    a) collecting larvae at intervals
    b) measure larvae
    c) age larvae with otolith technique

5. Juvenile growth by:
    a) collecting juveniles
    b) determine growth from otolith daily rings and from progression of modal lengths

6. Juvenile survival by:
    a) collecting juveniles at intervals
    b) measure juveniles
    c) age juveniles with otolith technique and from progression of modal lengths

7. Adult growth by:
    a) conventional fishery sampling programme
    b) aging technique

8. Adult survival by:
    a) conventional fishery sampling programme
    b) survey techniques

Environment Variables

1 Temperature by:
   a) moored instruments for vertical microstructure
   b) bottom temperature time series
   c) hydrographic surveys

2. Turbulence by:
   a) microstructure studies for vertical components
   b) satellite infrared (IR) and coastal zone color scanner (CZCS) imagery for horizontal components
   c) wind field from existing and additional stations

3 Transport by:
   a) wind field from existing and additional stations
   b) sea level from existing and additional stations
   c) mass field from hydrographic surveys and satellite infrared (IR) and CZCS imagery
   d) tidal field characteristics (to be determined if not available)
   e) direct current measurements where needed

4. Food by:
   a) vertical sampling by pump or closely spaced bottles
   b) determination of quantity of food by particle counting, optical or fluorometric techniques.
   c) determination of species composition and numbers by conventional methods
   d) determination of quality by larval bioassays

5. Predation by:
   a) stomach contents of potential predators including cannibalism

Laboratory Studies

IREX is a comparative field experiment, but WG 67 recognizes that laboratory studies will be required for many species or species groups. We recommend that for each species group it be decided what information is needed from laboratory investigations. Examples of the needed studies are work on nutrition of larval fishes, threshold feeding levels, behavior of predators on eggs and larvae, and effects of physical factors on development. An advantage of the IREX framework is that it can be used to define and justify specific laboratory studies. When completed, these studies will be used in the OSLR effort.

IREX IN RELATION TO HIGH DIVERSITY ECOSYSTEMS

WG 67 had difficulty in deciding how useful the IREX concept would be for understanding variability in high-diversity, multi-species fisheries. These fisheries are based on ecosystems that are characterized by having a large number of species present, each contributing relatively little to the total abundance, as opposed to ecosystems where there is a dominance of a few species. In practical terms, we think of ecosystems where 100 or more species make up 90% of the biomass as being high-diversity, multi-species in character, while those where 10 or fewer constitute 90% of the biomass are considered as being at the other extreme. High-diversity fisheries, particularly in inshore regions, are especially important to developing countries; but the unique problem of managing high-diversity, multi-species fisheries is not necessarily related to the economic status of the country. Many high-diversity, multi-species fisheries occur in tropical and subtropical latitudes; but some high latitude, rocky coasts of the Americas and Eurasia also have high-diversity, inshore "reef" assemblages that closely parallel the community structure on true coral reefs in the tropics. WG 67 feels that the management concept should be based on the unique biological character of the ecosystems.

It is possible (and some scientists believe that it is indeed likely) that in high-diversity ecosystems biological interactions are more important than environmental variability in determining the abundance of individual species in the community structure. WG 67 feels that the potential usefulness of the IREX approach to understanding variability in high-diversity ecosystems needs careful consideration, and that effort should be directed at understanding the role of environmental variability in these ecosystmes. The effort should be of the same intensity, or perhaps even greater, as the effort spent on the low-diversity ecosystem.

WG 67 therefore recommends that a separate working group be formed to evaluate the IREX proposal in view of the specific problems of high-diversity ecosystems and to amend, adapt or, if necessary, replace it with the aim of drafting another OSLR proposal with particular reference to such ecosystems. We note that centers with the necessary expertise to serve in the implementation of a high-diversity OSLR programme are already in existence in the Indo-Pacific region, in the form of the International Center for Living Aquatic Resources Management (SEAFDEC) in Bangkok. We suggest that until the report of the proposed working group is produced and adopted, IREX experiments based on the framework developed in this document should be open to all participants from high-diversity, multi-species areas who feel that participation in IREX could be beneficial to understanding variability of their living resources.

Other OSLR Components

There is a considerable body of oceanographers and meteorological data as well as ongoing monitoring programmes which are of great value to the OSLR programme and many other current fisheries research programmes. WG 67 recommends that the responsibility of making this oceanographic and meteorological data available be assigned to the Time Series Study Group of the Committee on Climate Changes and the Ocean (CCCO) Biology Panel. It would be unfortunate if many separate and incompatible data bases were developed. Alternatively, the development of self-defining exchange formats should be encouraged, and WG 67 urges the CCCO and National Oceanographic Data Centers to do so through International Oceanographic Data Exchange (IODE).

Advantages of the Proposed Strategy

1. An advantage of the proposed IREX framework is that it is a defined intellectual exercise in which progress can be evaluated. This evaluation sets the stage for making progress on OSLR in recognizable steps.

2. Resolution improves with the number of countries participating. A critical mass of participants is required. If there are too few participants for any particular species group, IREX should not be carried out on that group.

3. The option of the long-term continuation exists. Once started, participating countries can continue the programme to start the critical long-time series. No country is likely to set out alone to start an experiment that will not pay off for many years; but, once started in the OSLR exercise and given repeated evaluation, countries may elect to continue the effort.

4. Existing fishery programmes would be supported and would become part of the experiment. An integral part of the IREX experiments depends on existing fishery data collection programmes. Each participating country would be encouraged to continue this data collection.

5. The rate of analysis of collected data will be increased. IOC and FAO coordination will aid analysis of data obtained simultaneously throughout the world, and countries sharing data will be stimulated to keep up-to-date on data analysis.

6. The IOC and FAO framework facilitates collaboration between countries on transboundary stocks.

The Committee on Climate Changes and the Ocean (CCCO) through its Time Series Study Group provides a supporting intellectual framework for this experiment.

8. Transfer of knowledge and technology in marine ecology and oceanography will take place.

9. Many of the techniques used in this IREX experiment can be used by the participating country to aid in biomass assessment of its marine resources.

10. New knowledge on recruitment, which will be useful for management, could be used for resource forecasting and thus be of future benefit.

11. Methods of data processing could be exchanged to the mutual benefit of participants.

12 IREX will encourage scientists with particular expertise to exchange ideas and perception on important problems in oceanogrpahy and fisheries.

APPENDIX

Resolution XI-17

The Intergovernmental Oceanographic Commission

Recognizing the vital need for adequate understanding of the relationships between ocean environmental variability and fish stocks, and recognizing further that IOC activities in ocean science can enhance and complement the study of living resources,

Realizing the need for close collaboration among the Commission, the Food and Agriculture Organization and their advisory bodies in developing an appropriate scientific programme plan for ocean science activities in support of living resources research,

Decides to undertake development of plans for a major programme of the Commission on oceanographic studies of the marine ecological conditions in relation to fish stocks, as referred to in document IOC-XI/20;

Requests ACMRR and SCOR in consultation with the Vice-Chairman for Ocean Science to develop a comprehensive scientific programme plan and project proposals for research projects aimed at understanding the marine ecosystems to, and in support of, fisheries research and development as sponsored by the FAO.

Instructs the Secretary to:

(i) inform the FAO of this decision with a view to obtaining its agreement to collaborate in this initiative;

(ii) arrange for the appointment of a Rapporteur from IOC, and to discuss the appointment of a Rapporteur by FAO, to develop through correspondence an inventory of information on this subject;

(iii) arrange, in collaboration with FAO and interested countries, consultations of experts from ACMRR and SCOR and interested Member States in 1980 and 1981 in order to develop the scientific programme plan and initial project proposals to be submitted to the Commission prior to the twelfth session of the IOC Assembly (April 1982);

(iv) report to the Executive Council at its fourteenth session on the status of development of the scientific programme plan requested above;

v, develop, publish and distribute guidelines for interested Member States to follow in submitting specific TEMA needs for participation in the programme area when the scientific programme plan is available; and

(vi) prepare proposals as to how these TEMA needs can be satisfied.

APPENDIX 2

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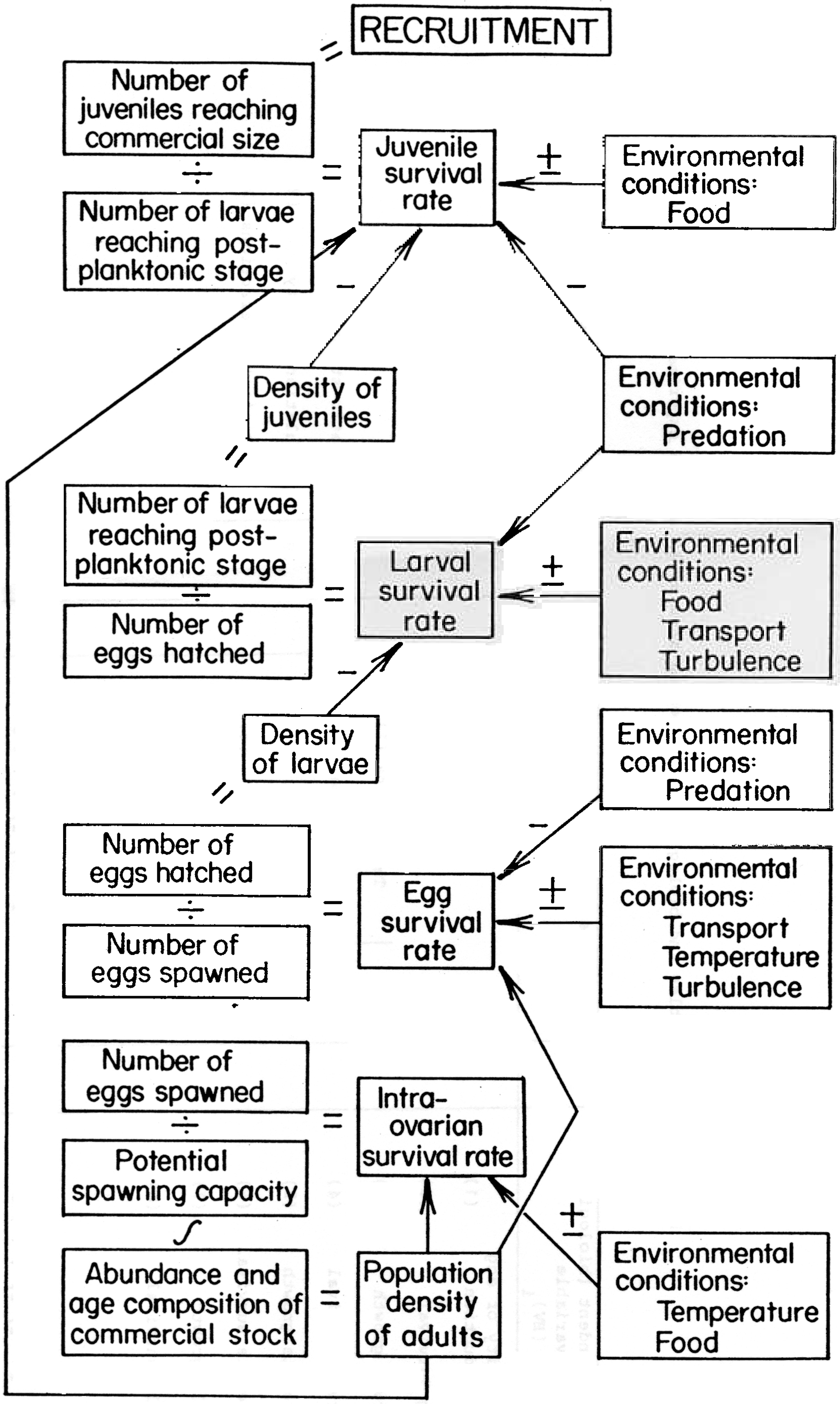

Figure 1. A conceptual model of the relationships between recruitment and the environment (modified after Sette, 1943).

Figure 2

Environmental variables and biological responses as studied in an OSLR experiment

Dependent (biological) variable $(BV)_i$	Independent (environmental) variables $(f)_i$	External Parameters $(g)_i$
Fecundity or egg production		
Egg Survival (2)		
Larval growth (3)	f_i: Temperature (1)	
Larvae survival (4)	Turbulence (2)	g_i: Genetic structure 1)
Juvenile growth (5)	Transport (3)	Population density (2)
Juvenile survival (6	Food (4)	Biological interactions (3)
Adult growth (7)	Predation (5)	
Adult survival (8)		
i = 1, 2, . . . 8	i = 1, 2, . . . 5	i = 1, 2, 3