NOT TO BE CITED WITHOUT PRIOR REFERENCE TO THE AUTHOR(S)

International Commission for the Northwest Atlantic Fisheries

Serial No. 5179
(D.c.1)

ICNAF Res. Doc. 78/VI/21

ANNUAL MEETING - JUNE 1978

Report on the First Scotian Shelf Ichthyoplankton Program (SSIP) Workshop, 29 August to 3 September 1977, St. Andrews, N. B.

Sponsored by

Department of Fisheries and Environment
Marine Fish Division
Resource Branch, Maritimes
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

TABLE OF CONTENTS

Convener : P. F. Lett

Rapporteur: J. F. Schweigert

ABSTRACT

The Scotian Shelf ichthyoplankton workshop was organized to draw on expertise from other prevailing programs and to incorporate any new ideas on ichthyoplankton ecology and sampling as it might relate to the stock-recruitment problem and fisheries management. Experts from a number of leading fisheries laboratories presented overviews of their ichthyoplankton programs and approaches to fisheries management. The importance of understanding the early life history of most fish species was emphasized and some preliminary results bearing on larval trophodynamic ecology were presented.

It was implicit in some of the other programs that a broader understanding of hydrography and primary and secondary production would be necessary to predict larval survival. A planning session followed the papers and relied heavily on the imported expertise to streamline and fine-tune the proposed Canadian program for ichthyoplankton research on the Scotian Shelf whose objectives are to examine larval fish ecology and provide insights to recruitment processes and ultimately management strategies.

TERMS OF REFERENCE

The concept of relating the abundance of recruiting fish year-classes to stock size was first introduced independently by Ricker (1954) and Beverton & Holt (1957). In the intervening quarter century we have made considerable progress in understanding the effects of fishing on various stocks but the exact form of the relationship between adult stock and recruiting year-classes still remains elusive although we are now cogniscent of some of the factors that determine recruitment. The majority of Canadian work on stock and recruitment (S/R) has been centered on West Coast salmon fisheries where the concept was first spawned and the underlying assumptions were most appropriate so it has been most usefully applied there.

The other major fisheries laboratory centered at Lowestoft, made no a priori assumptions about the S/R relationship but concentrated on the biological effects that could generate the density dependent and independent mortality to favour one of the S/R curves. Cushing (1973) and Cushing and Harris (1973) maintain that the shape of the S/R function will vary for different species since density dependence is related to fecundity. Garrod (1973) feels however that density independent mortality may produce major effects in the S/R function under exploited conditions. More recently Harris (1975) has examined the mathematical properties of the S/R function assuming various density dependent mortality functions and concludes that the S/R function asymptotes if mortality is dependent on both present and initial densities. However, we are still left with the problem of discerning the actual mechanisms of mortality for any given stock.

The S/R symposium (Parrish 1973) concluded: "The papers and discussions indicate that recruitment (defined as the number of progeny derived from a spawning population surviving to some subsequent, defined age) in both marine and freshwater fish and shellfish populations is determined by a complex of density dependent and density independent factors. The former may act as the main source of control governing the form of the relationship between recruitment and spawning stock size (egg production), and the latter give rise to the well known short-term, irregular fluctuations in recruitment characteristic of some teleost species having high fecundity. The papers and discussions indicate further that in most species for which detailed information is available these factors operate mainly during the early stages of development (i.e. between the egg and the end of the first year of life) so the year-class strength is determined and population control mechanisms for most fish stocks operate before the individuals enter the exploited phased."

This has provided the terms of reference for recent research which is being directed increasingly at the first year life histories of many important commercial species. Future research on the abiotic and biotic factors effecting mortality during the prerecruit life history stages should provide greater understanding of the S/R relationships for various species.

INTRODUCTION

The objectives of this workshop were to examine the experiences and expertise of other relevant ichthyoplankton programs in an effort to determine the areas where attention needs to be concentrated to obtain the information on the early life histories of fish larvae that would provide insights into the nature and form of the S/R function. The participants were experts from various fields ranging from oceanography to fisheries biology and provided insights into a variety of actual and potential problems involved in any program of the type proposed herein.

OCEANOGRAPHIC REGIME

One of the initial realizations was that a multi-disciplinary approach to the S/R problem needs to be implemented as a means of adequately understanding abiotic effects on larval survival. It was also discovered that there is a considerable gap between the disciplines of biology and oceanography. Essentially biologists were ignorant of what they could expect in terms of information and assistance from oceanographers and more particularly that both the jargon and scales of attack were major stumbling blocks to a linking of the disciplines. It was suggested that a multi-disciplinary approach would therefore necessarily require inputs from oceanographer to the specific problem at hand. Mann pointed out that although considerable progress had been made in technical terms in oceanography over the past 20 years there was still not the fine scale resolution of currents and related processes likely to be of use to applied biology in terms of identifying the impact of currents on dispersal and movement of larvae from the spawning areas. Oceanographers need to be included in program planning rather than as a posteriori consultants.

Mann also presented some very interesting work by Smith and Petre on the effects of warmwater eddy's breaking off the Gulf Stream and their subsequent intermixing with the Shelf water (Fig. 1).

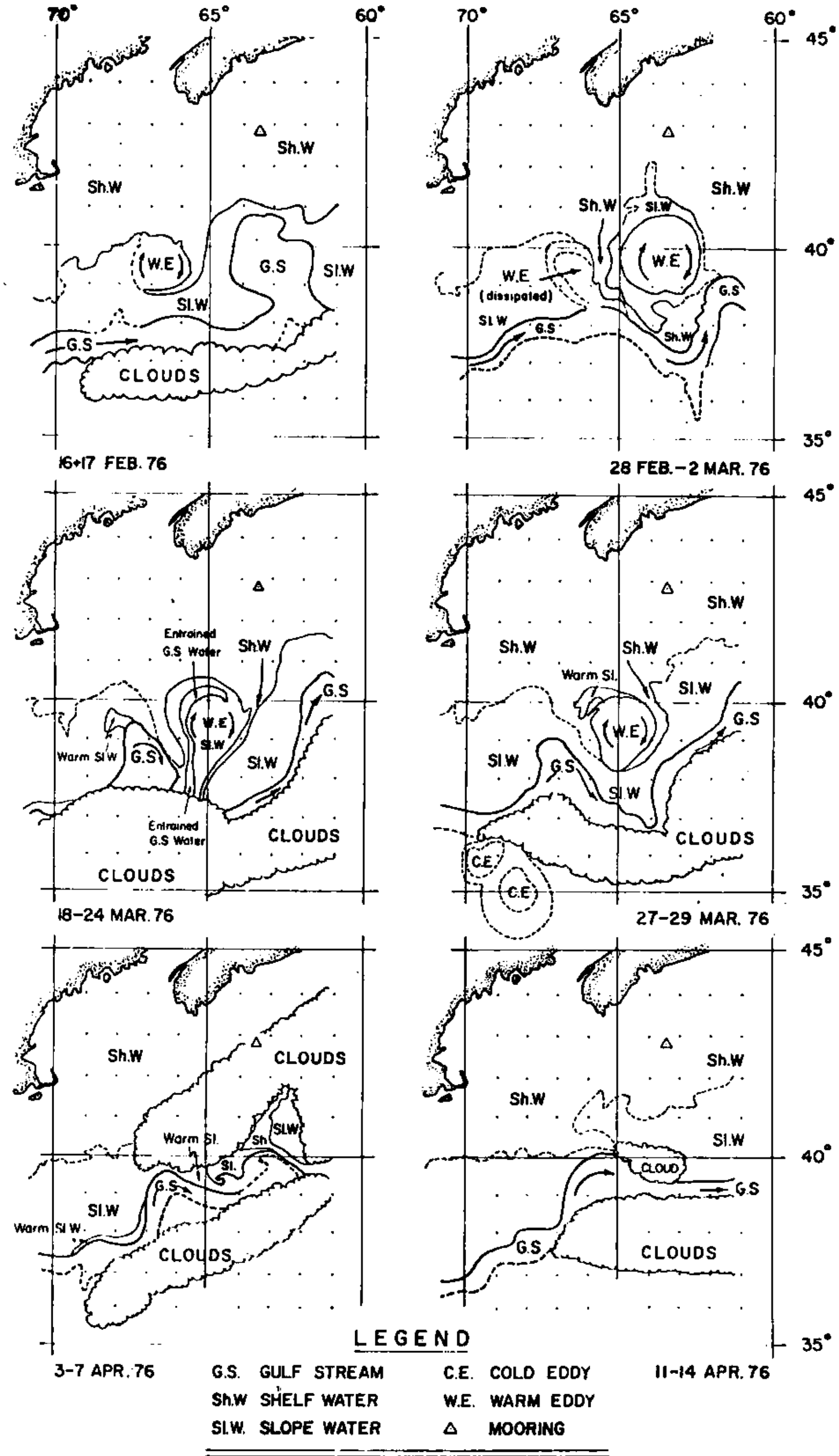

Fig. 1. An eddy-interaction event produced by variations in the Gulf Stream flow (from Smith and Petrie, manuscript).

Apparently variations in Gulf Stream flow produce an average of six eddy fluxes per year which contribute over 30% of the total annual solar input onto the Shelf as well as contributing substantially to the onshore salinity flux. Surface water is drawn offshore and the deep slope water moves onshore. The nitrate flux also appears to be related to the eddy-interaction events and could potentially affect the timing and duration of spring plankton blooms on the Shelf and consequently could have major effects on ichthyoplankton survival. These eddy interaction events are a relatively stable phenomenon but cannot as yet be well predicted. Their delineation and understanding could certainly facilitate our understanding of abiotic effects on survival of larval fishes.

OVERVIEW OF PRESENT APPROACHES

Canada

The importance of primary and secondary production in the survival of ichthyoplankton is still a contested issue but is a major unknown that has received little attention until recently. Boyd presented some data related to the Sheldon, Prakash, and Sutcliffe (1972) size particle theory which suggests an inverse relationship between particle size and concentration which in theory could provide estimates of production. The major difficulties result from the effects of growth and predation, since the theory assumes a steady state and doesn't accomodate patchiness or seasonal changes well because we don't know over what time scale the particle concentrations must be integrated. Boyd presented his findings on vertical distribution in Africa where zooplankton distribution was largely constrained by temperature and the majority of zooplankton were concentrated above the thermocline. He also found a considerable difference between tropical and temperate waters where low phytoplankton and high zooplankton biomass occurs, the converse of the tropical upwelling region. His particle counter, a variant of a coulter counter, and high speed plankton net, with a deck unit through which surface water is pumped were also used in the Mediterranean to examine horizontal patchiness. After integrating his counts to 30-100 M sections of surface, he was able to discern some horizontal patches whose spacing appear to be functions of the size of the zooplankton. His "orange fish" unit appears to be capable of providing preliminary estimates of temporal and spatial variations in the zooplankton food source for ichthyoplankton with perhaps the only drawbacks being that some avoidance by macroplankton has been noted and the size range of viable sampling is constrained to .5 - 2.5 mm. However, it provides a refreshing alternative to the tedium, expenses and time necessary for a manual operation. If this information can be integrated with a viable size particle theory we should be able to predict production in the lower trophic levels.

A discussion of the relationship between the temporal and spatial characteristics of fish spawning strategy and their food supply was presented by Ware for St. Georges Bay. For mackerel the timing of spawning coincides with the maximum abundance of the summer plankton. Spawning occurs from June to mid-August but peaks at the beginning of July. In addition there is a decrease in egg size over the reproductive period which is correlated with water temperature (Fig.2). The mackerel egg size is however correlated and in phase with the mean size of 80μ plankton. Interestingly, the mean egg size of the ichthyoplankton community as a whole tends to a minimum in mid-summer and is in phase with the size dynamics of the plankton. Large plankton (405μ) show the same size cycle as the 80μ plankton at all depths but during the summer large particles are considerably more abundant near the surface and the larger larvae are associated with these larger particles (Ware 1977). It appears then that the parent stock produces eggs of the right size at the right time so that the newly hatched larvae are pre-adapted to feed on the prevailing size-composition of the plankton. In addition the small larvae are more abundant at 5 and 20 M where smaller plankton abound while larger larvae coincide with the large plankton at the

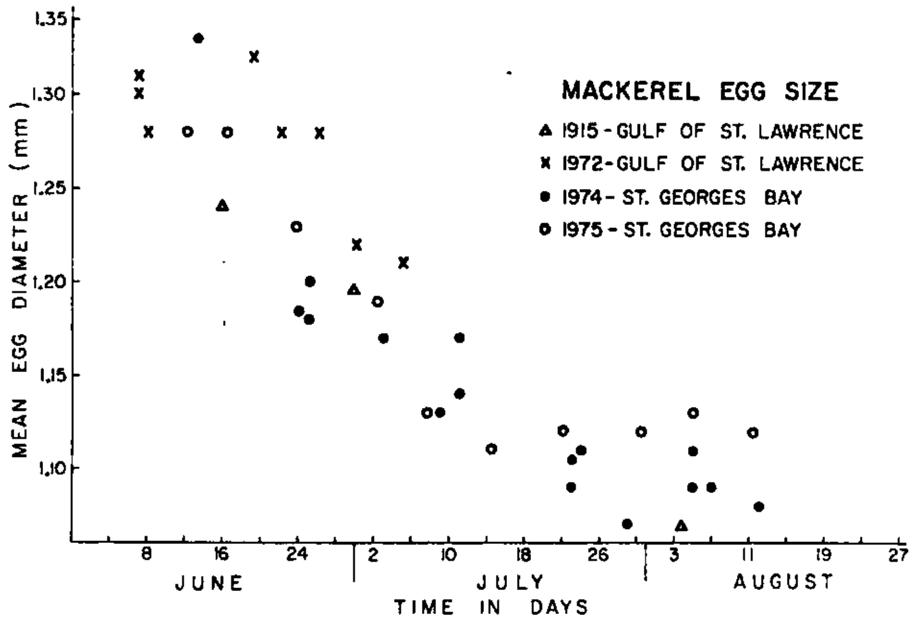

Fig. 2 Temporal decline in diameter of mackerel eggs over the spawning season in Georges Bay, and elsewhere in the Gulf of St. Lawrence. Means are based on at least 10 measurements (from Ware,1977).

surface. From this it appears that S/R depends on subtle variations in the timing of reproduction and the phasing of temporal and spatial size cycles of larvae and their food supply.

Iles reiterated some of these points relative to spatial and temporal synchronization of adult spawning and food supply for herring. Apparently herring "home" to specific spawning grounds off the southern tip of Nova Scotia and the larvae are subsequently swept into the Bay of Fundy (Iles, 1971) where the food and temperature regimes are more favourable for their survival (Fig.3). In this case the prevailing oceanographic regime consists of offshore surface currents and onshore bottom currents whereby the demersal eggs and larvae are carried into a retention area. Therefore the size of the spawning area will to a large extent determine stock size as currents would only favour survival of larvae in the spawning area. Similarly, the stock size will be constrained by the size of the retention area. It appears then that the spawning area and behavior of the larvae may have coevolved with the oceanographic regime to preserve the stock and to set up the retention area. He also emphasized that he was forced to do much

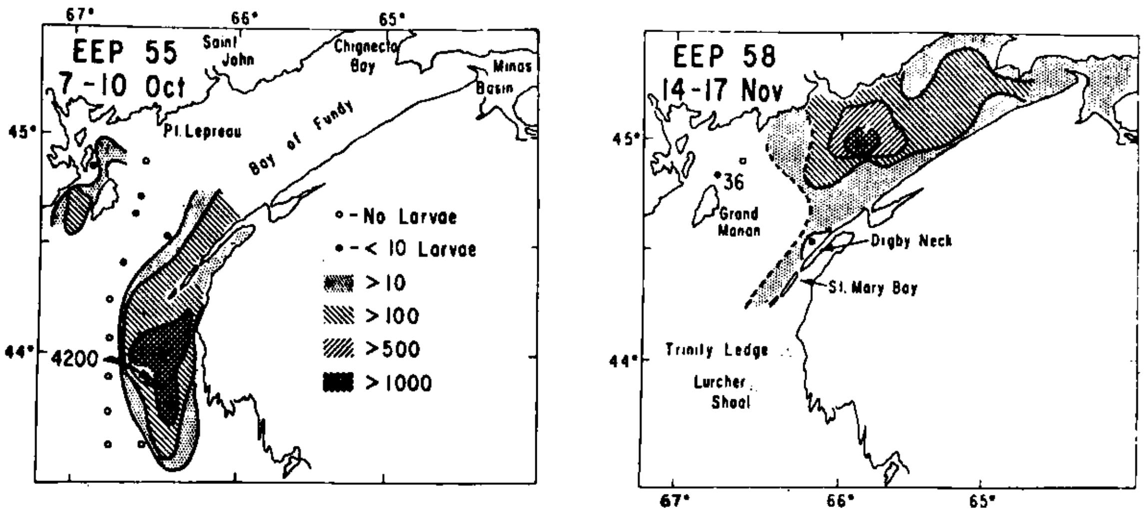

Fig. 3 Herring larval distribution indicating larval movement into the Bay of Fundy and their subsequent retention there, fall 1969 (from Iles, 1975).

of his own oceanography relative to his retention hypothesis because of the lack of biologically applicable oceanographic information (Iles, 1975).

Able presented another account of the importance of the oceanographic regime in relation to larval survival. He examined egg and larval distribution in the upper St. Lawrence estuary and found a seasonal decline in numbers suggesting that eggs and particularly larvae were transported downstream into the Gulf of St. Lawrence. There also appears to be a broad correlation between the peak of primary production and the peak in larval abundance suggesting that the spawning cycles are somehow tied into the production cycle in the estuary. The flow near the surface is generally downstream into the Gulf whereas the bottom highly saline water moves up into the estuary. The circulation pattern has an improtant impact on ichthyoplankton abundance and distribution. Of particular interest was the low abundance of eggs near the surface, they were inevitably less prevalent than larvae and on closer examination it was discovered that the species composition was quite depauperate. Only about 20 of the 40 odd species found in the southern Gulf occur in the estuary and, in addition there were few eggs of pelagic species in the estuary most having been transported into the Gulf. Thus it appears that the oceanographic regime has selected for resident species with demersal eggs. It also appears that although most larvae are found in the upper 50 M and so are susceptible to surface transport downstream metamorphosis may occur quickly in the resident species to favour the retention of larvae of these species in the estuary.

The utlimate goal of fisheries research is management and the only application of ichthyoplankton information to the S/R or stock assessment question was provided by Lett. The modelling approach he presented (Lett et al, 1975) permits the evaluation of our present sampling program and should illuminate any deficiencies as well as generating the possible structure of the stock recruitment function. He presented the essence of a cod-mackerel interaction model. It appears that the cod stock relies on changes in the maturity ogive to affect egg production and generate population stability (Fig.4). This is mediated through density dependent growth whereby the length of maturity decreases as the growth rate increases specifically the first year growth appears to determine when maturity occurs (Fig. 5). Therefore in big year-classes slow growth would cause later maturity and provide a homeostatic mechanism. It was also emphasized that temperature has an important effect on egg and larval viability and that there is considerable predation by cod and mackerel. This predation produces the depensatory effect in the Ricker-type S/R formulation (Fig. 6) for the larva to recruit stage (Lett, 1977). The mackerel and cod biomass would therefore also provide a stabilizing mechanism for the population.

In summary, Canadian efforts have emphasized individual larval species, primarily the estimation of numerical abundance and distribution, with only preliminary examination of temporal and/or spatial relationships with food or other ichthyoplankton species.

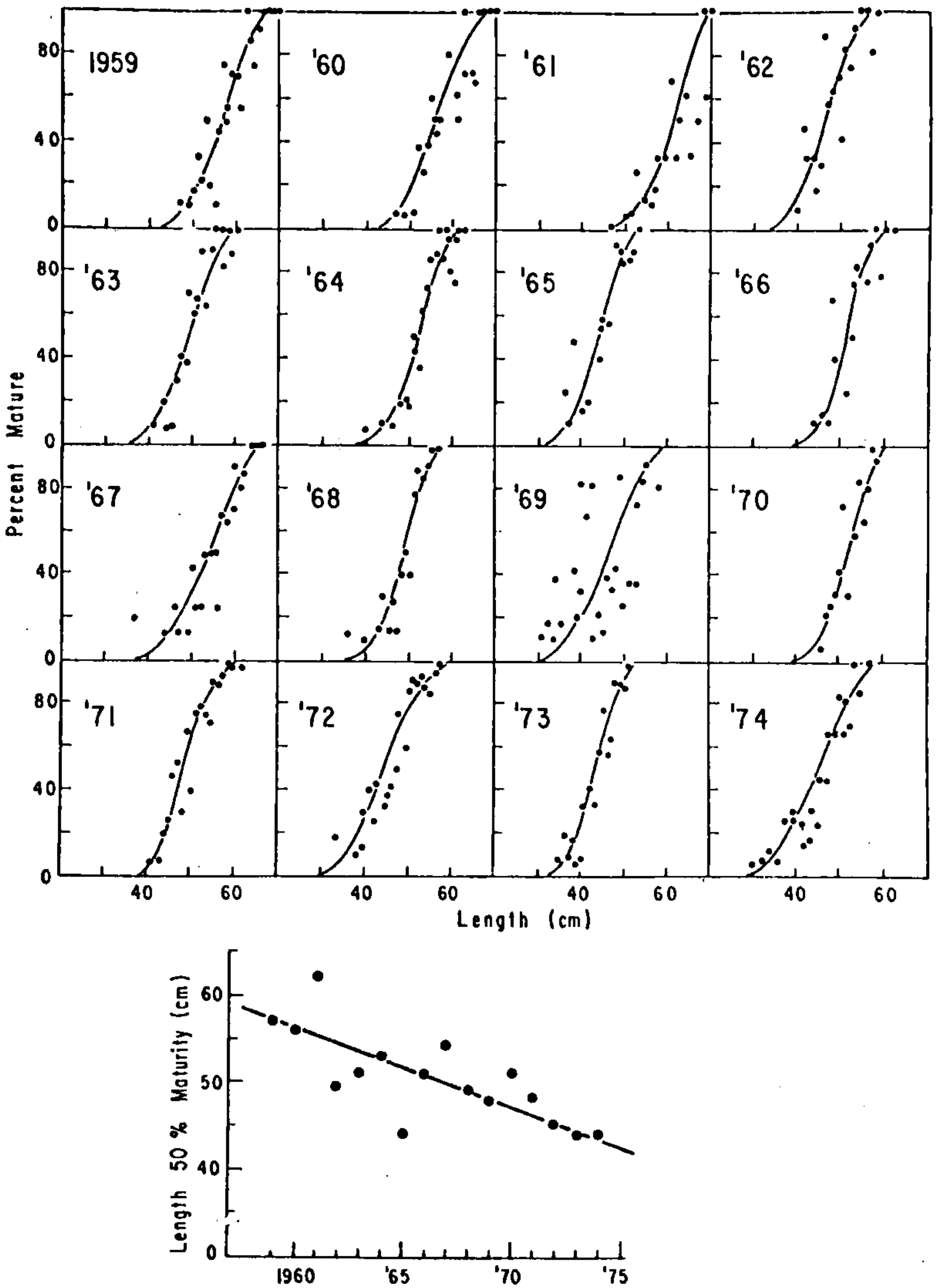

Fig. 4. Maturity ogives and their temporal variation in Gulf of St. Lawrence cod for 1959 through 1974 (from Lett, 1977).

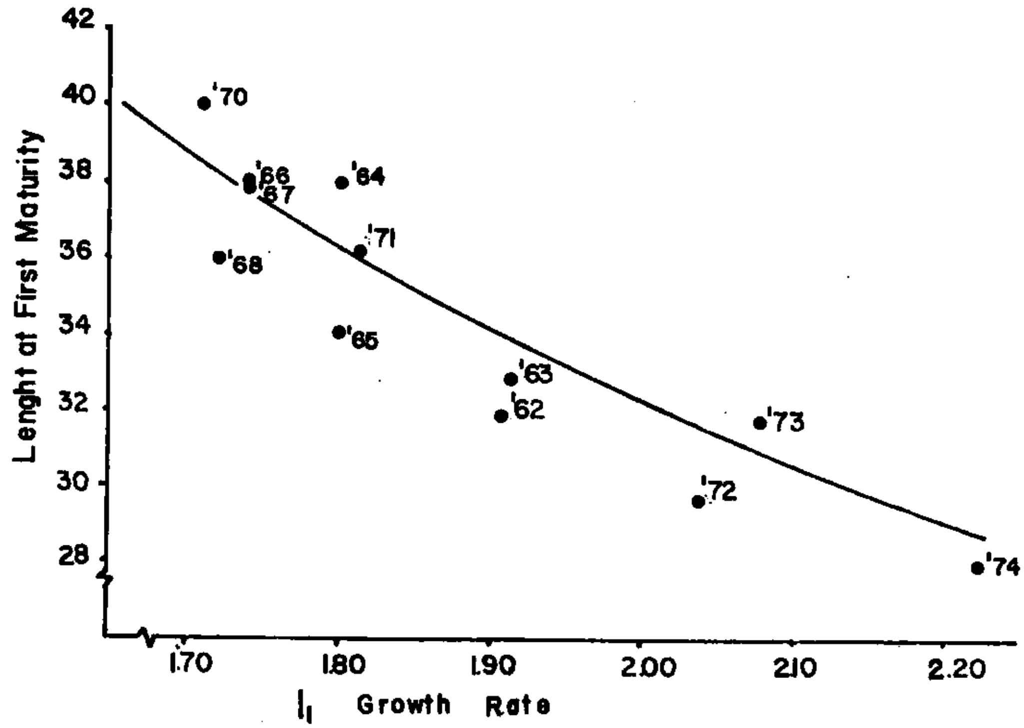

Fig. 5 Relationship between the first year growth of cod and the resulting length at maturity (from Lett,1977).

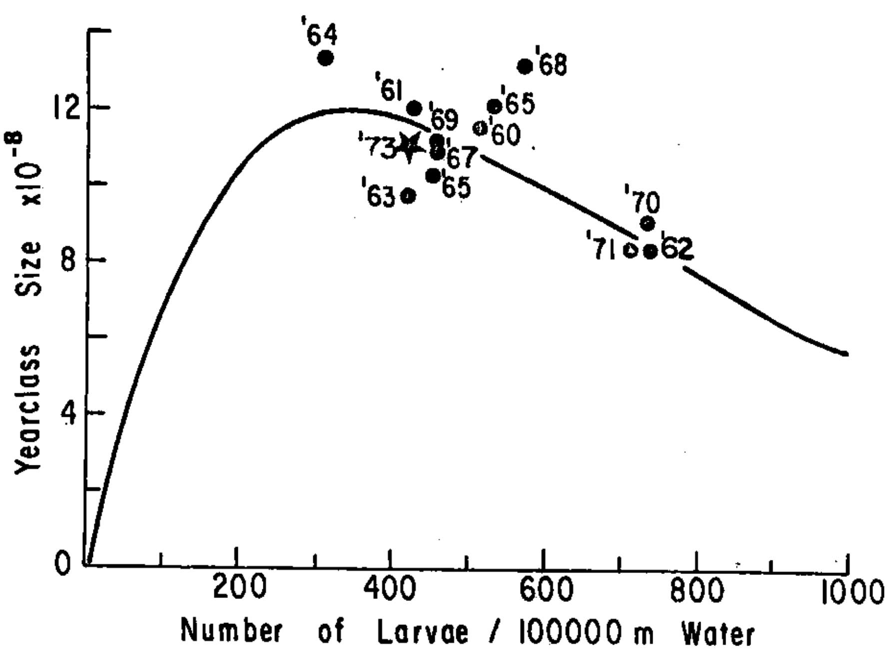

Fig. 6 The stock recruitment relationship for cod with larvae in their first summer and the resultant 2 year recruits to the fishery (from Lett,1977).

United States

The American fisheries work on ichthyoplankton is concentrated at Narragansett, Wood's Hole, and LaJolla. Sherman presented an overview of the approach at Narragansett with the basic hypothesis being to clarify the inter- and intra-specific relationships among the principal biomass components in terms of energy exchange through the trophic levels (Table 1, 2). He emphasized the need to examine the fish larvae enumeration in an ecosystem context rather than solely as a predictive index for S/R. Ichthyoplankton surveys began in the late fifties and concentrated on the delineation of spawning times and areas for principal species. From 1971 through 1976 standardized collections over broad geographic areas were made during MARMAP-ICNAF surveys of larval herring. Larval concentrations were used to identify spawning stocks and preliminary analysis suggests that the period of initiation of 1st feeding and over-wintering mortality are important determinants of recruitment. Trophodynamic aspects of larval herring survival are now under study.

Studies of zooplankton are isolated and sketchy save for the initial work by Bigelow and in 1964-1968 when seasonal variations in species composition, distribution, and abundance of zooplankton were made as part of the larval herring assessment study. More recently 1971-75, zooplankton volumes were collected as part of the larval herring study. In conclusion, it was emphasized that we should consider the importance of microdistribution of plankton and fish larvae in the sea relative to larval survival. This requires modification of our present sampling methods to include the utilization of various pumps and particle counters to obtain real measures of microdistributions and patches.

An important subarea of the Northeast Fisheries Centers total ecosystem approach relates to the larval herring project on Georges Bank conducted through Wood's Hole and designed to provide measures of larval production, dispersal, growth and mortality of sufficient precision to measure significant variations in these

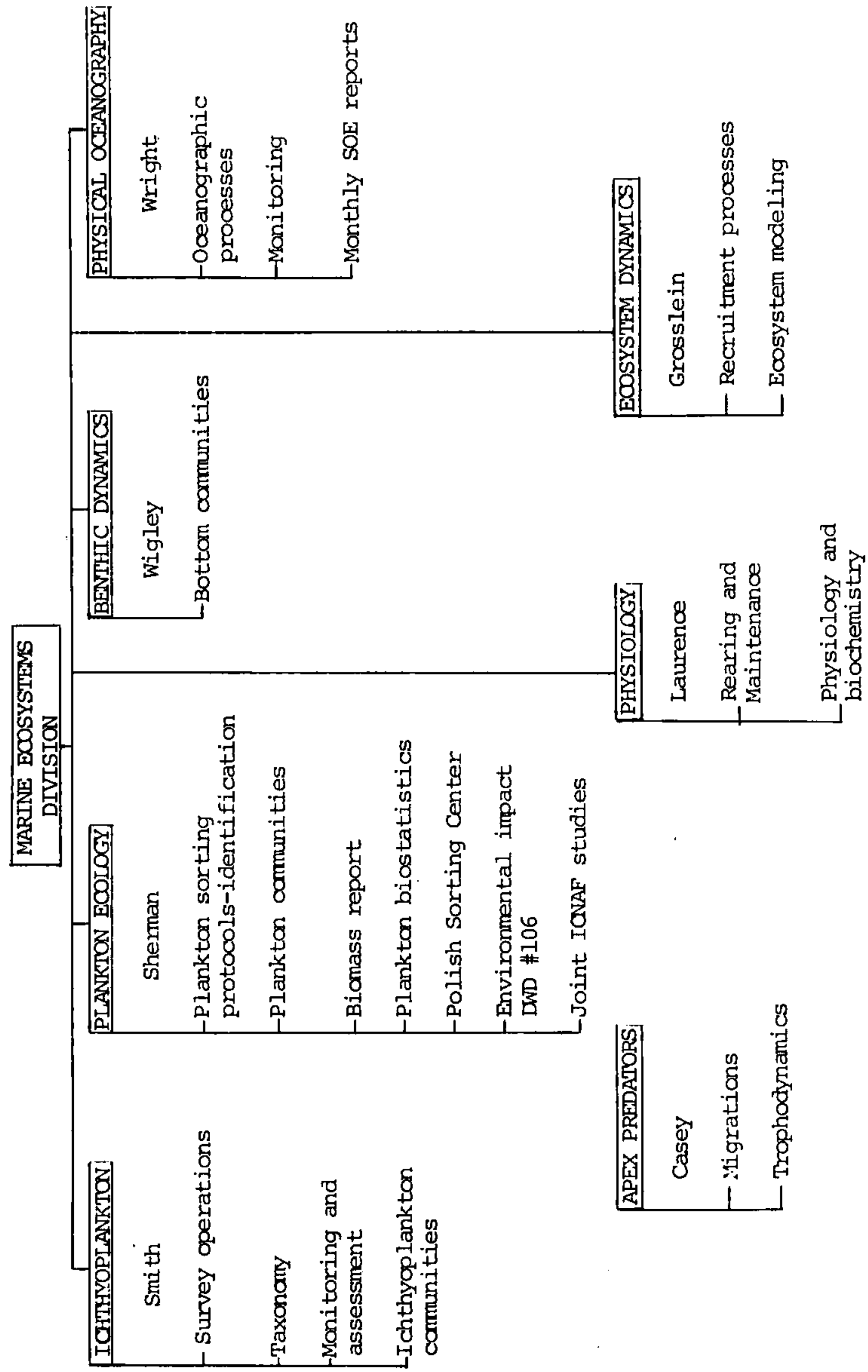

Table 1: An overview of the Northeast Fisheries center research efforts.

PRINCIPAL ECOSYSTEM COMPARTMENTS	DATA BASES TO BE SUMMARIZED		OUTPUT
PHYTOPLANKTON Cohen Thomas Ukeles	Standing stock (biomass) Primary production		1. Preliminary - Georges Bank ecosystem energy flow model(transfer pathways)
ZOOPLANKTON Bearse Laurence Maurer Colton Sherman Grosslein	Standing stock (biomass) Food ingested Productivity	Trophic interactions (energy transfer) 1. stomach contents 2. nutrients and energy utilized	2. Summary and organization of available information
NEKTON Sissenwine Laurence Grosslein Brown	Standing stock (biomass) Food ingested Productivity		3. Framework for future studies necessary for describing ecosystem relationships integral understanding production of fish stocks.
BENTHOS Wigley Pearc	Standing stock (biomass) Food ingested Productivity		4. Identification of information needs in each of the ecosystem components.

Table 2. An overview of the American approach to understanding ecosystem functioning.

parameters within and between spawning seasons. The program designed in ICNAF augments broadscale coverage with more frequent sampling of the egg and/or larval stages of selected species to identify mechanisms controlling survival or alternatively environmental conditions associated with good and poor year classes. Grosslein feels these insights are prerequisite to real advances in understanding S/R relationships as well as predicting environmental effects. The basic approach was to sample once per month from September through December to monitor larval production and intermixing of larvae from various spawning sites. Initially oblique tows with paired 60 cm Bongos (.333 and .545 mm mesh), temperature profile and surface salinity were taken. In 1973 FRG added night sampling with Bongos and neustons. In autumn 1974 paired 20 cm Bongos with smaller meshes (.253 and .165 mm) were added to sample the smaller plankton community and in May 1975 it was decided to examine ocean circulation on the Georges Bank-Nantucket Shoals area. Concurrently studies of primary and secondary production as well as fine-scale patch studies were to be initiated. Thereafter emphasis shifted to the Georges Bank - Nantucket Shoals area for intensive sampling because of a lack of vessel support. Sampling was however expanded to include complete hydrographic coverage (temperature, oxygen and salinity at each station), and nutrients, chlorophyll, and primary production whenever possible. The program has continued along these lines to date but little has been analysed completely. The 31 surveys of about 100 stations each covering the Georges Bank area required 15-20 days each, averaging 6 - 8 stations/day depending on weather and amount of hydrographic and special sampling (nutrients, chlorophyll, primary production). This represents 4800 60 cm Bongo zooplankton samples in the Georges Bank area as well as 3000 20 cm Bongo samples for the 6 year time series 1971-76. The ichthyoplankton sorting alone requires on the order of 3000 man-days work for the ICNAF time series of 3000 .333 Bongo samples which equals the annual sorting capacity of the Polish sorting centre. Sorting of zooplankton including measurements of all life stages of dominant species takes 5 times as long and the fine-mesh samples even longer. Obviously some cutbacks are necessary through subsampling or automated electronic size counters. A selection of cruises and stations in relation to variations in larval herring growth and mortality should provide a test of the match-mismatch (larvae vs. food) hypothesis without sorting all the zooplankton samples (Table 3). Initial results from the larval data indicate larval dispersal is consistent with hypotheses of ocean circulation and suggests that few larvae are lost from the periphery of the Georges Bank-Nantucket Shoals area and as they get larger they tend to concentrate towards the centre where survival appears to be enhanced. Grosslein also indicates e that the standard oblique hauls were sufficiently accurate to detect major differences in larval distribution and abundance. Some biases in the herring sampling are related to what appear to be extrusion of small larvae and escapement by the larger ones. This will require changes in sampling procedures possibly at lower speeds to prevent larval defecation and general deformation or newer type samplers. Very obvious differences in both growth and mortality estimates were detectable with these samples and refinement for the following small scale biases are in progress:

(1) Changes from exponential to logarithmic form of the growth curve for larger larvae, and more accurate classification of age versus length based on larval otoliths.

(2) Specific length-dry weight regression curves for individual years (instead of pooled regression for four years).

(3) Separate estimates for larval subpopulations to reduce possible bias due to mixing of larvae from Georges Bank and Nantucket Shoals.

(4) Day/night analysis to clarify the avoidance problem and adjust analyses accordingly.

(5) Correction for extrusion of small larvae from 0.333 mm samples.

Table 3. A summary of the mego- and microscale studies of larval fishes life history and ecology.

STUDIES OF MATCH/MISMATCH RELATIONSHIPS BETWEEN FIRST FEEDING LARVAL FISH AND THEIR PLANKTON FOOD.

Problem in balance: Mesoscale, microscale surveys

1. Logistics of broad scale time and area monitoring of spawning for important species.

2. Experimental studies of survival processes acquiring simultaneous information on microdistribution.

3. Larval herring ICNAF survey (10 x/yr)
   Good area and temporal survey coverage information on:

   a) Spawning areas

   b) Spawning time

   c) Dispersal

   d) Mortality

   e) Stock-recruitment relationships

4. Survival Processes Investigation

   a) Larval physiology, nutrition/food density dependent survival, biochemistry, environment (temp).

   b) Larval feeding

      alimentary tract analyses
      zooplankton density distribution

   c) Larval condition

      age-growth
      biochemical RNA/DNA
      nutrition, tissue, enzyme

5. Field Studies

   a) Lasker — Anchovy

   b) Smith — Spawning -- spatial/temporal

   c) Kendall — communities

   e) Grosslein/Lough — herring

6. Adult Fish food

   a) growth

   b) availability of adults

   c) predator/prey interactions

7. Patch Study, 1977

Possibly the most important deficiency of the net samples is the extrusion of a substantial proportion of the size range of food items found in the guts of herring. Truly quantitative zooplankton samples will require special water samples via a plankton pump or special plankton sampler.

The other group at LaJolla represented by Smith has been involved primarily in assessing the status of anchovy and sardine stocks. The fluctuation in relative abundance of the two species has provided the first major incentive for examining a "multi-species" situation. This has resulted as well in more difficult sampling problems. Their objectives are stock assessment but they are presently unable to estimate stock size. He presented a number of different estimates of the three subpopulations of anchovy (Smith 1972). The major thrust of their work at present relates to solving technical problems related to sampling specifically the effects of correction factors on the data. They are also looking at ways to improve historical data series by correcting biases in the sampling gear. The emphasis is on precision of the estimates and in the future, they hope to collect food items to determine food specific growth rates. He also emphasized that it was important to correct simple things like technical sampling problems and accept the natural insolubles like zooplankton patchiness.

In summary, the American effort has already progressed through some preliminary examinations of the importance of food to larval survival and they are looking at the importance of a number of physical and chemical variables with regards to ichthyoplankton ecology. They have also made major inroads into standardizing sampling procedures. The overall approach is a combination of large scale sampling for zooplankton and ichthyoplankton abundance and distribution and small scale intensive study of the local effects of biotic and abiotic factors on ichthyoplankton.

United Kingdom

The fisheries group at Lowestoft has moved from the Beverton and Holt era of stock independent recruitment through a stage of collapsing stocks and the realization that variability in the S/R variables obscures any relationship that may exist to the present queries of whether stocks are self-regulating at all or even stable in the conventional sense. They are in effect open to any new suggestions to solve the S/R dilemma. Garrod presented an overview of the present Lowestoft approach to S/R which includes two goals: short term predictions for adjusting fishing regulations and long term understanding to assist managment strategy. These require an understanding of density independent causes of egg and larval mortality and the identification of the S/R relationship if it exists. Their programme then concentrates on:

(1) environmental effects on year-class variation;

(2) detection of biological effects influencing mortality;

(3) theoretical studies of the implications of these mechanisms (modelling).

Garrod is personally skeptical of internal population regulation but feels recruitment may be random within a region bounded by external environmental processes. Density dependent processes may result from the environmental constraints but are not a population stabilizing mechanism in themselves. He stresses that although this view differs slightly from the equilibrium centered view implicit in a S/R formulation the latter may be mathematically more tractable but isn't solving the problem. He presented some data that delineated the importance of the climatic effects (Fig. 7,8) on the recruitment of a number of species (Garrod & Colebrook 1977). Other studies are primarily mesocale modelling of primary, secondary, and fish production in relation to hydrographic and meteorological models. There are also smaller scale models for predicting larval mortality over the spawning distribution and examining the stability of single and mixed species communities. Some laboratory work is being aimed at the larval energetics and ration questions to predict growth and mortality.

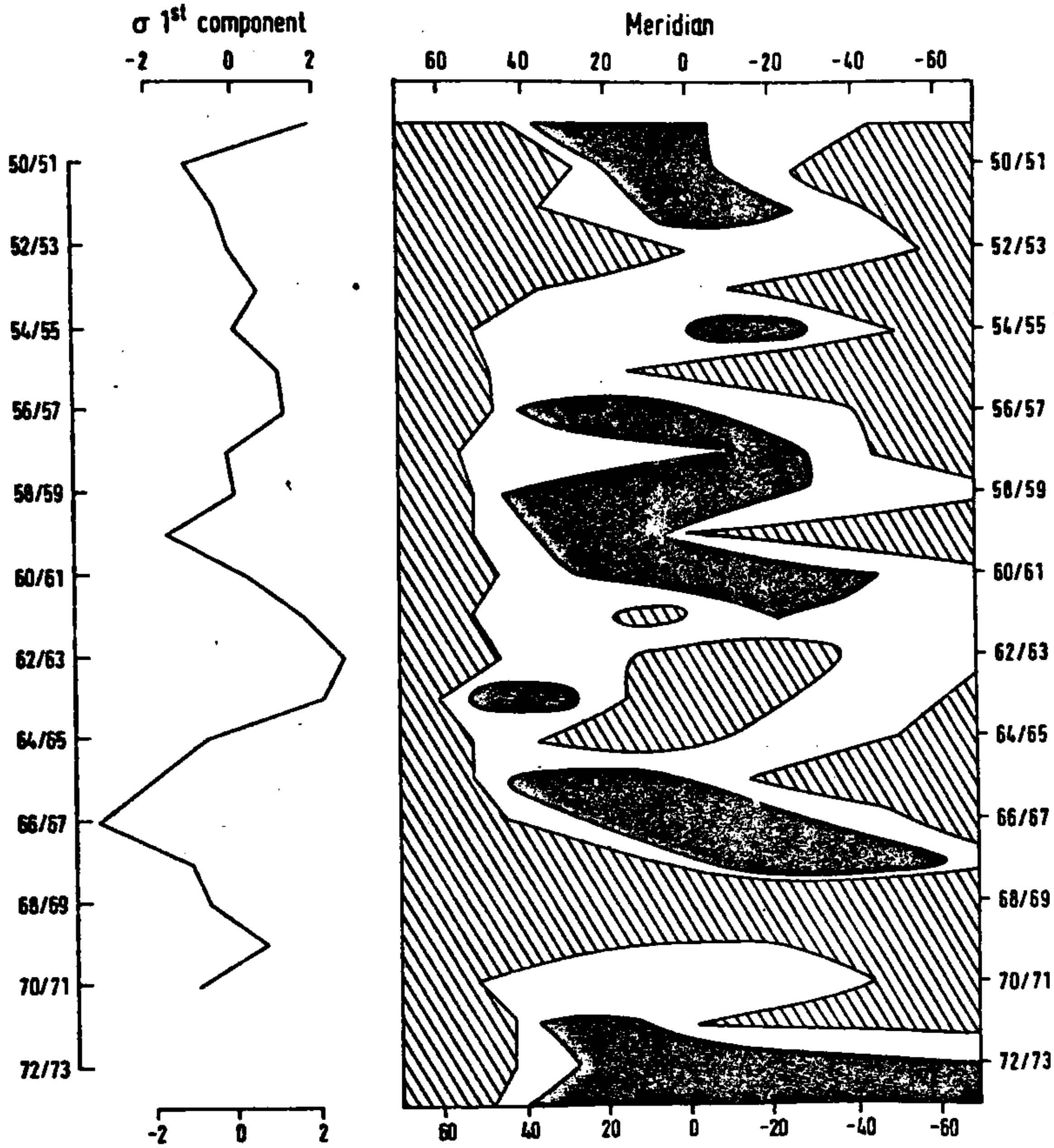

Fig. 7 Distribution of surface pressure with longitude in the north Atlantic 1949-1973 compared with the first component of variation in hydrographic and fish recruitment data (from Garrod and Colebrook,1977).

The major ichthyoplankton component at Lowestoft presently under the direction of Harding has conducted periodic plaice egg and larval surveys in the southern bight of the North Sea for some 15 years and has provided some insights into the temporal changes in abundance and distribution of plaice (Harding and Talbot 1973). In 1976 a series of surveys were undertaken in the west central North Sea to (1) identify distribution of eggs and larvae of all

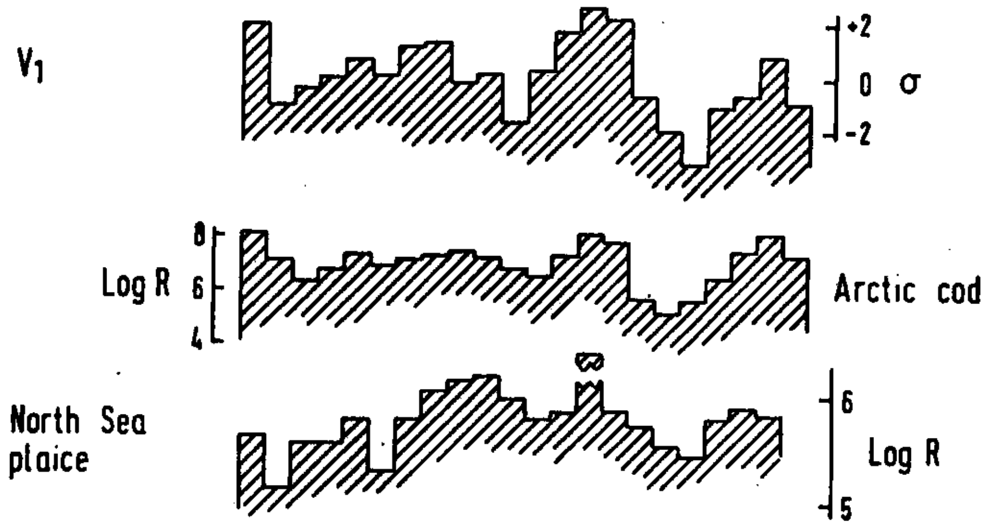

Fig. 8 Time series in the first principal component of variation in recruitment and hydrography and variation of recruitment in Arcto-Norwegian cod and North sea plaice (from Garrod and Colebrook,1977).

important commercial species; (2) to estimate abundance and mortality of egg and larval stages; (3) to determine major predators of eggs and larvae from stomach contents of plankton and fish predators; (4) to estimate speed and direction of larval drift to the nursery areas; (5) to study the seasonal recruitment, growth, and mortality of the young fish in nursery areas. Concomittantly measurements of phytoplankton standing stock (chlorophyll 'a' and phaeophyton) were made and identification, abundance, and size of phytoplankton as well as vertical, spatial and seasonal distribution and succession were examined. Zooplankton biomass was estimated volumetrically and in terms of particle size. Fish larval feeding and vertical distribution as well as laboratory developmental rates were used to estimate when they would become demersal. Physical aspects included measures of irradiance, extinction coefficients and turbidity in the water column and hydrographic observations of ocean circulation in the area.

Initial analyses of data allowed the delineation of three major circulation patterns over the year and suggested that larvae developing on the resultant gyre would remain stationary and take the deep onshore mass below the thermocline inshore to the nursery grounds (Fig. 9).

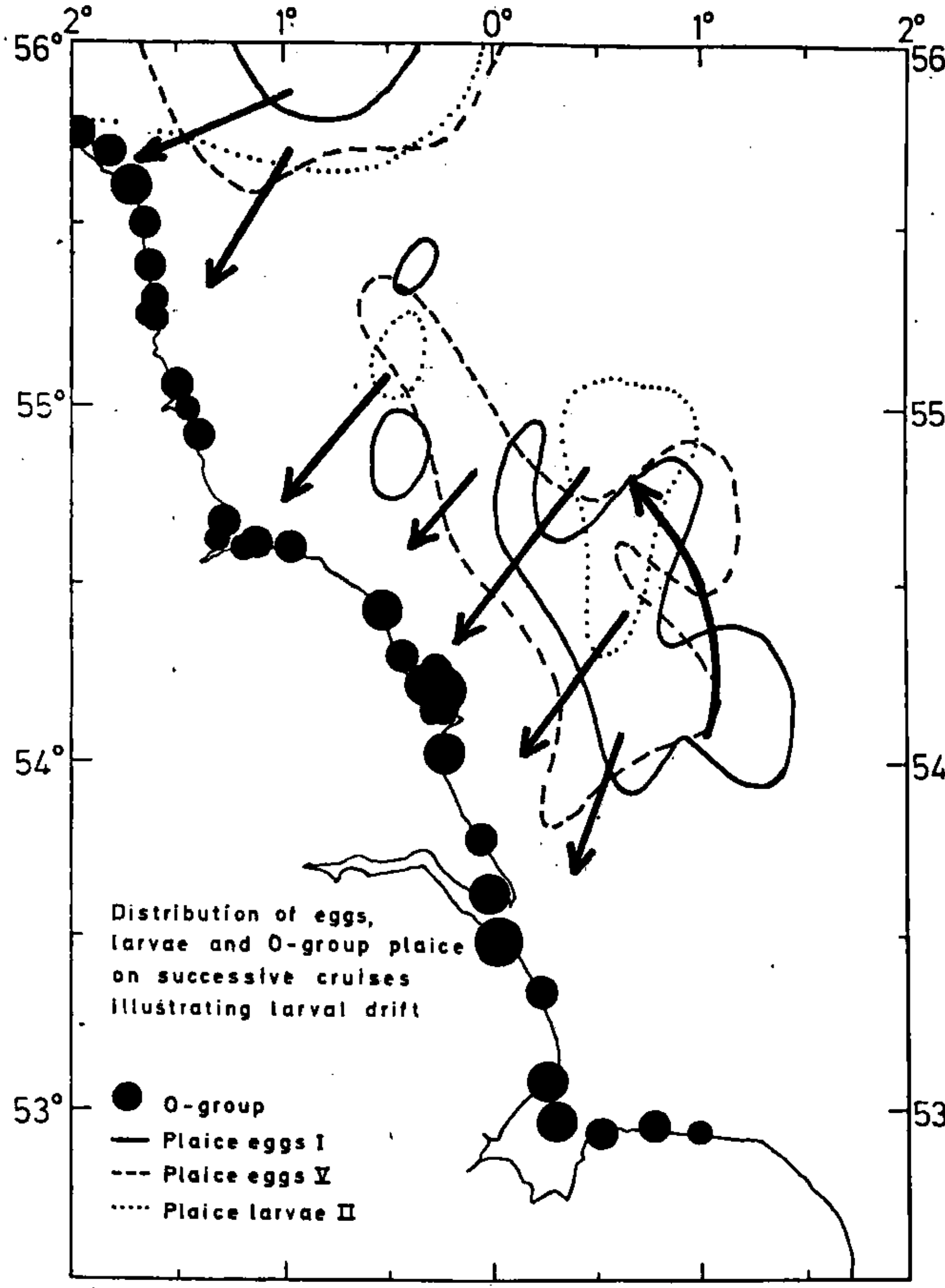

Fig. 9 Movements of developing eggs and the resultant plaice larvae in the west-central North Sea during 1976 (from Harding,manuscript).

In summary, Lowestoft seems to be taking as detailed and all encompassing a view of the total ecology relevant to the S/R problem as possible. They also seem to be much more concerned than North Americans with the importance of the abiotic environmental factors on larval ecology and S/R as a whole.

Federal Republic of Germany

The other major European ichthyoplankton component emanates from the Institute of Marine Research of the FRG at Kiel. Schnack presented a broad overview of the wide range of activities both laboratory and *in situ* of this institution. Activities range from general faunistic, ichthyogeographic and taxonomic surveys in many parts of the world oceans to the more applied ICNAF and ICES herring programs concentrating on delineation of spawning areas, estimation of changes in spawning stock size and year-class strengths.

Ecological studies of the abiotic factors affecting distribution and mortality of larvae include the effects of wind action, light and temperature. Other studies on feeding and growth include day/night sampling for diurnal feeding rhythm, vertical tows to relate feeding to food supply, both spatially and temporally, and seasonal changes in feeding relative to the food supply. Some work is also directed at the effects of predation by fish on eggs and larvae.

Laboratory studies are aimed at egg development and larval mortality relative to abiotic factors such as light and mechanical stress and the effects of predation and soluble compounds of crude oil.

Larger scale studies involve anchored floating enclosures to examine the effects on feeding, growth, and mortality of larvae of the

(1) density of natural food supplies

(2) density of larvae

(3) density of plankton predator population.

Schnack presented some data on feeding rate and food density from field data. He examined food intake and its partitioning to metabolism and growth in herring larvae by examining the decrease in gut contents at night when feeding ceases. He estimated that 50% of larvae could survive on the food ingested and of the others containing no food most could be starving. From this he estimated mortality of 7% per day. He also presented some data relating feeding rate to food density suggesting a decrease in the former at high density but indicated that food concentrations to larvae , in situ tend to be quite low and that larvae depend on finding dense food patches for survival.

The other major thrust of research here relates to the testing and development of sampling methods. These studies include mesh selection and clogging of the Bongo, filtration efficiency of encased and unencased samplers, and sampling variation of oblique high speed tows and low speed vertical tows. Other work includes general improvements of the sampling gear, tow profiles and filtration efficiency. Current developments include high speed opening/closing net and an accessory electronic system for any sampling gear that consists of a 9 channel conductor cable to: control net mechanics; measure depth, temperature, conductivity, flow (inside and outside gear); control additional sensors (light turbidity, oxygen, and particle counter); transfer information to deck units with digital display, analog registration and storage on punch tapes. The German effort tends to be quite diversified although relatively small scale and very aware of technical difficulties and the need for their solution.

SAMPLING RECOMMENDATIONS

As previously mentioned the group at La Jolla have standardized and streamlined most aspects of the fish egg and larvae sampling surveys. Smith distributed an extensive compendium (Smith and Richardson 1977) of much of their work which provides a standard against which to compare and evaluate our needs and requirements for the Scotian Shelf program. Briefly, it summarizes the recommended procedure for ichthyoplankton sampling (sampler, towing, sample preservation and storage), laboratory sorting procedures (volume determination, percentage sample to be sorted, identification, enumeration and measurement of eggs and larvae), data summarization (flowmeter calibration, standardization), data analysis, volumetric sampling (volume and distribution of depth sampled, clogging, avoidance, retention), alternate samplers and methodology, intercalibration of samples, cost minimization, and finally the best procedure for estimating larval growth and mortality.

SORTING PROTOCOLS

A sorting centre for the Scotian Shelf program has been set up at the Huntsman Marine Laboratory. Scott presented a brief historical overview of this institution and its functioning. Markle indicated that there were a number of technical problems that needed to be solved specifically with regards to preservation, measurements and splitting. The latter has been found to introduce errors up to 40 per cent. It appears that an approach similar to that presented by Smith will be adopted. Faber presented a brief overview of the types of larvae that might be expected on the Shelf, the importance of seasonal changes in species composition and distribution and the possible difficulties related to identification specifically of the hakes. The other point was that we don't really know what species may be expected in terms of deep-sea species on the Shelf edge and also with respect to larvae of migrant species that are not present on the Shelf as adults.

PLANNING SESSIONS

The planning sessions included discussions of the budgetary constraints, objectives, data processing, survey area, egg and larval production estimates, zooplankton sampling, hydrography, bioenergetics of larvae, and sorting procedures. Data analysis should include pictorial plots of larval abundances, length-frequencies of larvae and staging of samples of eggs. There should also be onboard mapping of temperature and chlorophyll profiles with area and depth and data on size and quantity of different phyto- and zooplankton particles as well as some contouring of the hydrographic and meterological regimes. The survey area would include the whole Shelf from Scaterie to north Georges Bank and as far as the edge of the Gulf Stream. Ichthyoplankton sampling for egg and larvae should emulate the American k standard to facilitate study of migratory species and zooplankton sampling would employ some type of particle counter in conjunction with the .333 mm Bongo sampling to examine the food and predators of larvae. It was also suggested to tow a 50 mesh net to identify species counted by a particle sampler since information on zooplankton distribution seems also to be relevant to the distribution of adult pelagic species. The determination of particle size, chlorophyll, and temperature on a continuous basis throughout the survey was also recommended as a means of assessing patchiness and could be relevant to advances in particle size theory. Hydrography in certain areas of high productivity is of utmost importance as well as general data on wind and tidal effects on circulation, temperature, water mass movement and transport of nutrients on the Shelf. With regard to sorting it was recommended that no splitting be done, tow time should be reduced instead. Much more quality control needs to be maintained on board relative to preservation and net care. Further ad hoc meetings by a working group would provide quality control and continual evaluation of the program.

SUMMARY AND RESOLUTIONS

The success of the workshop in producing a viable ichthyoplankton sampling program resulted to a large extent from the input of expertise from other programs. There was a particularly striking contrast in the approaches of the various laboratories. Lowestoft seems to be concentrating on large scale sampling of ichthyoplankton and abiotic variables to link recruitment to the production cycle hypotheses of Cushing (1975) while Kiel is concentrating on smaller scale studies of the biotic factors particularly the feeding and predation hypotheses. The Americans are looking primarily at energy flow but at two levels on the large scale with broadscale sampling of ichthyoplankton, zooplankton and abiotic factors and small scale intensive studies of the larval growth and mortality processes in for example herring patches. The Canadian approach has to date been primarily a large scale survey program. Hopefully the synthesis of the best portions of the aforementioned programs will provide the appropriate balance of large and small scale studies to produce the necessary insight into the events that determine the early life history of fishes.

The approach to be adopted for the Scotian Shelf will be then: (1) the seasonal and geographical delineation of ichthyoplankton species on the Scotian Shelf for 3 years; (2) to develop a time series of estimates of abundance, mortality and growth for various ichthyoplankton species in relation to the S/R problem; (3) to collect data on chlorophyll, particle size and hydrography for the development of models to expedite progress in fisheries science and management.

REFERENCES

Beverton, R. J. H., and S. J. Holt. 2957. On the dynamics of exploited fish populations. U. K. Min. Agric. Fish., Fish. Invest. (Ser. 2) 19:533 p.

Cushing, D. H. 1973. The dependence of recuitment on parent stock. J. Fish. Res. Board Can. 30 (12, 2): 1965 -1976.

1975. Marine ecology and Fisheries. Cambridge Univ. Press Cambridge, Eng. 278 p.

Cushing, D. H. and J. G. K. Harris. 1973. Stock and recruitment and the problem of density dependence. Rapp. P.-V. Reun. Cons. Explor. Perm. Int. Mer. 164: 142-155.

Garrod, D. J. 1973. The variation of replacement and survival in some fish stocks. Rapp. P.-V. Reun. Cons. Perm. Int. Explor.Mer. 164: 43-56.

Garrod, D. J. and J. M. Colebrook. 1977. Biological effects of variability in the north Atlantic Ocean. JOA ed. in press.

Harding, D., and J. W. Talbot. 1973. Recent studies on the eggs and larvae of the plaice (Pleuronectes platessa L.) in the southern bight. Rapp. P.-V. Reun. Cons. Perm. Int. Explor. Mer. 164:261-269.

Harris, J. G. K. 1975. The effect of density-dependent mortality on the shape of the stock and recruitment curve. J. Cons. Int. Explor. Mer. 36(2):144-149.

Iles, T. D. The retention inside the Bay of Fundy of herring larvae spawned off the southwest coast of Nova Scotia. Int. Comm. Northwest. Atl. Fish. Res. Doc. 71/98. Redbook Pt.III: 93-103.

1975. The movement of seabed drifters and surface drift bottles from the spawning area of the 'Nova Scotia' herring stock and the herring larval transport-retention hypothesis. Cons. Int. Explor. Mer. C. M. 1975/C:37.

Lett, P. F. K. 1977. A preliminary discussion of the relationship between population energetics and the management

of southern Gulf of St. Lawrence cod. CAFSAC Res. Doc. 77/8.

Parrish, B. B. 1973. (ed). Fish Stocks and Recruitment. Rapp. P.-V. Reun. Cons. Perm. Int. Explor. Mer. 164:372 p.

Ricker, W. E. 154. Stock and recruitment. J. Fish. Res. Board Can.11:559-623.

Sheldon, R. W., A. Prakash, and W. H. Sutcliffe, Jr. 1972. The size distribution of particles in the ocean. Limnol. Oceanogr. 17:327-340.

Smith, P. E. The increase in spawning biomass of northern anchovy Engraulis mordax. U.S. Fish Wild. Serv. Fish. Bull. 70:849-974.

Smith, P. E. and S. L. Richardson. 1977. Manual of methods for fisheries resource survey and appraisal. Part 4. Standard techniques for pelagic fish egg and larva surveys. Southwest Fisheries Center. Administrative Report No. LJ-77-11. 233 p.

Ware, D. M. 1977. Spawning time and egg size of Atlantic mackerel, Scomber scombrus, in relation to the plankton. J. Fish. Res. Board Can. 34:2308-2315.

LIST OF PARTICIPANTS

Canada

K. W. Able, Nelson Biological laboratories, Rutgers College, P. O. Box 1059. Piscataway, New Jersey.

C. M. Boyd, Dept. of Oceanography, Dalhousie Univ., Halifax, N.S.

D. J. Faber, C.A.I.C., National Museum, Ottawa.

R. G. Halliday, Marine Fish Division, BIO, P. O. Box 1006, Dartmouth, N. S.

T. D. Iles, Marine Fish Division, St. Andrews Biological Station, St. Andrews, N. B.

A. C. Kohler, Marine Fish Division, St. Andrews Biolgoical Station, St. Andrews, N. B.

P. F. K. Lett, Marine Fish Division, BIO, P. O. Box 1006, Dartmouth, N. S.

C. R. Mann, Atlantic Oceanographic Laboratory, BIO, P. O. Box 1006, Dartmouth, N. S.

D. V. Markle, Huntsman Marine Laboratory, St. Andrews, N. B.

W. B. Scott, Huntsman Marine Laboratory, St. Andrews, N. B.

D. M. Ware, Marine Ecology Laboratory, BIO, P. O. Box 1006 Dartmouth, N. S.

United States

M. D. Grosslein, Northeast Fisheries Center, Wood's Hole, Mass. 02543.

K. Sherman, Northeast Fisheries Centre, Narragansett Laboratory, R.R.7, South Ferry Rd., Marragansett, R. I. 02882

P. E. Smith, Southwest Fisheries Center, P. O. Box 271, LaJolla, Calif. 92038.

United Kingdom

D. J. Carrod, Fisheries Laboratory, Lowestoft, Suffolk NR 33 OHT

D. Harding, Fisheries Laboratory, Lowestoft, Suffolk NR 33 OHT

Federal Republic of Germany

D. Schnack, Institut fur Hydrobiologie und Fischereiwissenschaft, Universitat Hamburg, Hydrobiologische Abt., Palmaille 55, 2000 Hamburg 50.