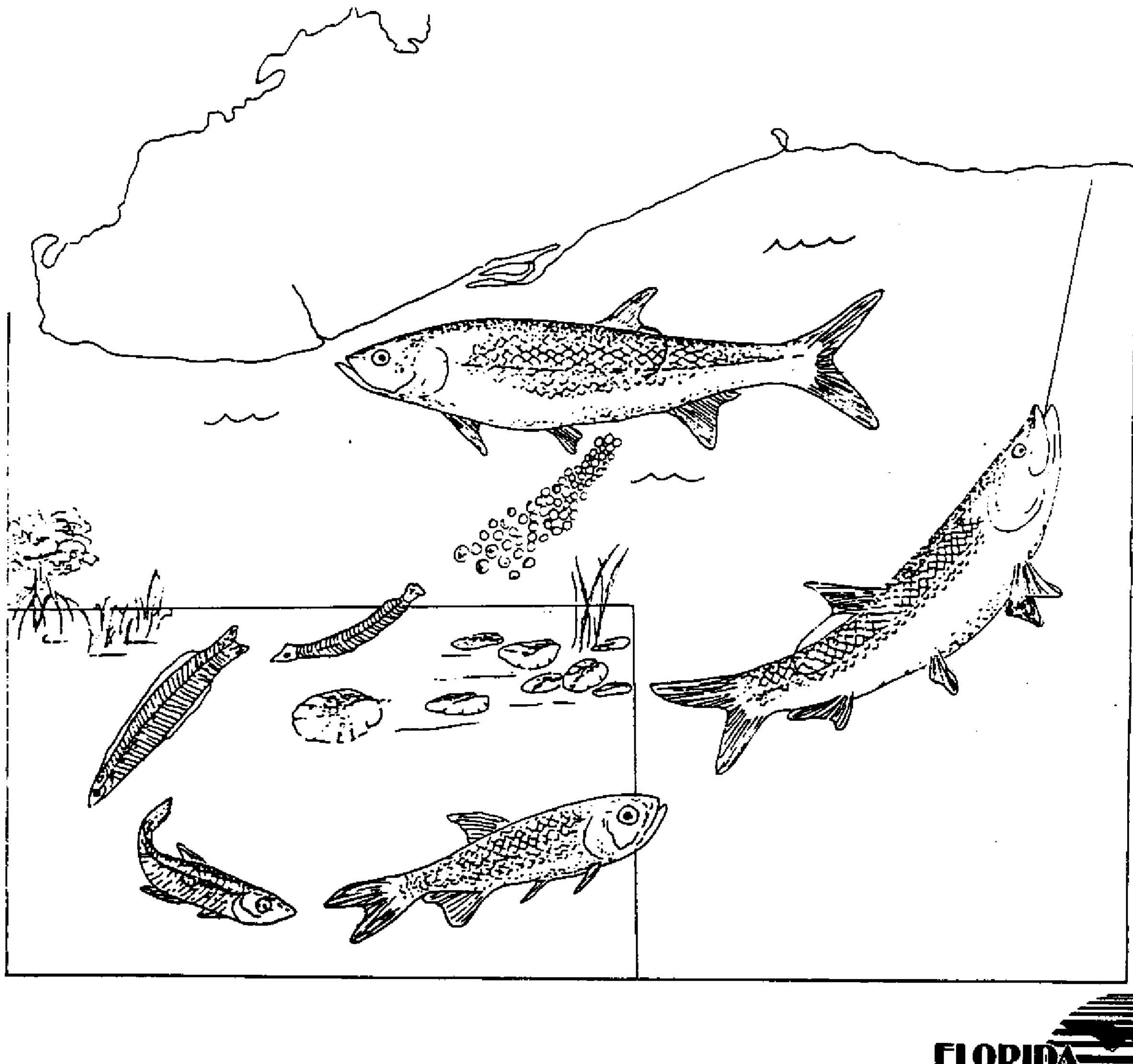
FLSGP-W-89-002 C2

Technical Paper No. 57

FISHERY RECRUITMENT IN FLORIDA WATERS

Toward a Predictive Capability

G.S. Kleppel and William Seaman, Jr.
Editors



FLORIDA SEA GRANT COLLEGE PROGRAM

Research, education, and extension for responsible marine resource use

FISHERY RECRUITMENT IN FLORIDA WATERS
Toward a Predictive Capability

Report of a Workshop
Held February 15-17, 1989
Live Oak, Florida

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Florida Sea Grant College Program
Florida Chapter of the American Fisheries Society

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Project No. IR-89-2
Grant No. NA86AA-D-SG068
Florida Sea Grant Technical Paper 57
September 1989
Price $2.00

Acknowledgments

Organizing, conducting and reporting on a workshop is a large, difficult and frequently frustrating task. In the end, hopefully, the benefits are worth the effort. Workshops generally do not highlight the talents of individuals and few of those who contribute are adequately recognized. Many of those who work the hardest never even see their names in print. The editors of this volume wish to express to those who contributed, often well beyond their level of compensation, our personal thanks and our belief that what you have helped to accomplish will ultimately benefit science and society.

We are grateful to all of the scientists and managers who participated in the workshop, and especially to those who later did the report writing. We thank Ken Haddad and his staff at the Florida Marine Research Institute (Department of Natural Resources) and the Florida Chapter of the American Fisheries Society for their efforts in organizing and conducting the workshop. Dr. James Cato of the Florida Sea Grant College Program provided support, staff and considerable motivation for this undertaking. Marilyn Little and Jay Humphreys of the Sea Grant office provided valuable administrative and editorial assistance. Kathy Maxson of the Nova University Oceanographic Center did much of the typing and most of the art work. Denis Frazel, also of Nova, contributed his time to organizing and preparing the final product. Finally, we thank the Steering Committee who spent many hours designing the conceptual framework upon which this workshop was built.

G.S. Kleppel
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Fishery Recruitment in Florida Waters:
Toward a Predictive Capability

Executive Summary

Marine fisheries in Florida encompass 109 finfishes and invertebrate species, reflecting the state's diversity of coastal and ocean habitats. Management of Florida's valuable fisheries necessarily entails forecasting fluctuations in fished stocks. By understanding recruitment, the processes that result in the survival of fishes from early life history to the adult or exploited stage, management potential can be improved. Responding to an interest in recruitment expressed by Florida's academic scientists, the Florida Sea Grant College Program, in conjunction with the Florida Chapter of the American Fisheries Society, organized the workshop at Live Oak to determine the usefulness of understanding recruitment, the likelihood of success and the mechanism for proceeding. The workshop elicited national attention; over 100 scientists and managers attended. The participants provided the framework for a multidisciplinary, academic-government research initiative to elucidate the processes controlling survival in certain key state fisheries. Workshop participants determined which fishes and invertebrates (usually species but in one case, a family), representative of Florida's fishery habitats, should be the focus of recruitment research over the next decade. The fishes (and invertebrates) selected for further study are economically valuable, typical of certain geographical regions and biological processes, and generally have been well studied. Further study of these fishes is likely to bring significant gains in knowledge and management potential. In addition, participants identified the information and technology improvements that will be necessary for successfully defining the relationship between fishes, their habitats and the fluid environment.

What follows is a description of the Live Oak workshop's objectives and results. The document represents the collective wisdom of many of Florida's leading scientists. It is designed to provide guidance for strategic planning in future fishery research and management activities.

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Report of the Steering Committee

G.S. Kleppel, W. Seaman,Jr.,
J. Bohnsack, M.E. Clarke, J. Napp, R. Nelson

I. Introduction

In this report, we present the rationale, objectives and some of the results of the Fishery Recruitment workshop from the perspective of the Steering Committee. As explained below, workshop participants spent much of their time in small, thematic working groups which have reported their findings individually, in the papers that follow. In this paper we attempt to merge the concepts and ideas offered by the working groups, emphasizing those ideas that were recurrent. We believe that these key concepts provide a framework around which a state recruitment research initiative can be developed.

Recruitment is the set of processes that results in the survival of organisms to a certain stage in the life cycle. In the context of fisheries, the terminal stage of recruitment is often considered that at which reproduction or economic exploitation occurs. It can be argued that if one understands the processes that facilitate survival among a population of organisms, then one should be able to estimate the proportion of that population that will survive to a given stage. As a result, one might better predict changes in the population over time. And, if the population is exploited (fished), one could, potentially, manage the human impact on it. Developing the ability to predict stock dynamics is a major goal of fishery science. Achievement of that goal may depend, in part, on our understanding of recruitment.

In spring 1988, a group of scientists, identified by Florida Sea Grant as sharing an interest in recruitment, met in Miami to discuss the motivation for a research initiative addressing the problem of recruitment in some of Florida's fisheries. In response to increasing, but mostly independent, activity in this field, a multidisciplinary dialogue was proposed in the form of a workshop to further identify scientists involved in recruitment research, to prioritize the research objectives of a statewide recruitment initiative and to relate these objectives to the goals identified in Florida Sea Grant's long-range plan (1988). The meeting at Live Oak in February 1989 was organized for these purposes.

II. Workshop Rationale

In contrast to many areas of the country where only a few fishes or invertebrates are exploited, over 100 marine and estuarine species are fished in Florida (FMFC 1986). Management of marine fisheries in Florida is complicated by this diversity of exploited species, and by the variety of habitats and life history strategies of these species.

Workshop participants considered the need, feasibility, and strategy for studying recruitment in the context of boosting the potential for management of Florida's marine and estuarine fisheries. The workshop objectives were to:

1. identify key or representitive species for which an understanding of recruitment might be feasible within the next decade,

2. identify the interactions between the biology of fishes (and invertebrates), and physical properties and processes in the environment that are pertinent to recruitment and tractable scientifically,

3. determine the major gaps in our understanding of the processes that contribute to recruitment in general and for key species in particular,

4. consider the unifying principles around which processes that result in recruitment can be described,

5. define the roles of Florida's diverse scientific community in studying recruitment, especially potential pathways for collaboration and cooperation between scientists from academe and State and Federal facilities.

III. Workshop Organization

A. General Structure

The workshop was divided into three components: formal scientific presentations, thematic working groups, and plenary discussion sessions (see Agenda, Appendix 2). Scientific presentations opened the meeting to help define the scope of the problem and to identify the interests of the workshop participants. The remainder of the time was devoted to small working group meetings, intermingled with plenary discussion sessions.

There were four working groups, of 12-20 participants, and designated on the basis of major fisheries: Open-Ocean Pelagic; Coastal Pelagic; Reef/Benthic; and Estuarine. The choice of these groups was based on the types of environments that are exploited in the state's fisheries. It was recognized, however, that fishes frequently utilize more than one habitat during their life cycles. Thus, while the working groups were named for the habitats where the adults are fished, discussions of the species comprising each fishery were not limited to any single habitat. In fact, certain species were considered important by more than one working group.

B. Working Group Objectives

Through review and discussion of existing fishery information, each working group sought to identify: the important or key species (see below) in the adult fishery; the characteristics of the environment that are important to that fishery; and, the data and technology needed to demonstrate progress in our understanding of the fishery.

1. Key species -- The criteria for establishing the priority of species (i.e., deciding which fish species are important) were determined within the working groups. Among the major weighting factors were: value of the fishery; potential for significant progress in understanding its recruitment (or population dynamics) within the coming decade; fishing pressure on the stock; how well the species represented a certain life-history strategy.

2. Environment -- There is growing recognition that biological and physical hydrodynamic process are intimately coupled (Legendre and Demers 1984; Bratkovich 1988). As such, hydrodynamics represent a driving force in ecosystems (Haury and Pieper 1988) and may influence fish population dynamics in a variety of ways and at all life-history stages (Lasker 1981; Mearns 1988; Svejkovsky 1988). Among the goals of the workshop was to promote an increase in the awareness, discussion and study of physical-biological interactions that may affect fish recruitment. This emphasis was apparent in the opening session (D. Olson this volume). It is critical for the scientific community to know the extent to which the links between the recruitment of "key species" and the fluid dynamic environment can be and need to be resolved in order to obtain predictability and management capability.

3. Data needs and technical limitations -- The workshop was designed to draw attention to gaps in the data base that limit our understanding of recruitment and to shortcomings in technology and methodology that limit sampling efficiency and the estimation of population sizes. Emphasis was placed on identifying tractable problems and upon developing multidisciplinary approaches to solving them. A second focus was on gear development and on the recognition that the understanding of fish population dynamics is limited by sampling efficiency.

IV. Results of the Workshop

Although the working groups represented a diversity of specialties, interests and scientific orientations, certain recurrent themes and messages seemed to be projected. We present below, a summary of these themes from the perspective of the Steering Committee. The perspectives of the working groups can be gained from their detailed, individual reports.

The workshop results are divided into three components: **scientific observations; approach;** and, **consensus.** The first component, scientific observations, deals with three topics: key species, environmental attributes and technology. Working group discussions of these topics focused on existing and needed data for understanding recruitment. This section represents our perception of the major elements of the working group discussions.

The component on **approach** addresses certain procedural and conceptual issues of a recruitment research initiative. The final component, **consensus,** deals with the question of whether recruitment is an important issue from the standpoint of the Florida's scientific community. The discussion focuses on our interpretation of the higher than expected attendance and broader than expected regional interest in the workshop.

A. Scientific observations

1. Key species -- With few exceptions, the organisms selected as key or representative species are commercially or recreationally exploited, rather than simply abundant (Table 1). The working groups tended to include some fishes as target species because significant progress in understanding their seems feasible within the next decade.

2. Environment -- It was apparent that data are needed on many of the biological variables classically associated with recruitment (Table 2). These include habitat, predator/prey interactions, competition, movement patterns, biogeography and community structure. It was also recognized that interactions between organisms and hydrodynamic processes or phenomena, such as occur through advection or at fronts, may have enormous significance on survival of early life history stages and ultimately upon recruitment (Table 3).

Another theme expressed by the working groups was the need to understand low frequency variability through long term data acquisition (Table 3). It was noted that ocean-atmosphere coupling on a variety of time/space scales can influence recruitment. There are few systematic evaluations of long term environmental variability, especially with respect to fish recruitment.

Finally, all of the working groups made reference to the need to identify and understand human impacts on recruitment. The focus of the working groups varied from assessment of fishing pressure to understanding the impact of habitat modification. It was pointed out that the anthropogenic impact on fish population dynamics is often not resolveable from natural variability given the current data.

3. Technology -- A final recurrent theme was sampling. The need to develop gear and techniques that permit quantitative sampling of all life history stages and habitats is critical, and at present, not available for most fisheries. One of the clear-

Table 1. Key* species of fishes and invertebrates (scientific names are given in each working group report) identified by working groups as most suitable for future recruitment research.

		Reason(s) for choice as priority species**							
Habitat	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Open Pelagic:	Menhaden	++	++	++	+	++	+	++	
	Black Mullet	+	+	++	+	++			
	Dolphin	+	+	++	+	++	+		
Coastal Pelagic:	King Mackerel	++	+					+	
	Spanish Mackerel	++	+					+	
Reef/ Benthic:	Black Sea Bass	++			++				
	Vermillion Snapper	++	+		++		+	+	+
	Gag Grouper	++			++		+		
	Spiny Lobster	++			++			+	+
	Red Porgy	+			++				
	Grunts		+		++		+	+	
	Red Snapper	++	+		++	+			+
Estuarine:	Not given***								

*One group preferred the term "representative" instead of key.

**Reasons for choosing a species:
1. Economically valuable; 2. strong data base/high probability of progress; 3. representative of physical process(es) or physical-biological interaction; 4. representative of geographic region; 5. representative of life history strategy; 6. easy to sample (throughout life cycle)/in culture; 7. abundant at one or more ontogenetic stages; 8. other.

Rating: ++ strong reason for choosing; + weak reason for choosing; blank -- not a reason

***The working group considered the establishing priorities inappropriate at this time (see Estuarine Working Group Report).

Table 2. Biological factors and processes considered important by working groups to recruitment of key fish and invertebrate species in Florida waters.

Habitat	Factor/Process
Open Pelagic	movement between habitats life history/biology representative of a common biological process or interaction with environment
Coastal Pelagic	predator/ prey interactions early larval stages sources and size of mortality
Reef/Benthic	ontogeny planktonic dispersal community structure biogeography predator/ prey interactions competition
Estuarine	spawning dynamics growth/ontogeny developmental bottlenecks predator/prey interactions competition habitat structure and utilization

Table 3. Physical characteristics of marine environments that may affect recruitment.

Habitat	Characteristics
Open Pelagic	fronts and associated dynamics advection (vertical and horizontal) and associated forcing functions low frequency events
Coastal Pelagic	advection/ transport ocean-atmosphere coupling at many scales fronts and other aggregating mechanisms
Reef/Benthic	transport at scales affecting larval dispersion low frequency events that influence bottom topography
Estuarine	hydrological & climatic regimes physical habitat processes and structures

est messages of this workshop was that gear development and sampling methodology need to be given priority in future research agendas. Quantitative sampling of fishes throughout their life histories, in numerous habitats, and on a variety of time scales is an important objective, upon which the success of the recruitment research initiative will depend.

B. Approach

In developing a scientific program focused on understanding fishery recruitment, several operational priorities emerged. These concern political boundaries, multidisciplinary interactions, and unifying concepts.

1. Political boundaries -- States must take a regional or larger focus, as fish stocks are often migratory and definitely not confined by state boundaries. An intermural, cooperative approach was evident at the workshop through attendance by scientists from state and federal institutions in Georgia, North Carolina, Tennessee, and Michigan. It is proposed that an interstate dialogue be established throughout the Southeast to begin development of a regional approach to fishery management.

2. Multidisciplinary approach -- There was a strong appreciation among the workshop participants for the intimate association between the organism and its environment. Understanding that association will improve the ability of researchers to describe the characteristics of "the survivors,"those fishes that recruit.

Recruitment is affected by the biotic and the physical environments, and studies of these processes must be undertaken in an integrated, multidisciplinary fashion. The workshop derived much of its strength from the interactions that developed between physical oceanographers and fisheries biologists, and between practitioners of various subdisciplines of biology.

3. Unifying concepts -- Florida exploits 109 species of marine fishes and invertebrates (FMFC 1986). It is impractical to believe that management of all of these species is possible within the decade. What is possible is that certain general categories of organisms can be identified based on common life history or other attributes (Miller et al. in press; Crowder this document) It is normal for scientists to seek general principles that govern processes. Whether we work from the specific to the general, or vice versa, it will nonetheless be critical to have certain operational models at our disposal.

It was, however, difficult to come to terms with the concept of unifying principles. At this point the idea apparently requires further refinement. However, most participants seemed to favor the effort to seek generalizations, so long as the importance of the species is not lost. Clearly, generalization requires a strong data base on individual species. Resistance to the unifying concept idea may reflect weakness in the data base.

C. <u>Consensus</u>

Among the most important messages of the Live Oak workshop was that the community views recruitment as an important area for study. The expected participation of the workshop was between 30 and 50 individuals. While the official registration of the meeting was about 60, the actual attendence of the opening session was much higher (we believe over 100). There is no doubt that recruitment is an important topic in the scientific community at all levels (academic, goverment, private). The attendance of the meeting, the diversity of disciplines represented, and the geographical range of the participants indicates that serious consideration needs to be given to fishery recruitment at the program development levels of Florida's government.

V. Toward a Recruitment Research Initiative

The Live Oak workshop provided a clear consensus that a state research effort in recruitment is in the best interest of Florida and has local, regional and national support. This scientific consensus is based on the beliefs that:

1. Management of fisheries depends in part on an understanding or predictability of stock fluctuations;

2. Understanding the processes that lead to recruitment will enhance understanding of the causes of stock fluctuations and, hence, the development of fishery management;

3. A predictive understanding of certain critical aspects of recruitment seems feasible within the next decade for some fisheries.

A recruitment research initiative within Florida can be perceived to have three components: Research; Development; Education. The program's structure must foster collaboration between government and academe, and among the scientific disciplines. A committee of academic and government scientists might ultimately be responsible for program development and oversight. While the nature of this program would necessarily be long-term (there are 109 species to ultimately manage), progress toward specific goals would be measurable by the achievement of discrete tasks. Ultimately, the unifying concepts approach will be feasible and the implications of the recruitment program will extend beyond Florida's borders.

Collaboration with regional and federal projects and promotion of the Florida program within and beyond the state will be an important component of the committee's activities. This will help to reduce the cost of the program within the state, and increase the rate of data base development.

VI. What is Gained -- the Ultimate Goal

American fisheries are conservatively valued at about $15 billion annually. However, these fisheries are highly susceptible to economic disaster from natural processes that are recognized but not predictable (e.g., el Nino), anthrogenic activities, and as yet poorly understood natural variability in the environment and in fish stocks. The American public has supported the effort to manage fisheries and avoid economic disasters by improving the scientific understanding of fishes and the processes that govern their production. Continued public support requires that the scientific community demonstrate some level of success in the ability to predict fish stock fluctuations. The Live Oak meeting resulted in a consensus that we are close to that end for certain species. It is this groundswell of interest at the level of the scientific community which suggests that a commitment to recruitment research is presently appropriate. Much hard work is still ahead. However, it would appear that significant progress is feasible.

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Part I. Committee and Working Group Reports

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Report of the Working Group on Open-Ocean Pelagic Fisheries

L. Barthouse, A. Bratkovich, M. Clarke, W. Conley
L. Crowder, D. Frazel, E. Fritz, D. Hoss, D. Kendall,
S. Killey, G. Kleppel, M. Murphy, J. Napp**, D. Olson
P. Ortner*, J. Silberman, R. Taylor

* Chair
** Rapporteur

I. Introduction

Each working group at the Recruitment Workshop was charged with identifying the major biological and physical processes associated with time varying recruitment of fishes in specific habitats. In particular we were asked to to identify those processes which:(1) are relevant to specific life history stages of many fishes; (2)are amenable to further study; and (3) have the potential of eventually yielding predictive models - i.e., fisheries forecasts (potential harvest).

We focused our initial discussion on the general phenomenon of physically-induced, temporal fluctuations in populations of fishes and decided that "representative" rather than "key" species would be more useful. Our strategy was to consider how one might study such problems without regard to regional jurisdiction or local/state economic interests since many fishes cross state boundaries during their lifetimes. We quickly came to an agreement that among the most suitable species for study there were two generic life history strategies: (1) the "transgressive" [1] species which are common inhabitants of oceanic, coastal and estuarine waters throughout the Gulf and South Atlantic coasts; and (2) species that appear to be associated with coastal/pelagic frontal systems. We also felt that the focus of a successful program should be towards obtaining a general, process-oriented understanding of natural variability in fish populations rather than toward an immediate prediction of next year's catch from this year's catch or spawn. This approach is advantageous because it is prerequisite to discriminating changes related to anthropogenic stresses (overfishing, pollution, habitat destruction) from natural variability of fish stocks(i.e., internally regulated or induced by climatic variation and/or global changes, for example, in circulation pattern or water mass characteristics).

[1] Transgressive species are those that spawn in coastal or oceanic waters, but whose juveniles are dependent upon estuarine nursery areas.

II.Tractability of Research Problems Addressed with "Representative Species"

Coordinated biological-physical programs are notoriously expensive. To sustain national and regional momenta and work within projected, available funds, it is crucial that a tractable problem be identified and addressed before pursuing problems that are less amenable to scientific study. It is also critical that the information obtained be relevant to as many species or species types as is possible. Five criteria were suggested to evaluate the suitability of specific fisheries-recruitment problems for a pilot study.

1. The species of choice must exhibit time varying recruitment.

2. The species of choice should have a relatively short life span or reach sexual maturity in a short time period.

3. The life history stages of the chosen species should be both identifiable and abundant in standard sample collections.

4. There should be a definite spatial separation between at least two of the important life history stages.

5. An historical data base should exist for the pertinent aspects of the chosen species' life history and the physical environment in which it lives.

The first criterion is a given; it is pointless to study how variable biological and physical processes interact to affect recruitment if the stocks are invariant. A short life span or time to sexual maturity (1-3 years)is esential to maximize the number of recruitment cycles studied within the life span of a typical field program - i.e., one should have the opportunity to test and modify mechanistic models more than once. Although some species (e.g., mackerels) that are not commonly collected during sampling of early life history stages have enormous economic importance as adults, the scientific task of understanding recruitment will be easier if the population size can be accurately assessed for all life history stages. In fact, if certain life history stages are difficult to sample (e.g., juvenile stage), then it will be essential to develop new, adequate samplers and sampling strategies to assess their abundance. Ontogenetic separation of stages is advantageous in at least two regards: one, cannibalism is relatively less important as a source of mortality for the pre-recruits and two, at least one physical mechanism (advection) is likely to play an important role in determining recruitment variability. The existance of a substantial biological and physical data base will permit a research program to formulate hypotheses at the outset and the analysis objectives can then be pursued in parallel with field observations. A long-term data set would permit hindcast analysis and model corroboration as well as facilitate the link to long-term climate change effects.

III. Specific Recommendations and Considerations

A. Null Hypothesis

As a modus operandi we suggest adopting the following "strawman" hypothesis:

H_0: Recruits to a population are chosen at random from the field of propagules.

H_1: Recruits to a population are not drawn randomly from the field of propagules.

The utility of this approach is that upon rejection of the null hypothesis it directs effort toward identification of exactly which non-randomly selected set of propogules, which discrete reproductive "event", was differentially successful. These conceptual steps lead to the critical, subsequent step of identifying the reason(s) why those individuals survived to recruit to the population - i.e., what were the common biological and physical factors that determined survivorship?

One method suited to this type of question is otolith analysis for birthdate distribution (e.g., Brothers 1975; Methot 1983; Rice et al. 1987). In practice, the birthdate distribution of a population is determined several times during the recruitment process. If the birthdate frequency distribution of the survivors to a particular stage is the same as the spawning date distribution (which also has to be determined), then the null hypothesis cannot be rejected. If, on the other hand, the birthdate distribution of the recruits is distinct from the distribution of reproductive effort, then the recruits were not drawn at random from the field of propagules, and one can go on to identify the commonalities among the survivors. Otolith analysis also provides the mean and variance of growth rates of individual fishes and can potentially provide growth rate trajectories from ring spacing patterns. We recognize at least two inherent difficulties with this type of analysis: it doesn't directly address the contribution of egg mortality to recruitment variability and its rigor depends upon the degree to which one can samplethe same population (cohort) over time throughout its range.

B. Potential Life History Strategies and Species for Study

We considered examples of "representative" species types mentioned earlier: transgressive species and pelagic/coastal, front-related species. Transgressive species are those whose adults spawn offshore but whose juveniles are found inshore, often in estuarine nurseries. Front-related species are those whose larvae or juveniles may be found in particularly high abundances in association with coastal/pelagic fronts (e.g., the western edge of the Gulf Stream). Potential species include: Transgressive - black (striped) mullet (*Mugil cephalus*), Atlantic menhaden, Gulf menhaden (*Brevoortia tyrannus* and *B. patronus*), spot (Loeiostomus xanthurus), croaker (Micropogonias undulatus), grey snapper (Lutjanus griseus), and flounder (Paralichthys sp.). Front-related - dolphin (Corphyaena hippurus), swordfish (Xiphias gtladius), king mackerel and Spanish mackerel (Scomberomorus cavalla and S. maculatus) and blue fin tuna (Thunnus thynnus).

Although the majority of larval fish in oceanic waters belong to the families Myctophidae, Gonostomidae, and Sternoptychidae (Ahlstrom 1965; Loeb 1980; Richards 1984), the life history of these animals preclude their successful recruitment into Florida waters. Further, although there are several active fisheries for myctophids in other parts of the world because there is no existing local fishery for any species of these families, we have little knowledge of the degree to which their annual recruitment is variable. Last, because of their exclusively pelagic life style, these fishes are less likely to exhibit annual variations in recruitment than transgressive or front-related species.

C. Specific Representative Species

Based on the above criteria, two transgressive and one pelagic/coastal front-related species seemed to offer the most advantages. Black mullet and menhaden were chosen as representative transgressive species and the dolphin fish was chosen as a representative pelagic/coastal, front-related species. Dolphin fish, however, fulfilled fewer of the above criteria, than either of the transgressive species.

Black mullet, abundant on the west coast of Florida, leave their estuarine habitats and migrate offshore (to the shelf edge) to spawn. This offshore migration may be correllated with the passage of low pressure systems (Mahoudi et al. 1989). Cross shelf transport of larvae may also be dependent upon storm-induced shelf exchange processes (for discussion of physical response see Hseuh et al. 1982). An appropriate question for this population would be whether recruitment is event-driven (e.g., only during the largest or strongest storms) and varies as a function of spawning distance fronm the estuary (which may relate to large scale physics, such as the shoreward excursions of the Gulf Loop Current). This fishery accounted for 20% of the tonnage of finfish landed in Florida in 1986-87 and has been biomass dominant for two decades. Although the literature is limited (Arnold and Thompson 1958) researchers in Florida's Department of Natural Resources have been studying the growth, life history and reproductive biology of black mullet for some time (Mahoudi et al. 1989) and have recently developed otolith techniques that provide daily growth for both larvae and juveniles (Conley, personal communication).

Atlantic and Gulf menhaden spawn in coastal waters in the fall and winter, and after hatching many larvae are transported across the shelf and into estuarine nursery areas. In both the Atlantic Ocean and Gulf of Mexico wind driven currents and storm events are important in the transport of menhaden larvae (Nelson et al. 1977; Miller et al. 1984; Checkley et al. 1988). In the Atlantic Ocean, variability in the speed and direction of the

Gulf Stream may also play an important role in defining the spawning area, and intrusions of Gulf Stream water may facilitate transport of larvae across the shelf (Pietraffesa and Janowitz 1988). Intrusions (meanders and eddies) of Gulf Stream water may cause upwelling of nutrient rich water in their wakes (Atkinson 1985) stimulating both primary and secondary productivity (Yoder 1983; 1985; Paffenhofer 1985) which produces food for the menhaden. In the north central Gulf of Mexico, Gulf menhaden larvae may be mostly dependent on wind events for their transport, while in the northwestern Gulf both wind events and the relative position of the Gulf Loop Current may be important (Shaw et al. 1985a; 1985b; 1988).

The existing biological data base for both Gulf and Atlantic menhaden is more extensive than for any other east or Gulf coast fishery. Data exist on: the distribution, morphology, growth, behavior and feeding of various life history stages (Reintjes 1969; Fore 1970; Hoss and Blaxter 1982; Govoni et al. 1983; Hoss and Phonlor 1984; Powell and Phonlor 1986; Sogard et al. 1987; Govoni 1989) and on the reproduction of adults (Higham and Nicholson 1964). Culturing is now routine (Hettler 1981) and otolith aging has been documented (Simoneaux and Warlen 1987; Warlen 1988). While commercially important in their own right, it is equally important that black mullet and menhaden are important forage fish for other, larger, and more individually valuable in both sport and commercial fisheries.

Little is known about dolphin fish by comparison to menhaden, but they are one of the most studied pelagic, front-related species. The adults spawn in blue water following a lunar periodicity and both larvae and juveniles are commonly found in association with flotsam and sargassum in the Gulf Stream front. Dolphin reach maturity in only 1-2 years, and can be cultured (Beardsley 1967; Hassler 1975; 1977). The degree to which population recruitment is dependent upon frontal features and whether this dependence relates to feeding or perhaps refuge from predation is unknown, but these factors are thought to be important. The dolphin fish fishery is not currently managed, but the National Marine Fisheries Service predicts that it will have to be managed within the next 5 years (Hoss, personal communication). Physical data relating to the Gulf Stream front are extensive and the dynamics of the system is the subject of current oceanographic research programs within the academic community.

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Report of the Working Group on Coastal Pelagic Fisheries

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I. Introduction: Key Species

Coastal pelagic species include, but are not limited to, king, Spanish and cero mackerel, dolphin, bluefish, menhaden and a group of clupeid and carangid species often referred to as coastal herrings. Our discussions concentrated on the king and spanish mackerels, in part, because of the regional importance of these species. For example, commercial catches of king mackerel in the Gulf of Mexico are approximately 2000 metric tons annually with a market value of about $5 million. Recreational landings are approximately 700 metric tons/year. While there is presently considerable scientific interest in the mackerel fisheries, we believe that the research questions, data requirements and sampling problems are generally applicable to most coastal pelagic species.

II. Recruitment and Fish Stock Dynamics

Four forces act upon fish populations to determine stock size. These are growth and recruitment, which tend to increase stock size, and natural and fishing mortality, which act to decrease the fishable population. The "equation of fishing", i.e., that the rate of fishing determines the catch, underlies population dynamic models used to predict the effects of different levels and strategies of fishing. While estimates of growth and natural and fishing mortality have been made, estimates of recruitment have proved to be intractable.

Recruitment, the process by which eggs are spawned, fishes hatch, survive and grow to a harvestable size, can and usually does, vary by orders of magnitude. Inadequate understanding of the factors that regulate recruitment, and the inability to predict recruitment, represent major obstacles to the development of population dynamics models that accurately simulate fishing effects and predict future stock sizes and yields.

We perceive two component objectives in recruitment research: (1) The ability to predict entry into the fishery; and (2) understanding year class variability and its causes. The first of these usually involves sampling to estimate juvenile abundance, then establishing the reliability of the estimate as a predictor of recruitment to the fishery. This process is intended to provide managers with estimates of new recruits which can be used in stock assessments to adjust harvest levels. The process, however, does not provide a means to identify the causal mechanisms that determine year class strength.

The consensus of the working group was that three factors contribute to the largest extent to the success or failure of a year class: (1) feeding success, (2) predation, and (3) transport. Physical variability in the ocean (ranging from major ocean climate events, such as el Nino, to small scale phenomena, such as local wind events, fronts and upwelling) has important consequences for all three factors (Legendre and Demers 1984). These coupled oceanographic-meteorological phenomena influence early life history stages of coastal pelagic fishes in a variety of ways (cf. Lasker 1981).

III. Issues for Research

It was the consensus of the working group that the recruitment of coastal pelagic species reflects the impact of both trophodynamic and environmental processes upon the organism during the early larval period. It follows that research must focus on evaluation of the association between young fishes and potential aggregating and survival enhancement features or mechanisms (e.g., fronts). Efforts must be made to describe and understand the spatial and temporal variability in larval growth and mortality associated with predator and prey densities and with environmental forcing functions.

Lastly, it is important to point out that a major need in future research is for the ability to sample all size and age classes in coastal pelagic fisheries. Presently, no reliable means exists for representative sampling of the large larvae and juveniles of many coastal pelagic species. Innovative use of traditional gears (e.g., small mesh gill nets; small mesh purse seines) and creative development of new sampling methods (e.g., high speed trawls) provide fertile ground for future technological development.

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Report of the Working Group on Reef and Benthic Fisheries

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I. Introduction

The reef resources task group met on 16 and 17 February to discuss reef resource recruitment in Florida waters. This report summarizes the collective group opinion on various aspects of recruitment. Although recruitment can be defined in many ways, the group used the term in the general sense as the resupply of organisms into a population. The task group concluded that increased attention should be directed at recruitment phenomena.

II. Results

A. Reef Fauna Characteristics

General characteristics of fauna from reefs and hard bottom areas include planktonic dispersal of eggs or larvae, occupation of a series of different habitats for different life history stages, and populations that undergo cyclic fluctuations of abundance. Most harvested species are characterized by a suite of life history traits that include long life, slow growth, large size, low natural mortality during demersal phases, and iteroparity.

Reef habitats are widely distributed and important in Florida. Local ecological conditions are different and large enough to justify dividing the state into three to five regions for the purpose of recruitment studies. The major regions suggested include northeast Florida, osuthern Florida, and northwest Florida.

B. Targeted Species Research Efforts

A preliminary listing of possible target species for potential research was assembled by region. Suggestions were black sea bass (*Centropristis striata*), vermillion snapper (*Rhomboplites arorubens*), and red porgy (*Pagrus pagrus*) for northeastern Florida; grunts (*Haemulidae*) and spiny lobster (*Panulirus argus*) for southern Florida; and gag grouper (*Mycteroperca microlepis*) and red snapper (*Lutjanus campechanus*) for northwestern Florida.

These targeted species were selected based on their economic value, known information, widespread distribution in reef habitat, regional abundance, and their potential to be appropriately tractable for answering questions about interactions between oceanography and population dynamics. Most species were selected as possible recruitment models primarily because they could provide information for predictive fishery purposes that would be applicable to a suite of species. Grunts were suggested because of their wide distribution and tractability to sampling, the short larval duration, and their potential usefulness for theoretically oriented studies. Also they are diverse, easily sampled, and apparently not overfished in Florida. Gag grouper were selected in part because much of the life history is known and prejuveniles are accessible to monitoring during ingress and egress from estuaries. Also, they are subject to coastal front conditions, current transport, and are potentially topographically constrained by gyres.

Although the group picked target species for study, they emphasized the simultaneous need and importance of research on reef habitat, the reef ecosystem, and reef species complexes. The task team noted the danger in targeting only certain species for study. Examining specific species without monitoring competitors, predators, other fish species, food resources, and habitat quality may be doomed to failure. For example, plankton predators may limit recruitment via the "wall of mouths" hypothesis. Could jellyfish abundance determine jack recruitment success?

Long term monitoring was concluded to be important for the ultimate understanding of the cause and effect relationships of recruitment variability. Research should be a mix of long term and short term studies. Some studies could have rapid payoffs in terms of management advice, e.g. an index of juvenile gag grouper during their estuarine resident phase could predict recruitment to the reef fishery one or two years later.

Knowledge of planktonic duration was recognized as important for defining scales relevant to individual species and physical transport.

Priority for study should be given to species most likely to be impacted by coastal modifications and human impacts (i.e. lobster are affected by siltation, mosquito spray, habitat alteration, fishing mortality, coastal development, etc.).

III. Specific Research Considerations

The task group concluded that prioritizing goals was impossible because of variations in funding, research difficulty, variations in proposal strength, unpredictable local research opportunities and differences in researcher capabilities and resources. The task team did make specific recommendations to guide recruitment research efforts and funding which are listed below:

1. Emphasis should be placed on key questions that are broadly applicable to several species.

2. Increased basic information is needed on life history parameters and natural history for specific species.

3. Length of larval life needs to be determined for given species and regions to set appropriate time scales for further study.

4. Ontogenic information is needed for taxonomic identification purposes for many species, especially for larvae.

5. Museum collections were recognized as important sources of data that needed additional support.

6. Better descriptions were needed involving physical oceanographic transport mechanisms with emphasis on the Loop Current, cross shelf tansport, the Florida Current, Charleston Bump Gyre, etc.).

7. Behavioral studies are important to explain actual distributions which often differ from passive transport trajectories.

8. Recruitment sources and sinks needed to be better identified.

9. The effects of fisheries on the spawning stock biomass needs greater attention with regard to the supply of larval recruits and fecundity.

10. Genetic studies are needed for better stock identification.

11. Many of the recruitment problems were recognized to be international in scope because of widespread distributions and long distance transport capabilities among species. Progress and resolution of these problems requires greater international cooperation, coordination, and investigation.

12. Research and monitoring should emphasize hypothesis testing rather than blind data collection.

13. Links need to be defined between habitat and occurrence and shelter and food availability.

14. Available databases should be searched for environmental correllations with abundance cycles.

15. To make progress on recruitment problems, many grants will need to be larger and for longer terms than the one or two year grants currently favored.

16. Research should be directed at distinguishing between human and naturally induced recruitment variability.

17. Research should determine whether successful recruits are random survivors or a definable cohort subset.

IV. Worksheets

The task group drafted study sample worksheets for some target species that were intended to be representative but not exclusive of possible research targets.

SPECIES: Lutjanidae (snappers)
REGION: All Florida

ADVANTAGE FOR STUDY:

GENERAL: Important, common, locally abundant, settlement habitats vulnerable to human coastal disturbances.

SPECIFIC DATA AND RESEARCH NEEDS: (not prioritized)

1. Determine larval duration, age and growth of early juveniles.
2. Determine survival during pre-settlement transport phase.
3. Describe functional relationships between settlement and distribution and quality of juvenile habitat.
4. Determine survival rates in secondary (pre-adult) habitat.
5. Describe taxonomy for larvae less than 15 mm.
6. Determine spawning locations and behavior.

SPECIES: Panulirus (lobsters)
REGION: Southern Florida (Pan-Caribbean)

ADVANTAGE FOR STUDY:

GENERAL:

1. Economically important.
2. Subject to impacts from human coastal modifications.
3. Abundant populations.
4. Much information already available.

SPECIFIC DATA AND RESEARCH NEEDS:

1. Distribution, population structure, movements, and reproductive patterns of adults and late juvenilesare well known in Florida.

2. Considerable information is available on newly settled and algal dwelling stages.

3. Temporal patterns of inshore invasion by postlarvae and their entry into Florida Bay via channels between islands from the the Atlantic side of the Keys is well documented.

ESSENTIAL FUTURE RESEARCH NEEDS: (not prioritized)

1. Determine distribution and dispersal processes of postlarvae in Florida Bay. This includes information on current flow patterns, length of postlarval life, behavior, algal habitat, distribution, and sources of mortality.

2. Determine source regions for Florida stocks. Seek international cooperation for potential upstream sampling of parental stocks.

3. Determine ecology, distribution, and abundance of juvenile stages between algal-phase and about 50 mm carapace length. Emphasize habitat needs and sources of mortality at these stages.

4. Develop and test predictive models of fishable stocks based on setlement patterns, mortality estimates, and juvenile habitat extent and condition.

5. Promote research on usable methods of identification of oceanic phyllosomas (electrophoresis, mitochondrial DNA, meristics, etc.).

6. Determine oceanic transport mechanisms and local behaviors that regulate larval recruitment importance to Florida. This includes current studies, and rates and depths of vertical migration at specific larval stages. (Australia has used this approach).

7. Determine advactive processes and transport from the Florida Current into the reefs.

8. Validate methods of measuring postlarval settlement into Florida Bay and subsequent movements and distribution.

Report of the Working Group on Estuarine Fisheries

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I. Introduction

Of the four regions considered in this workshop, estuaries are perhaps the most complex in terms of factors leading to recruitment variability in fishes and macro-invertebrates. This complexity is due to the diversity of species, life history stategies, and habitats. On the other hand, estuaries are somewhat more readily sampled from a logistical and economic point of view (i.e., many of our laboratories are located on estuaries, and the waters are generally shallow), even though obtaining quantitative samples in most important habitat types is difficult.

The importance of studies of recruitment variability in estuarine species cannot be overstated due to the great overall economic importance of many species, coupled with their great vulnerability to anthropogenic perturbations. We would suggest the following list of critical areas for future research to be considered by funding agencies: evaluation of the state of our knowledge regarding recruitment-related factors in the life history of Florida's estuarine fishes; generation of long-term data bases; studies of single species or guilds which concentrate on description of early life history stages, collection of basic early life history data, determination of important habitats and habitat selection mechanisms; ecosystem studies which concentrate on interacitons among species and system energy flow patterns; development and evaluation of quantitative, habitat-specific and species-specific collecting gear. This list is not meant to be exhaustive, but we feel that it does indicate some of our major needs for successful management of Florida's estuarine fish and macro-invertebrate communities. Some of these needs are considered in more detail below.

II. Research Needs

A. Data Base Evaluation

The first priority for estuarine recruitment research, as with all research, is the evaluation of what is currently known about the subject. This effort should include an assessment of existing literature, data bases, and archival collection resources in order to develop a data matrix indicating the state of our knowledge regarding recruitment-related factors in the life history of Florida's estuarine fishes. This information is relatively cheap to obtain and can save money in the long run by preventing duplication of effort.

B. Long-term Data Acquisition

An often recognized priority for recruitment research is the development of long-term data bases. Such work is expensive, tedious, and requires a dedicated, well-trained staff. Nevertheless, it is absolutely essential for our understanding of natural variability in recruitment and as baseline data for understanding the effects of various perturbations on estuarine systems. In order for these studies to be of value, funding agencies must be willing to commit to long-term funding with the understanding that maximum benefit of the research will not be realized for at least several years. Funding agencies should also encourage managers of long-term studies to make specimens, data, and other resources available to other researchers whenever possible in order to derive maximum benefit from funds committed to these projects.

C. Life History Studies

One area of research that could benefit greatly from data and specimens collected in long-term projects is the general area of early life history research on estuarine species. Basic data such as descriptions of egg, larval, and juvenile stages; spawning location and time; and age and growth of early life history stages are lacking for many abundant species in Florida estuaries. A complete egg-to-adult series has not been described for many Florida species, and no comprehensive guide exists for the identification of the early life history stages of Florida fishes. Spawning season and location as well as basic age and growth data are available for some species (especially those of direct economic importance), but most growth data are at the level of annual growth and, thus, may miss important early life history events. Also, almost no attention has been given to geographic variation in life history patterns within species. This type of research obviously provides the foundation of basic data upon which all other recruitment-related research must be based.

D. Fishes in the Environment

1. Physical and chemical -- The effects of physical/chemical regimes on movement and survival at all life history stages have rarely been studied in detail for any species. For example, current and precipitation patterns occurring at critical periods in the animal's life history can affect locality of settlement and, thus, amount of suitable habitat available for a given year class. In other words, if current patterns in a given year carry

larvae of a seagrass-dwelling species into areas with no seagrass, recruitment of that year class should be affected. Similarly, heavy rains during the recruitment period of a species showing strong salinity preferences might either increase or decrease the amount of available nursery habitat. These relationships can again be best studied with long-term monitoring of physical/chemical factors along with population fluctuations among fishes.

2. Habitats -- Studies to determine critical nursery habitats and the behavioral means for locating these habitats among estuarine fishes are also of critical importance. Such studies have generally concentrated on structural habitats, but other physical/chemical features should also be considered. Furthermore, most studies to date have merely documented habitat utilization as opposed to preference, selection, or behavioral mechanisms for selection. The relevant scales for conducting such studies also need to be considered. For instance, in a study of fishes in seagrass habitats, is the relevant scale seeagrass versus unvegetated substrate or should comparisons be made among species of seagrass or among sites containing the same species of seagrass but under different hydrological conditions.

3. Ecological interactions -- Another cause of recruitment variability that is extremely complex and, therefore, difficult to quantify is the various levels of interaction among populations in the estuary. Even if all chemical and physical factors were held constant, recruitment success of a given species would still depend on population density of prey and competitors. Thus, ecosystem-level studies are necessary to clarify food webs and determine important competitive interrelationships. Such studies can rapidly expand beyond reason for any funding agency, and, therefore, the determination of appropriate temporal and spatial scales for recruitment-related ecosystem studies is a critical problem. Areas of special concern would be levels of food availability for early life history stages of species of interest as well as the determination of bottlnecks in ontogenetic development since these life history stages may have a disproportionate effect on subsequent year class strength.

III. Technology Needs

Much of the above-mentioned research requires adequate means of quantitatively collecting estuarine fishes in a variety of habitats. We could fill quite a few pages with descriptions of sampling gear that has been designed to collect estuarine fishes. The basic need is to find a sampling gear that gives a true representation of the fish community in such diverse habitats as seagrass, mangroves, cordgrass, shellfish beds, seawalls, open sand to mud bottom, channels, etc. The basic problems are quite familiar to anyone who has conducted ecological studies in estuaries: no gear functions in the same manner in many different habitats, and no gear functions with the same efficiency for all fish species. In practice, therefore, strictly quantitative studies must generally be limited to few habitat types and a particular species or guild. Ecosystem-level studies must include multiple gear types, and meaningful comparisons can often only be made using rank abundance and/or frequency of occurrence. Development of new habitat-specific and species/guild-specific gear types for quantitiative, estuarine sampling needs to be an ongoing process and requires continued funding.

All of the data produced by new gear types and the above-mentioned studies should be used to generate and test hypotheses relating to life history bottlenecks for particular species. Questions generated will deal with population fluctuations at various life history stages and/or recruitment variability in relation to various life history strategies or environmental variables.

IV. Anthropogenic Effects

Finally, a critical area for research in Florida estuaries is the study of the effects of man's activities on recruitment success. Activities of interest include various types of construction (e.g., the building of spillways, seawalls, causeways, marinas, etc., as well as channelization), degredation of water quality through production of effluents, and changing of physical/chemical regimes by such activities as regulation of freshwater flow. Considering the rapid rate of coastal development in Florida, all of the above-mentioned studies need to be designed with these anthropogenic influences in mind.

Part II. Abstracts of Participants

Are reef fishes fruit trees? -- The marine wilderness strategy

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Fishery practices that maximize biomass or economic returns may exploit reef fishes without adequate consideration of interspecific interactions, reef fish life history strategies, and the evolutionary responses to intraspecific genetic diversity. Fishing mortality selectively depletes older and larger individuals and may have become a major evolutionary selective pressure for many reef fish species. Reef fishes are characterized by slow growth, long life, low natural mortality, and iteroparity. Evolutionary theory predicts that these life history characteristics are selected under conditions of high uncertainty for prereproductive survival and relative stable survival of reproductives. Fishing mortality is predicted to select for life history characteristics of short life span, small size, and early reproduction. Under intense fishing mortality, some species may face acute recruitment failure, phenotypic shifts, and loss of intraspecific genetic diversity, which could be disastrous to reef fish fisheries. Permanent marine wildernesses, areas protected from consumptive exploitation, could provide areas with stable population age distributions and natural community structure. Such areas will help protect intraspecific genetic diversity, maintain ecological balance, and ensure against recruitment failure. Economic, social, and fishery benefits may exceed fishery costs.

The Gulf Stream front, its role in larval fish survival and recruitment in Florida

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The Gulf Stream is a pervasive mesoscale feature in the North Atlantic that has a significant impact on the oceanography, meteorology and biology of this ocean and the adjacent coastal regions. It is hypothesized that, off southeast Florida, the recruitment success of many fishes is influenced by the dynamics of Florida Current cross shelf transport and by the habitat characteristics of the Gulf Stream front.

A multi-institutional, interdisciplinary program, involving biological and physical oceanographers will examine, through coordinated field and laboratory experiments and sampling, the frontal region of the Florida Current off Broward County. The program will seek to ascertain: (1) the suitability of the Florida Current shoreward front as a larval fish habitat (relative to regions on either side); (2) some of the fluid-dynamic characteristics of this region that could influence the transport of fish larvae to nearshore and estuarine environments. Moored instruments and cross shelf transects will be used to describe pertinent aspects of the physical and biological environment with a resolution that reflects the intra-annual frequencies of energetic variability in cross-shelf transport. Methodologies will be combined to describe the time varying strength of the front and the biomass composition of larval fish, the microplankton assemblage and the predators present within and on either side of the front. Bioassays will be used to determine how the survival and growth of larval fish are affected by the composition and abundances of food typical of frontal and non-frontal regions.

Aspects of the biology of the Nassau grouper, *Epinephelus striatus*

Patrick L. Colin, Caribbean Marine Research Center and Lee Stocking Island, Bahamas

The Caribbean Marine Research Center is engaged in a program of fish resource ecology in the Bahamas with emphasis on western Atlantic groupers. The program is designed to investigate the entire life history of the local groupers, particularly the Nassau grouper, in order to obtain biological information useful in resource management. In this regard the research includes work on spawning, larval development (both at sea and in the lab), recruitment, juvenile and adult life with regard to oceanographic factors. Progress to date (since January 1988) has included collection of adults from spawning aggregations, documentation of spawning, ichthyoplankton collections in areas of spawning, laboratory larval rearing work, and monitoring and collection of recruits. Initial results will be summarized.

Unifying concepts in recruitment

Larry B. Crowder, Department of Zoology, North Carolina State University

In this presentation, I will focus on the mechanisms influencing recruitment variation in fish populations. Mechanisms previously considered to be alternative hypotheses (e.g. starvation, predation, advection) interact and must be considered jointly. Body size and growth dynamics of larval fish explain a substantial portion of the variation in the ecological performance of both freshwater and marine fish larvae. Future recruitment research should focus on the unique characteristics of survivors rather than on the sources of mortality for the large number of fish that die. New techniques including otolith analysis and individual based modeling will prove useful in understanding recruitment variation. Recruitment variation is often correlated with both short and long term environmental variation, but different empirical approaches may be necessary to address questions at the different temporal scales. The future of recruitment research will require diverse, but integrated, approaches to the problem.

Reduction and shifts in occurrence of larval and juvenile Sciaenidae in the lower St. Johns River, 1980- 88

Carole DeMort and Jan Murphy, Coastal Fisheries Laboratory, University of North Florida

The occurrence and distribution of larval and juvenile members of the family Sciaenidae have been studied from 1980-88 in the lower St. Johns River from Green Cove Springs to Sisters Creek. Collection methods included plankton nets, hoop nets, seines, and otter trawls. Preliminary analyses of the data indicate decreases in total number of larvae collected from the sampling areas and significant decreases in the juveniles of most species within the family. This study also indicates a shift in maximum population densities of both larval and juvenile stages of spot and croaker from the lower river stations to the more northern sites within the study area. All members of the genus *Cynoscion* appeared to be decreasing in numbers of juveniles collected at all stations. However, since 1986-87, the number of juvenile silver perch and star drum appear to be increasing within the study area. This is part of a larger juvenile fin-fish- shellfish study that is being carried out in cooperation with the Florida Game and Fresh Water Fish Commission.

The importance of early-juvenile habitat to Florida Fishery Recruitment

Randy E. Edwards, Mote Marine Laboratory

Traditional recruitment theory for marine fishes has focused on processes like egg production, larval feeding, growth, predation, transport and dispersal, with recruitment being largely determined by the end of the larval stage. There is little doubt, for marine fishes having planktonic larval stages, that these processes are very important to recruitment. For certain pelagic or open-sea fishes, recruitment may be almost totally determined by processes occurring during the larval stage. However, the life history of many marine and estuarine fishes includes another stage that is critical to recruitment. This stage can be termed the early- juvenile (EJ) stage and usually includes a period of many weeks following metamorphosis.

During the EJ stage, many species have requirements for very specific types of nursery habitats that are very different from those of larvae, later juveniles and adults. Although, for a number of important species, these habitat relationships are not yet fully known and understood, in most cases they involve very shallow, marginal and fringing habitats. In the case of estuarine species, these EJ habitat relationships also often involve low salinity conditions. Nursery habitat relationships such as these have been at least partially elucidated and documented for several important estuarine fishes, including red drum, snook and striped mullet. Comparable EJ nursery relationships probably exist for many coastal species (e.g., grouper, snapper and other reef fish), but are not as well known. Overall, there is a high likelihood that the recruitment of many commercially, recreationally and ecologically important species is potentially limited by availability of suitable EJ nursery habitat and by processes occurring during the EJ phase.

Another important and practical reason to begin to analyze relationships between EJ habitats and recruitment is that these habitats, because of their shallow/fringing character, are highly subject to anthropogenic alteration and destruction. In Florida, many of the most important fisheries could become diminished and totally limited because sufficient productive EJ nursery habitat is no longer available. In view of the State's rapid population growth and attendant environmental impacts, analyses of early-juvenile nursery habitat relationships should be given high priority in efforts to understand and predict fishery recruitment in Florida waters.

Predicting fishery recruitment: Florida, the southeast, the nation

Eugene Fritz, National Seagrant Office

The fisheries resources of the United States are, with a few notable exceptions, products of coastal ocean waters and adjacent estuaries. These resources support the Nation's major industries. However, fish populations and communities fluctuate, sometimes substantially, from year-to-year and to even greater extents on longer intervals (interdecadally). This variability and lack of knowledge of its causes reduce the effectiveness of resource management and cause economic dislocations so characteristic to fisheries.

A major goal of fisheries science is the accurate prediction of the status of species for both short-term (inter and intra-annual) and long-term (interdecadal) time periods. Most of the existing forecasting methods are known to be inadequate, particularly in regard to long time scales and radical population change. Short- term predictions are needed to better set harvesting levels and conditions (timing, place, etc.). Long-term predictions are essential in identifying the booms, collapses, and changes in community structure that cause the major dislocations in fisheries. Recruitment is the process by which young fish (or shellfish) are added to the adult or fished stock, and is, therefore, the essential process on which the continuity of a fishery depends. Evidence to date suggests that recruitment variability is intimately linked to the physical dynamics of the oceans and large-scale climatic fluctuations. Fisheries scientists throughout the world have identified recruitment fisheries oceanography as the most important topic in fisheries science, and the key to accurate predictions.

A research program on fisheries recruitment not only has the potential for improving fisheries management responsibilities, but also for improving man's understanding of the linkages between the physical environment and the ocean's productivity.

Seagrass, mangrove swamp and herbaceous halophyte marsh fish communities, spatial and trophic guilds, faunal overlap, population dynamics and the importance of relative habitat associations.

R. Grant Gilmore, Harbor Branch Oceanographic Institution, Inc.

Extensive long-term fish collections, using a variety of innovative techniques, have provided new information on the nature of fish communities inhabiting seagrass, mangrove swamp and herbaceous salt marsh habitats. The distribution of fishes over a variety of physical, hydrological and structural gradients in all habitats has been found to be highly predictable. However, the relative abundance of various species has been found to be variable from one annual cycle to another. Despite quantitative changes in populations, a predictable occurrence of various spatial and trophic guilds is described from all habitats. Species replacement within these guilds occurs on environmental gradients which are often of greater importance than qualitative vegetative change in habitat.

As the definition of microhabitat associations of most common species show high predictability, it is recommended that the more complex problem of annual, quantitative variability in population be considered of high priority in future research activities. This problem has to be approached with a long-term interdisciplinary research program which places priority on climatic and hydrological conditions, particularly during periods of high mortality, i.e., periods of larval transit from spawning sites to juvenile habitat. Predatory pressures, trophic competition and resource availability, along with a variety of other ecosystem factors which are critical to species survival, need to be isolated before a rudimentary understanding of population fluctuations can be obtained.

Predation on Juvenile Spiny Lobster: Who's been eating our lunch?

William F. Herrnkind, Mark J. Butler IV, and Kenneth Smith, Florida State University

Present knowledge suggests that, by far, the greatest natural mortality in spiny lobsters occurs during the 6-plus month, planktonic phyllosoma period. True or not, impacts on this part of the life cycle are pretty much beyond human control and even useful measure. It is when the post-larval stage comes inshore that we can first assess its condition and, hopefully, conserve the recruits. At present, we conserve mainly by protecting the "nursery" habitat; perhaps later we can enhance recruitment by increasing settlement, or survival without understanding the source of natural mortality on the post-larvae and juveniles. Conditions and events contributing to mortality probably include as yet undocumented effects from abiotic stresses, such as seasonal or apeariodic salinity reductions, low O_2, and severe low temperature. Continuous impact probably arises from predation. The questions become, at which age and to what extent? Postlarvae can be effectively hunted by piscine and invertebrate predators in a wide array of microhabitats: in sandy substrate-portunid crabs; just above the substrate -squirrel fishes; midwater - yellowtail snapper, amidst vegetation - white grunts, gray snapper. Many other species are certainly among the gauntlet run by postlarvae between the reef and inshore algae beds. Predation on juveniles decreases with age (size) but may remain surprisingly high through the first half year of benthic life. Factors involved include shelter type and distribution as well as the type and number of local predators. In the Keys the latter include nurse and bonnethead sharks, and sting rays.

Estuarine spawning of the red drum in Mosquito Lagoon on the east coast of Florida

Darlene R. Johnson, Department of Fisheries and Aquaculture, University of Florida, and

Nicholas A. Funicelli, National Fisheries Research Center, U.S. Fish and Wildlife Service

A study was initiated in the fall of 1987 to determine in red drum were spawning in Mosquito Lagoon, an estuary on the Florida east coast. Weekly plankton tows to collect eggs were taken from mid-September to mid-November, and floating fish eggs were removed from samples and incubated for 16-36 hours. Three hundred and twenty-nine red drum larvae were hatched. Red drum eggs were collected over a four-week period from October 27 to November 18. Catch salinities ranged form 29 to 32 ppt, while catch temperatures ranged from 21 to 23 C. This is the first documentation of red drum spawning in an estuary. Mosquito Lagoon red drum may be more estuarine-dependent than red drum in other estuaries.

Cross-shelf distributional ranges of newly settled Haemulids and Lutjanids (18 species) among several habitat scales and techniques for collecting, visual surveying and field/aquaria manipulation

Ken Lindeman, Division of Biology and Living Resources, University of Miami, RSMAS

To determine complete spatial ranges of larval settlement and early habitat associations, distributions and abundances of early life stages of 5+ genera of grunts and snappers have been examined among barrier island and mainland channel sites of Bear Cut, Jupiter Inlet, Snake Creek, and adjacent areas of SE Florida for two to four years. Primary sampling stations include most habitat types within a windward barrier island to mainland tidal creek gradient of coastal lagoon communities of northcentral Biscayne Bay. Habitats surveyed include red mangrove overwash islands, adjacent ecotones of attached and drift grasses and macroalgae, grassbed blowouts, and other sedimentary, invertebrate, and shoreline tree habitats. Several survey methods are required to adequately sample settling larvae and juveniles among this diversity of fine- and cross-scale structural habitats. When cryptic behavior or identification problems require benthic collection, particularly useful devices include handnets paired with hand-held Nitex screens or wheel-mounted pushnets. A variety of settlement trap and net designs are discussed relative to specialized water column and benthic sampling needs. Visual surveys often require inspection of complex microhabitats for transparent 8-12 mm fishes. Resolution is optimized by staying close to the substrate to backlight epibenthic larvae, sampling at MHW ± 2 hrs., and the use of lights and angled mirrors when required. High resolution discrimination *in situ* of both sizes and species are critical tools and should be tested and refined for accuracy. In some genera, distinctive pigment patterns are fine size references. Live individuals of many species can be readily transported from water to boat to aquaria in 6 oz. museum jars. Lab or field manipulation to examine habitat utilization and feeding among common multispecies assemblages of settling stages is a ready opportunity.

Mangrove root habitats of windward channels of Bear Cut, N. Key Largo, and Snake Creek were used by juvenile or newly settled life stages of over 65 species within 29 families of coastal marine fishes during this study. Of these, 43 species are commonly considered "reef" fishes. Both small, individual *Rhizophora mangle* trees and substantial overwash islands comprise of several intergrown trees can support large relative abundances of at least 9 species of haemulids and lutjanids. These species and _Abudefduf saxatilis_ can continuously use these habitats for all or most of the year. Total densities can reach 20+ inds./m^2 prop-root and associated water column habitat. Similar patterns are also present in mangroves of channel and backreef communities of emergent reef lines of SW Puerto Rico. Attached sea grasses and algae, piles of various detached macrophytes, and adjacent sedimentary habitats appear to be primary settlement sites for larvae of many species. Colonization of mangrove root habitats in many species is usually via post-settlement immigration by early juveniles. Periodic tide and storm induced disturbance events can limit abundances of all life stages of most species.

Newly-settled larvae and schools of early juveniles of at least 7 species of _Haemulon_ and _Lutjanus_ are more abundant in euhaline estuaries or backreef lagoons than mid-shelf reefs. It is predicted that two main factors, transient use of mid-shelf habitats by larvae, and predation mortality on mid-shelf reefs, determine the observed higher estuarine and backreef abundances of newly-settled and early juvenile stages -- the actual mechanisms being differential survivorship among communities, behavioral avoidance of deeper environments, or a combination of both factors. Since within-habitat abundances can differ greatly among physiographic communities, evaluation of nursery habitat values will be highly site-specific for many reef and estuarine species.

Use of otoliths to determine the age and growth of spotted seatrout

Michael J. Maceina, South Florida Water Management District

Age and growth was estimated from sectioned otoliths for 426 Spotted Seatrout *Cynoscion nebulosus* collected from Galveston Bay, Texas. Marginal increment measurements showed that a single annulus formed on the otolith during March and April. Agreement between two independent readers for annulus counts was 99%, suggesting that age interpretation from sectioned otoliths was precise. Maximum longevity reported by other workers using scales was generally six to eight years with one specimen reported to be 10 years old. In this study, I interpreted 12 annuli in one male fish, thus extending the maximum age known for this species. Spotted seatrout grew considerably faster in Galveston Bay, Texas, compared to the Gulf of Mexico in Florida. This variation in growth rate may be due to genetic differences or environmental conditions. However, this discrepancy may also be due to differences in annulus interpretation between scales and otoliths.

SEFCAR: The University of Miami's southeastern Florida and Caribbean recruitment study

Michael F. McGowan, Division of Biology and Living Resources, University of Miami

Beginning in 1989, a multidisciplinary program to study recruitment of reef fishes and lobsters to the Florida Keys will focus on the effects of coastal oceanography on distribution, periodicity, and intensity of subsequent recruitment. Separate components of the study will include plankton collecting, monitoring settlement of juveniles, biochemical characterization of population genetics, laboratory experiments on reared larvae, documenting the physical oceanography on multiple time and space scales, and synthesis through simulation modelling. Interactions between a gyre, coastal countercurrents, and vertical migrations of larvae and juveniles will be considered. SEFCAR will interface with and complement ongoing research at other Florida universities and by state and federal agencies. Anticipated results should be generally applicable to downstream regions such as the South Atlantic Bight and to upstream regions in the wider Caribbean, in addition to helping to understand and predict recruitment of coastal species in Florida.

Drum prior to recruitment to the offshore spawning population

Michael D. Murphy and Ronald G. Taylor, Florida Marine Research Institute

Current management of red drum in Florida is designed to increase recruitment to the offshore spawning stock by reducing fishing pressure on the inshore subadults. Although age-structured simulation models have been used to predict management-associated increases in abundance, direct evaluation of the effectiveness of these regulations has not been made. During October-November 1988, the abundance of post- exploited-phase, subadult red drum was estimated for a 6- sq. mi. area of lower Tampa Bay using tag-recapture data. Movement and length frequency data suggested the population examined was essentially closed to recruitment or emigration during this period. Thorough random mixing of tagged fish with untagged fish also appeared to occur within the prescribed sampling area. An estimate of abundance for catchable, post-exploited- phase subadults was 4,647 (95% confidence interval: 3,932-5,680). The efficacy of tag-recapture programs for monitoring recruitment of red drum to the spawning stock depends on 1) the spatial coverage required during tagging for estimates of relative abundance to be representative of the entire population, 2) the precision of abundance estimates, and 3) the strength of the correlation between post-exploited-phase subadult abundance and spawning stock recruitment.

Pro-active management: Will the lights come on in Florida?

Russel Nelson, Florida Marine Fisheries Commission

Florida's estuarine, coastal and oceanic waters encompass more than 8,000,000 acres along a 1170 mile coastline and support thousands of invertebrates, fish, reptiles, and mammals. Over 120 species of fish and invertebrates are harvested on a regular basis in the state. Commercial and recreational fishing industries which depend upon these resources generate almost $6 billion annually in expenditures and revenues in Florida. Unfortunately, the current state of knowledge is insufficient to allow for efficient, pro-active management of renewable marine resources.

Fisheries management in Florida is beginning to move beyond the stage of crisis intervention. With the prospect of funding available from a saltwater fishing license, managers are looking forward to augmenting current catch and effort data with area-specific fisheries-independent surveys of juvenile and adult abundance and distribution. In order to use the data generated by these efforts to develop a comprehensive, predictive management capability, we must have a reasonable understanding of basic life history characteristics, population dynamics, and recruitment dynamics. The Marine Fisheries Commission has developed a matrix of information needs identifying areas in which we lack adequate data on the biological, ecological, and physical factors affecting the abundance and production of renewable marine resources in Florida. This matrix may serve as a starting point for defining future research goals associated with the recruitment initiative.

In order to effectively assess the effect of current management plans and to move towards a predictive management capability, we must increase our understanding of the generic, as well as species-specific, elements which control recruitment variability in coastal and oceanic pelagics, inshore estuarine-dependent species, reef fishes -- especially the upper level predators which sustain the directed fisheries, and transgressive species such as spiny lobsters, tarpon, and bonefish with long- lived larval stages and the potential for stock:recruitment relationships over large geographic areas.

Lessons learned from the grunts: Observational studies of recruitment

John C. Ogden, Florida Institute of Oceanography

The events immediately surrounding recruitment are critical in the determination of the adult population size and the composition of communities of coral reef fishes. Grunts (Haemulidae) are ideal subjects for observation as they have a very short planktonic larval life compared to other coral reef fishes, are relatively easily identified, collected and manipulated in the field, and are prolific in recruitment through broad periods of the year. Our studies over a number of years at the West Indies Laboratory in St. Croix, involving many students and colleagues, were designed to discriminate the importance of recruitment rate and post- recruitment mortality in the determination of adult population size.

In a long-term observational study, we monitored recruitment and population densities of the juvenile size classes of the French grunt, Haemulon flavolineatum, from October 1978 through December 1980, in a portion of the reef and associated lagoon in Tague Bay, St. Croix. The mean annual recruitment rate for the French grunt is among the highest yet reported for reef fishes: 44/m2 adult habitat/yr. Post-recruitment mortality in this species is also very high: 0.9 during the first month of benthic life. Fewer than 8 out of every 10,000 recruits survived for one year. Using an open, density- independent model of benthic population dynamics for French grunts, Shulman and Ogden (1988) estimated that changes in the post-recruitment mortality rate had a much greater effect on the abundance of adults than did a proportionate change in the recruitment rate. This same analysis was applied to other coral reef fishes for which appropriate data are available. For 2 out of 3 species for which recruitment limitation has been demonstrated, the same conclusion was reached.

As potentially important as such models are to the understanding of population dynamics in fishes, studies of recruitment with relevance to management must expand their temporal and geographic scales in order to reasonably encompass the appropriate time-space scales of the process of recruitment in the target species. For the French grunt, these scales are as compressed, and therefore as tractable, as we can expect to find in a coral reef fish. Nevertheless, successful realization of studies at this level will require unprecedented coordination and integration of investigators and institutions.

Physical aspects of fishery recruitment

Donald B. Olson, Rosensteil School of Marine and Atmospheric Science, Division of Meteorology and Physical Oceanography

Recruitment is dependent upon transfers between source regions for potential recruits and the final environment where an organism is going to exist in a given life stage. In the marine environment, this process is often controlled by the nature of flows found in given regimes and the degree of mixing that occurs between environments. This control may be direct, as in the case of planktonic forms, or indirect in the situation where an organism actively migrates but is still dependent upon navigational queues which are effected by the fluid motion. While the drift of inert particles provides a first approximation to the redistribution of plankton in general, behavior is important in both of these types of interaction with the physical environment. The Florida marine environment can be separated into three distinct regimes: the pelagic environments of the Gulf of Mexico and Florida Current, the shelf, and the semi-enclosed bays and rivers along the coast. Recruitment occurs in both directions between these regions. The physical mechanisms for exchange within and between these three regimes are briefly discussed along with some of the possible ways in which organisms can exploit or, alternatively, eliminate the effect of these processes. FInally, conditions in the Florida Environment are contrasted with the more completely understood conditions on the U.S. northeast and west coasts.

Recruitment analysis program for the Little Manatee River/Tampa Bay estuary

Ernst B. Peebles, USF Department of Marine Science

A two-year database is being collected with the purpose of identifying environmental factors associated with successful recruitment of the early stages of estuarine-dependent fishes into nursery habitat. Otolith microstructure will be used to compare birth-date frequencies calculated from larvae and juveniles from the same cohort. A general length-frequency derived mortality curve will be used to help compensate for mortality effects on abundance within each stage. Discrepancies between the birth-date frequencies of the ontogenetically-discrete samples will then be used to generate time-series data for survival during protracted spawning seasons. The survival data will be used in a time-lag correlation function with physical and biotic data to identify important environmental factors. A wide range of variables will be available for this analysis, including phytoplankton and zooplankton counts (food availability) and physical variables which might influence larval transport.

Roughly 80,000 fish specimens, constituting more than 65 species, have been identified from the first year's plankton collections. However, due to insufficient data for juveniles of many of these species (particularly those which are cryptic after the larval stages), the recruitment analysis will probably concentrate on sciaenid and clupeiform fishes.

Fishery research in Florida: A systematic approach to a diversity of problems

William Seaman, Florida Sea Grant College

The combined freshwater and marine fisheries of Florida constitute a multi-billion dollar activity. A high diversity of coastal and oceanic finfish and shellfish species are sought for commercial and recreational purposes, thereby compounding needs for scientific information on which to base management. As a means of ordering its own priorities for research, and to contribute to statewide planning of related programs, Florida Sea Grant is using a workshop format to identify information needs related to fishery recruitment in Florida waters. Technical working groups bring an international perspective to the identification of state priorities and ways to organize research and funding.

Part III. Appendices

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Appendix 2. Workshop Agenda

GENERAL PROGRAM

Wednesday February 15, 1989

14:00 - 15:15	Plenary Session
15:15 - 15:30	Break
15:30 - 16:30	Contributed Papers
16:30 - 16:45	Break
16:45 - 18:00	Contributed Papers
18:00 - 19:00	Dinner
19:00 -	Begin Poster Session
19:30 - 20:30	Contributed Papers
20:30 - 21:15	Discussion: Themes of the workshop
21:15	Social

Thursday February 16, 1989

08:00 - 09:00	Breakfast
09:00 - 10:00	Discussion: workshop goals and major questions Instructions to working groups
10:00 - 12:00	Working Group Session: Select working group leaders & recorders Identify important/representitive species
12:00 - 13:00	Lunch
13:00 - 14:00	Discussion: Initial progress reports
14:00 - 17:00	Working Group Session: Consider comments from discussion session Evaluate the existing data on recruitment of key species Identify physical processes important to recruitment of key species
17:00 - 18:00	Discussion: Identify generic and non-generic components of recruitment Describe principal data needs
18:00 - 20:00	Dinner