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Emerging ecosystem theory in relation to plankton studies in the Northwest Atlantic[1]

by

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Trophodynamic studies of larval fish survival will need to take into account the early modelling of the production cycle developed by Riley (1941, 1946, 1947); Riley and Bumpus (1946); and Riley et al. (1949). They have not been used effectively in the Gulf to forecast conditions principally for lack of systematic input parameters that would allow for prediction in annual, seasonal, and/or more frequent time scales. Since the early studies of primary production of the Woods Hole and Bingham groups we have experienced a hiatus in making systematic observations. Some beginnings are underway. Matrices of information are being developed now for key elements in the ecosystem. Our goal is to develop a food budget for Georges Bank, and to continue satisfying our most critical information voids by expanding our effort from Georges Bank to the inner Gulf of Maine and Mid-Atlantic area. Progress is being made on defining the benthic communities on the shelf (Williams and Wigley, 1977). Examples of distributions of benthic species are given in Fig. 1. Changes in fish distribution and abundance are monitored with bottom trawl surveys conducted over the shelf for the past 15 years (Grosslein, 1969; Grosslein and Bowman, 1973). A generalized pattern of species mixtures along the shelf in spring and autumn is given in Fig. 2. The MARMAP oceanographic effort includes the monitoring of current systems, temperature, and salinity changes and the effects of the movement of water masses on the fish stocks in the area. Surface temperature and salinity charts have been prepared for the bottom trawl surveys (Pawlowski

[1] Extract from the MARMAP Fisheries Ecosystem Study News, National Marine Fisheries Service, Northeast Fisheries Center, Narragansett Laboratory Reference 79-12, February 1979.

et al., 1978) (Fig. 3). In addition, new information on water movements is now becoming available from moored current meters monitoring flow in the northeast channel of Georges Bank (Fig. 4). High velocity in flow from the Scotian Shelf into the Gulf of Maine and Georges Bank areas has been observed directly for the first time.

Primary Productivity Studies and Fish

Significant activity is now underway in the New York Bight. A group headed by John Walsh of Brookhaven National Laboratory is now investigating the energy flux of the Bight and principal driving forces of the system. Nutrient enrichment through storm mixing appears to be the principal mechanism for recycling nutrients within the ecosystem in spring (Walsh et al., 1976). The dominant forcing function of the wind-stirred water column is similar to the upwelling system off the Oregon coast. Other similarities between the two systems were also observed in annual primary productivity, food chain diversity, and fish biomass (Table 1).

In contrast to the coastal Oregon and the New York Bight area similarities, differences can be found in a preliminary comparison of the New York Bight, Georges Bank, and the North Sea. The estimated levels of primary productivity range from 100 $gC/m^2/yr$ for the North Sea to 150-200 $gC/m^2/yr$ for the New York Bight, and 400-500 $gC/m^2/yr$ for Georges Bank. The latter value has recently been reported by Cohen et al. (1978), based on C^{14} measurements made during MARMAP surveys in 1975. The estimated average production of fish biomass for the three areas increases from a low of 10 $mt/km^2/yr$ for the North Sea to 15 $mt/km^2/yr$ in the New York Bight, and a high of 19 $mt/km^2/yr$ for Georges Bank (Fig. 5).

The extremely high value for Georges Bank primary production is now being reexamined critically. A series of C^{14} measurements have been made in the area in 1976. Preliminary evidence supports the high value.

Observations of Stressed Ecosystems in the Northwest Atlantic

Recently Steele and Frost (1977) described a model of a stressed ecosystem, wherein overall levels of primary production are not affected by stress. But significant shifts in species composition were in evidence. In a stressed system the production of small fast growing species is favored over the larger species. The theoretical basis for the model is supported by the authors with field data describing long-term changes in the plankton of the North Sea based on Continuous Plankton Recorder data. In addition, recent experimentation in stressed large-volume plastic enclosures have shown a shift from essentially large-celled diatom populations to smaller dinoflagellates following dosings with copper and petroleum hydrocarbons (Steele and Frost, 1977; Thomas and Seibert, 1977).

In addition to plankton changes in the North Sea, described by the IMER group in Plymouth, Ursin (1977) reported a decline in mackerel and herring stocks in the North Sea coincident with an increase in the biomass of fast growing and shortlived species--sprat, Norway pout, and sandeel (Fig. 6). Although much of the data is preliminary in nature, the implication is clear. In a summary statement describing the results of the Symposium on the "Changes in the North Sea Fish Stocks and their Causes," Hempel (in press) reported that changes in food and predation of fish larvae may have been the key to the observed increases in growth and recruitment of cod and haddock. The decline in herring and mackerel abundance

> ". . . was at least partly responsible for improved living conditions for young gadoids and that fast growing, short lived fish with higher ecological efficiency took the place of the slower growing (but higher priced) species which altogether caused a higher productivity of the total fish population in the North Sea."

Implications of Biomass Changes in the Northwest Atlantic

In the Northwest Atlantic off the U. S. coast the changes in the size of the fish biomass over the past eight years have been dramatic. Recent estimates of primary production levels indicate that Georges Bank is far more productive than previously estimated. Considerable effort is now being directed to verify the higher values. Given that the value is reasonable, then we would look for evidence of changes at levels below the primary-production "lid." Significant shifts have occurred among the fish species. Mackerel and herring stocks have declined, and "coincidentally" the abundance of sand lance, a short lived, fast growing species with high-ecological efficiency, has increased dramatically in abundance, particularly in the Southern New England and Mid-Atlantic Bight areas (Fig. 7).

Some between year and among area differences in zooplankton abundance have been detected. However, the causes for the changes in zooplankton densities are not clear. It will be important in the future to partition zooplankton mortalities into environmental and predator compartments. This is a difficult but important task.

The implications of these kinds of species shifts is clear. Resource managers, now more than ever before, need to evaluate the consequences of multispecies interactions and be able to sort out the impacts resulting from the removals of presently unfished "ecological species" (e.g., four-bearded rockling, and/or sandeels in favor of "commercial" species (e.g., cod, haddock, herring, flounders, and mackerels). Proper evaluation is dependent on the best scientific advice available, and to this end it is necessary to re-evaluate how best to get on with studying marine ecosystems from a fishery management perspective.

Available evidence from the northeast Atlantic indicates that fluctuations of fish biomass as documented in the Symposium on the Changes in the North Sea Fish Stocks were of several orders of magnitude, and measurable with the present methods of combining, and analyzing data from fish-catches and fisheries-independent assessment surveys of fish stocks and their environments. In the northeast Atlantic, largely through the framework of ICES, catch-data is systematically reported and joint international surveys for demersal, and pelagic adults, juvenile, and larval fishes are conducted, usually for target species. Measurements of pollutants, primary production, hydrography and zooplankton biomass, species composition and productivity are generally studies of limited areas and/or relatively short-duration. The exception, is the Continuous Plankton Recorder surveys of the North Atlantic underway for nearly three decades.

The approach in the northwest Atlantic is largely an evolution of ICNAF joint international studies to support the total fish biomass management regime adopted in 1973. Standardized MARMAP surveys are underway for monitoring population changes of fish, plankton, shellfish and benthos, and hydrography by the Northeast Fisheries Center.

Principal focus in the MARMAP ecosystem study is on the early life stages of fish (Fig. 8). Estimates are being made of the magnitude of the size of the spawning biomass of a stock based on abundance and mortality estimates of eggs and early stage larvae. To support the activity, a major commitment was made to conduct in cooperation with other countries a "patch" study in 1979. The operations were conducted on Georges Bank on a microscale level using new sampling strategies including pumps, to observe the relationships among fish larvae, their prey and predators in relation to growth and survival. Macroscale ichthyoplankton-zooplankton surveys of up to 6x/yr are continuing to monitor temporal and spatial changes in: (1) fish spawning and estimates of larval fish production, (2) changes in zooplankton abundance and species composition, and (3) changes in hydrography and their effects on fish. The common denominator to the studies is energy flow among the principal species. An initial energy budget has been developed by Cohen et al. (1978) for Georges Bank. Serious deficiencies exist in several of the key components. One of the most significant is in the fragmentary nature of the secondary production component, both in the zooplankton and benthos. The initial stimulus for developing the budget was in fact to identify the weakest components and develop the necessary research initiatives to overcome them.

Principal focus over the next several years in the MARMAP program will be on predator-prey interactions at all trophic levels. To date approximately 70,000 stomachs have been examined to frame the most critical questions. Preliminary evidence suggests that silver hake Merluccius bilinearis, plays a principal role in regulating the ecosystems (Edwards and Bowman, 1978). Also, the estimate of turnover rate of benthos and plankton will be refined. The degree to which primary production serves as the probable "lid" on the ecosystem now needs to be examined carefully. Studies of primary production will be accelerated in an effort to confirm or modify the extremely high values attributed to Georges Bank, and the impact of these values on the fish stocks. The MARMAP studies are serving to improve primary production estimates, and provide a better understanding of the links between plankton and fish production.

Literature Cited

Cohen, E., M. D. Grosslein, M. P. Sissenwine, and F. Steimle. 1978. Production studies at the Northeast Fisheries Center. Northeast Fisheries Center, Woods Hole, Laboratory Reference Report No. 78-14.

Edwards, R. L., and R. E. Bowman. 1978. An estimate of the food consumed by continental shelf fishes in the region between New Jersey and Nova Scotia. Northeast Fisheries Center, Woods Hole, Manuscript, 25 pp.

Grosslein, M. D. 1969. Groundfish survey program of BCF Woods Hole. Comm. Fish. Rev. 31(8-9): 22-35.

Grosslein, M. D., and E. Bowman. 1973. Mixture of species in Subareas 5 and 6. ICNAF Redbook 1973 Part III: 163-208.

Pawlowski, R. J., S. R. Nickerson, and W. R. Wright. 1978. Spring and fall sea surface temperature and salinity on the northeastern continental shelf; Cape Hatteras to Cape Sable, 1972-1977. Northeast Fisheries Center, National Marine Fisheries Service, Woods Hole, Laboratory Reference No. 78-22.

Riley, G. A. 1941. Plankton studies. IV. Georges Bank. Bull. Bingham Oceanogr. Coll. 7: 1-73.

Riley, G. A. 1946. Factors controlling phytoplankton populations on Georges Bank. J. Mar. Res. 6: 54-73.

Riley, G. A. 1947. A theoretical analysis of the zooplankton population on Georges Bank. J. Mar. Res. 6: 104-113.

Riley, G. A., and D. F. Bumpus. 1946. Phytoplankton-zooplankton relationships on Georges Bank. J. Mar. Res. 6: 33-47.

Riley, G. A., H. Stommel, and D. F. Bumpus. 1949. Quantitative ecology of the plankton of the western North Atlantic. Bull. Bingham Oceanogr. Coll. 12(3): 1-169.

Steele, J. H., and B. W. Frost. 1977. The structure of plankton communities. Phil. Trans. of the Royal Soc. London B. Biol. Sci. V280, pp. 485-534.

Thomas, W., and D. Seibert. 1977. Effects of copper on the dominance and diversity of algae. Bull. Mar. Sci. 27: 23-33.

Ursin, E. 1977. Multispecies fish stock assessment for the North Sea. ICES C.M.1977/F: 42.

Walsh, J. J., T. E. Whitledge, L. A. Codispoti, S. O. Howe, C. D. Wirick, and L. J. Castiglione. The biological response to transient forcing of spring bloom within the New York Bight. Unpublished Manuscript, 66 pp. Brookhaven National Laboratory, Upton, N. Y. 1976.

Williams, A. B., and R. L. Wigley. 1977. Distribution of decapod crustacea off northeastern United States based on specimens at the Northeast Fisheries Center, Woods Hole, Massachusetts. NOAA Tech. Rept. NMFS Circ. 407: 44 pp.

Table 1. A comparison of habitat variability, species diversity, and productivity between two shelf ecosystems of the same latitude.[1]

	Oregon	New York
Temperature range of the inshore mixed layer	8-14°C $year^{-1}$	4-24°C $year^{-1}$
Cumulative nitrate within the inshore mixed layer	2.2 g-atom NO_3 m^{-3} $year^{-1}$	1.3 g-atom NO_3 m^{-3} $year^{-1}$
Primary production of inshore waters	193 gC m^{-2} $year^{-1}$	150-200 gC m^{-2} $year^{-1}$
Number of inshore copepod species	26 within 18 km of the coast	29 within 25 km of the coast
Estuarine dependent fish species	44% of commercial catch $year^{-1}$	45% of commercial catch $year^{-1}$
Marine fish species on shelf and slope	∿ 219	∿ 200
Fish yield of the shelf ecosystem	10 tons km^{-2} $year^{-1}$	5-10 tons km^{-2} $year^{-1}$

[1] Walsh, John J., Terry E. Whitledge, L.A. Codispoti, Steven O. Howe, Creighton D. Wirick and Louis J. Castiglione. The biological response to transient forcings of the spring bloom within the New York Bight. Unpublished manuscript Brookhaven National Laboratory, Upton, N.Y. 66 pp. 1976.

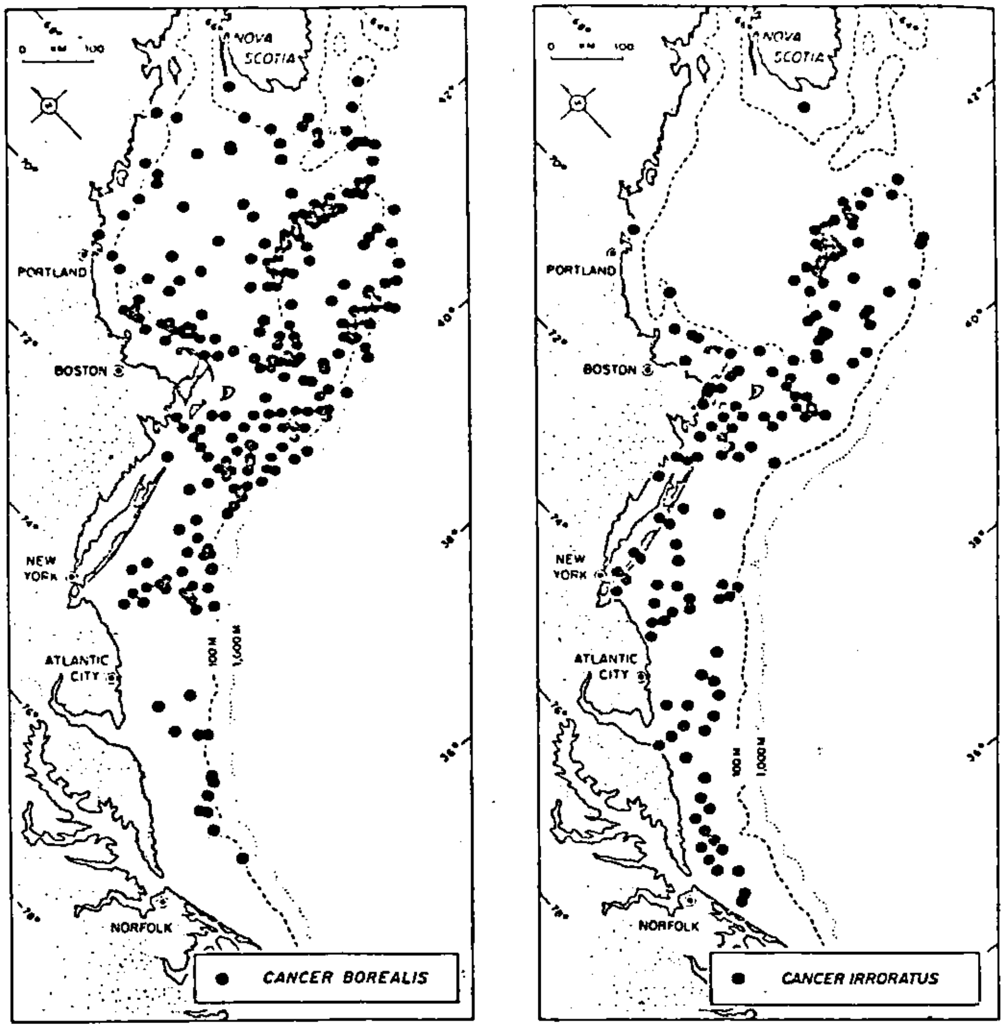

Fig. 1. Examples of distributions of macrobenthos, Cancer borealis and C. irroratus from the MARMAP sampling area off the northeast coast of the United States. From Williams and Wigley (1977).

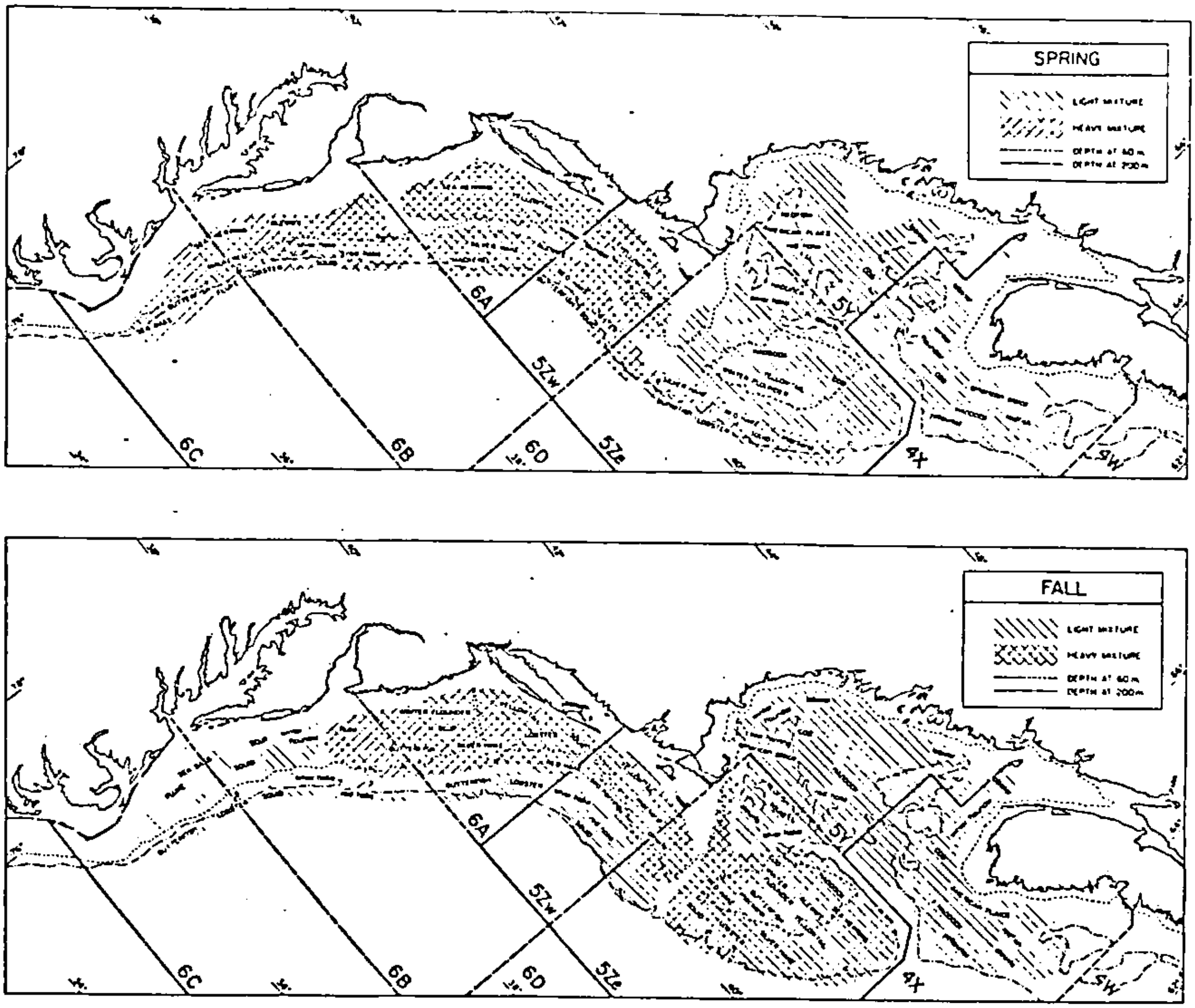

Fig. 2. Generalized pattern of species mixture of fish in the MARMAP sampling area off the northeast United States. From Grosslein and Bowman (1973).

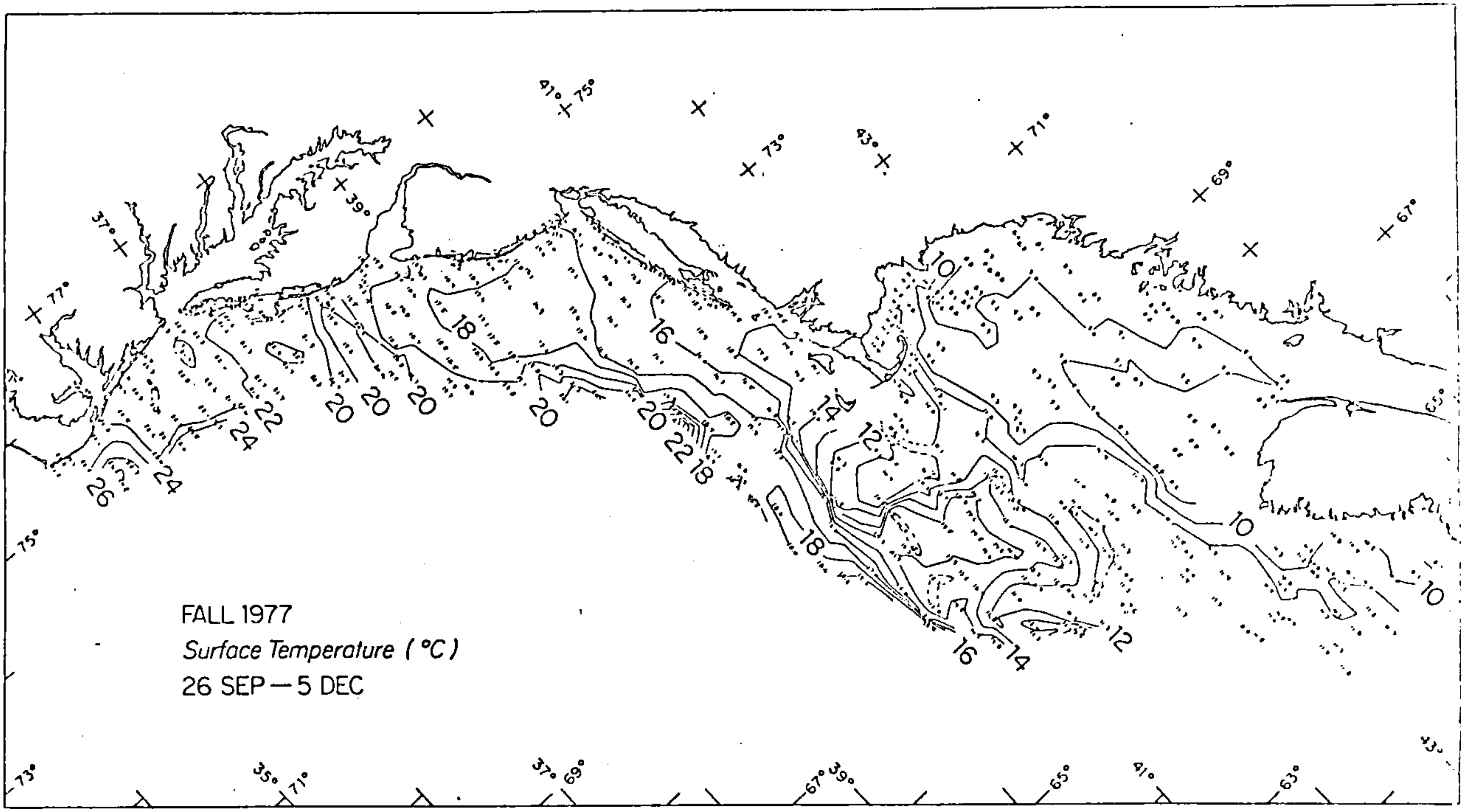

Fig. 3. An example of the surface salinity and temperature charts prepared from the observations made on the MARMAP bottom surveys, autumn 1977. From Pawlowski et al. (1978).

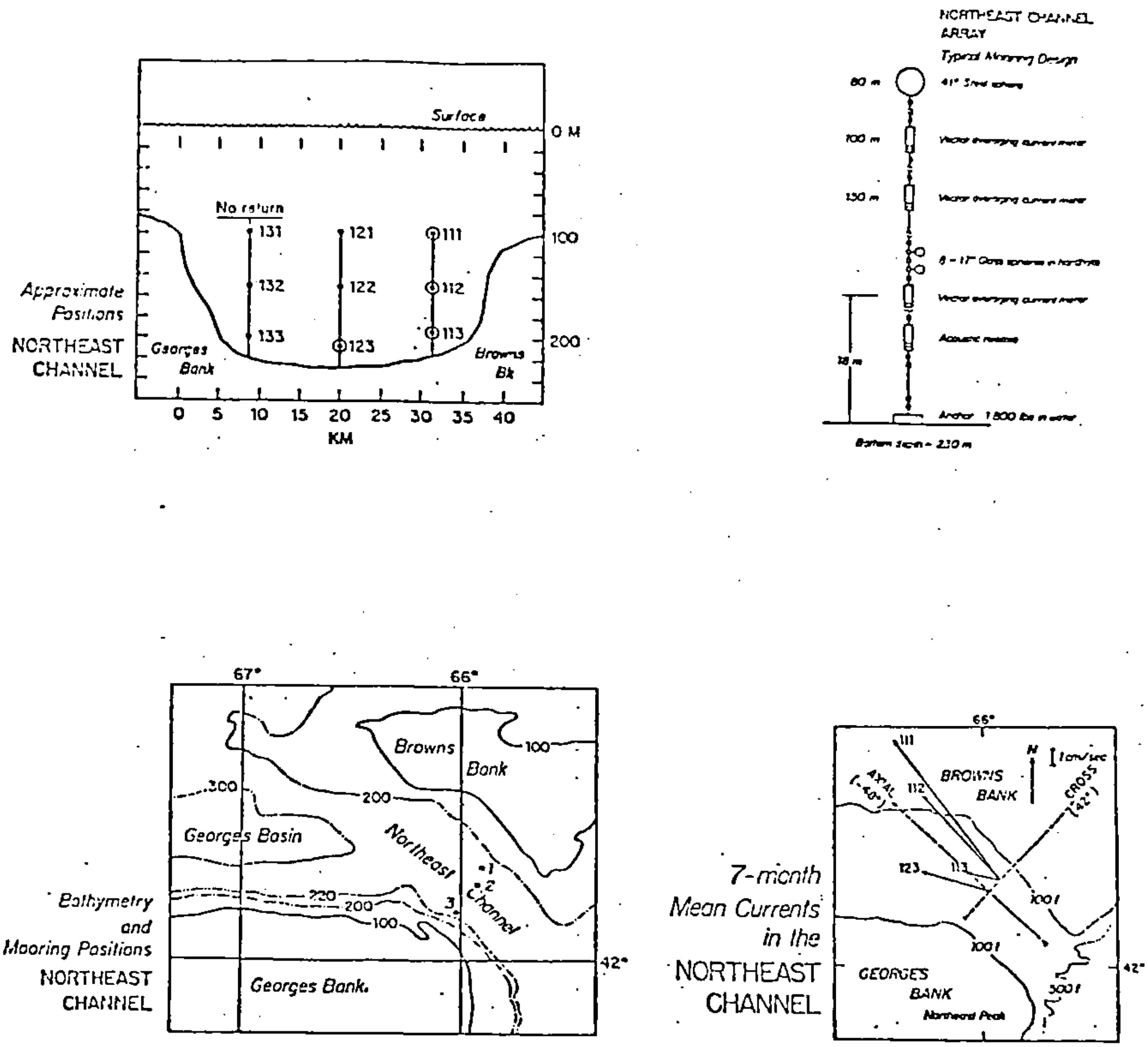

Fig. 4. MARMAP bottom current monitoring experiment in the northeast channel of the Gulf of Maine. Lower left depicts general area of the experiment; upper right shows the typical current meter array; upper left shows the approximate positions of the array in the water column; and lower right indicates the mean directional flow and relative velocity of the currents, the numbers representing the current meter positions with respect to depth.

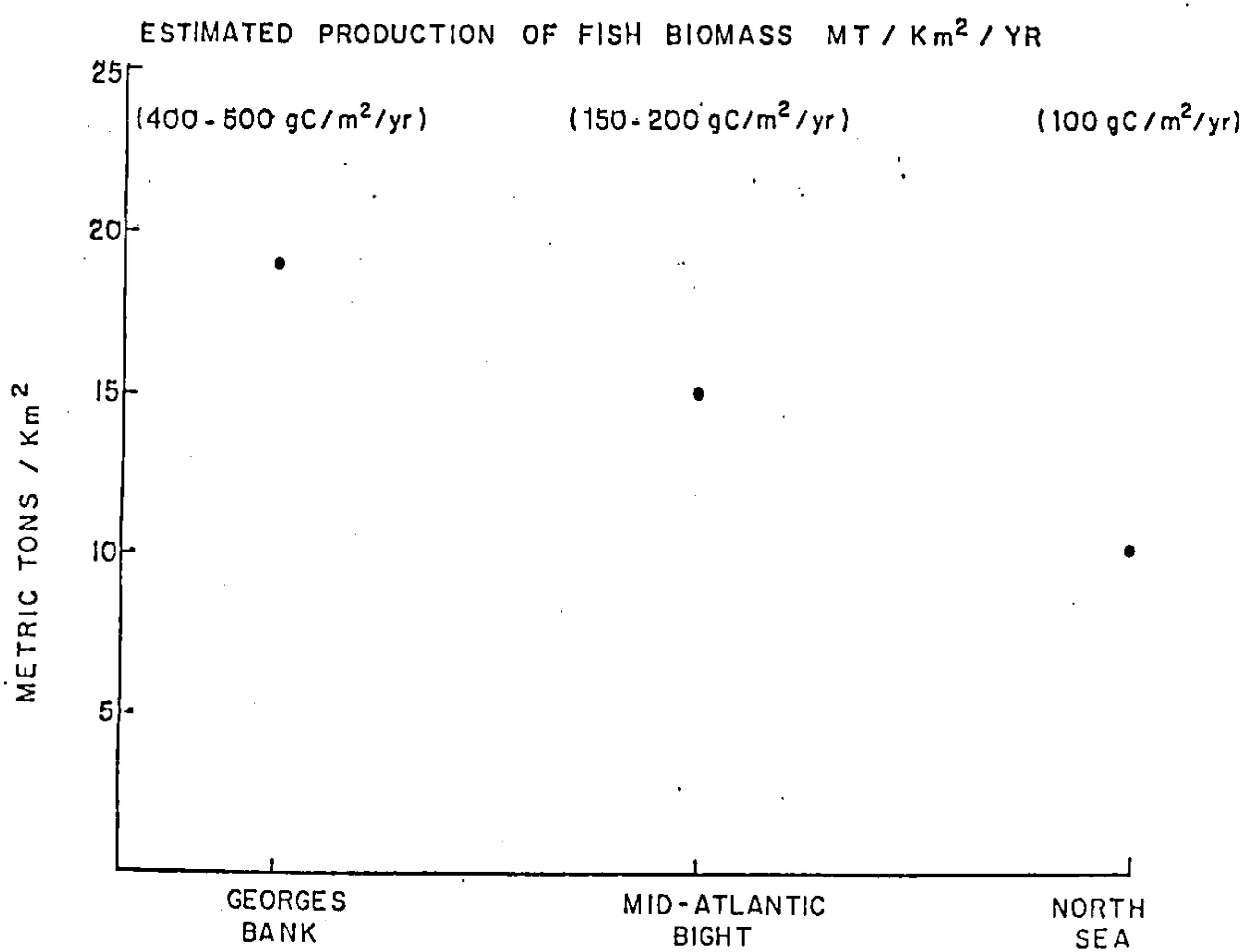

Fig. 5. Estimated annual primary production of three areas - - Georges Bank, Mid-Atlantic Bight, and the North Sea - - compared against estimated production of fish biomass.

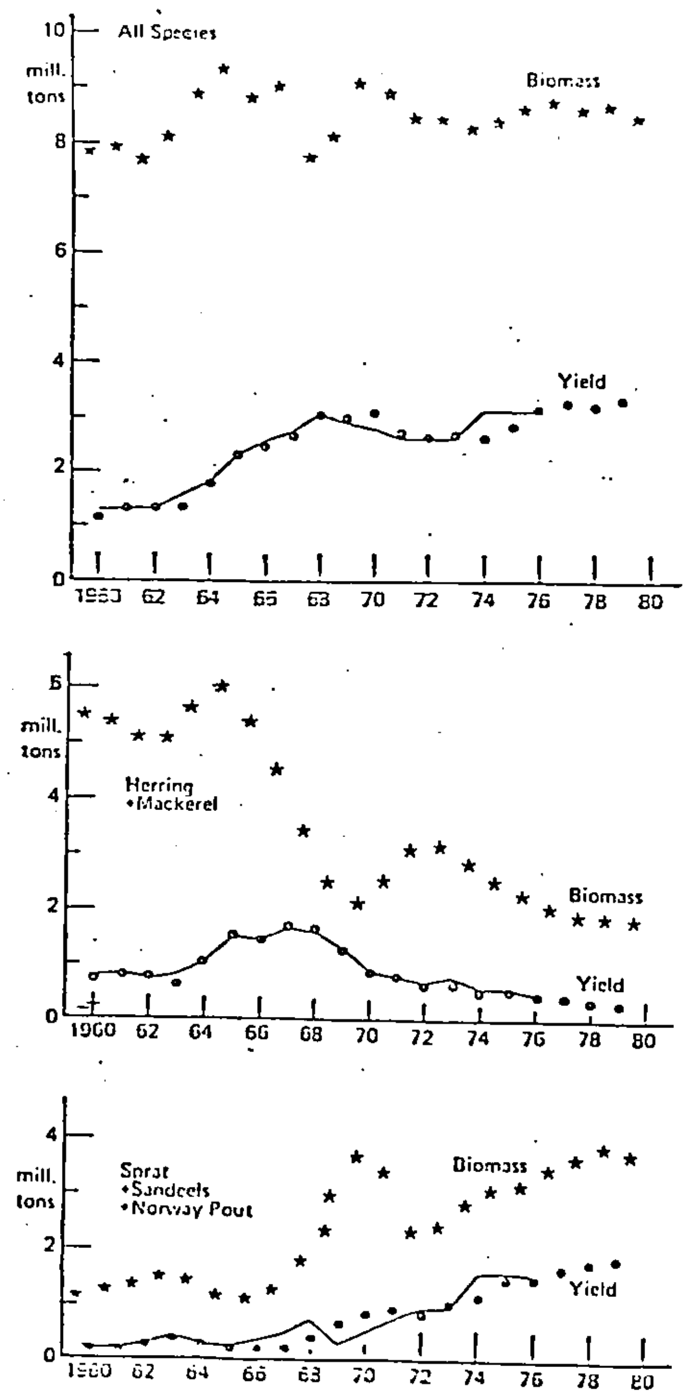

Fig. 6. Estimated changes in the biomass of fishes in the North Sea, 1960-1976, with model simulated projection to 1980. From Ursin (1977).

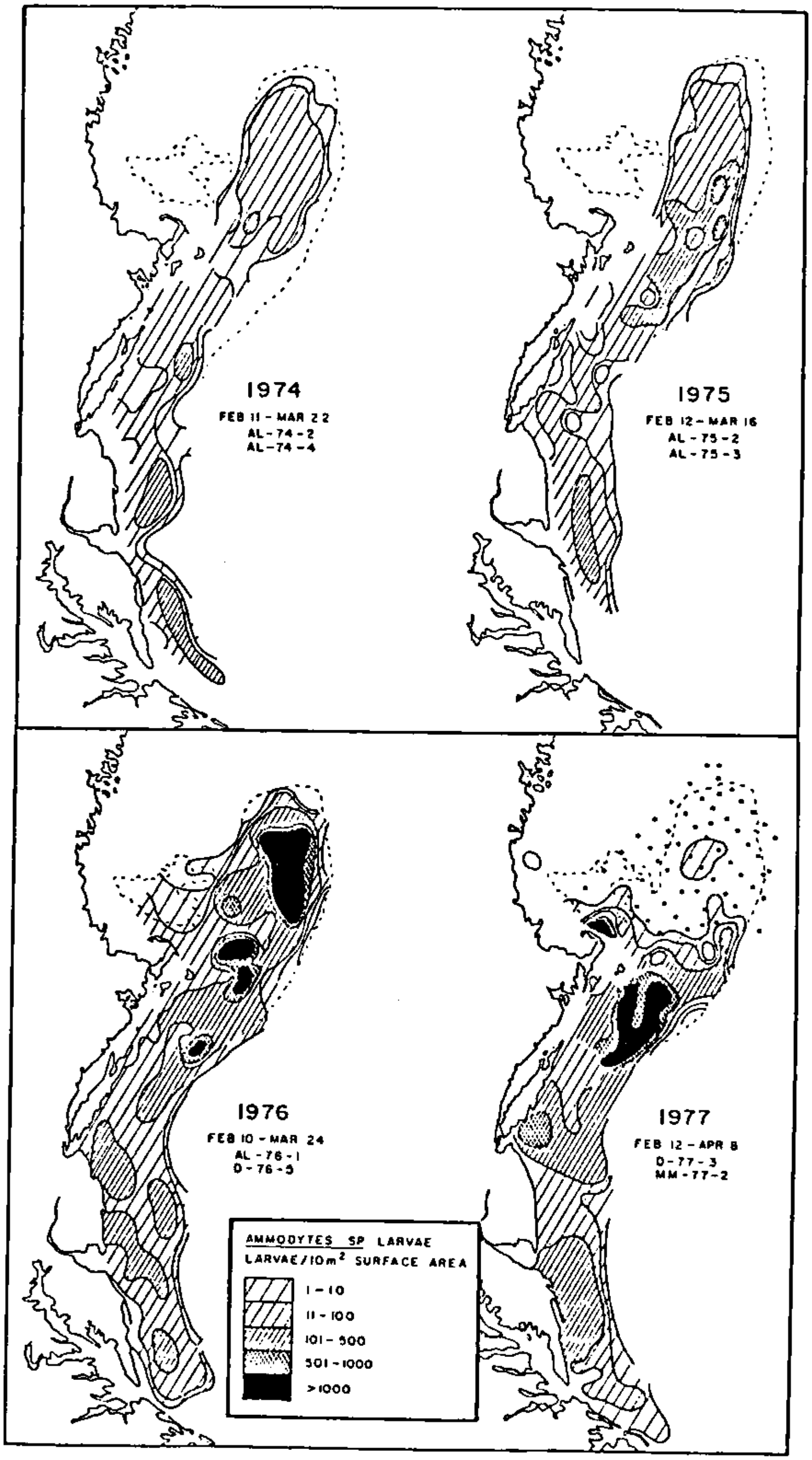

Fig. 7. Changes in the abundance of _Ammodytes_ spp. larvae in early spring in the MARMAP sampling area off the northeast United States coast, 1974-1977. From Smith _et al._ (1978).

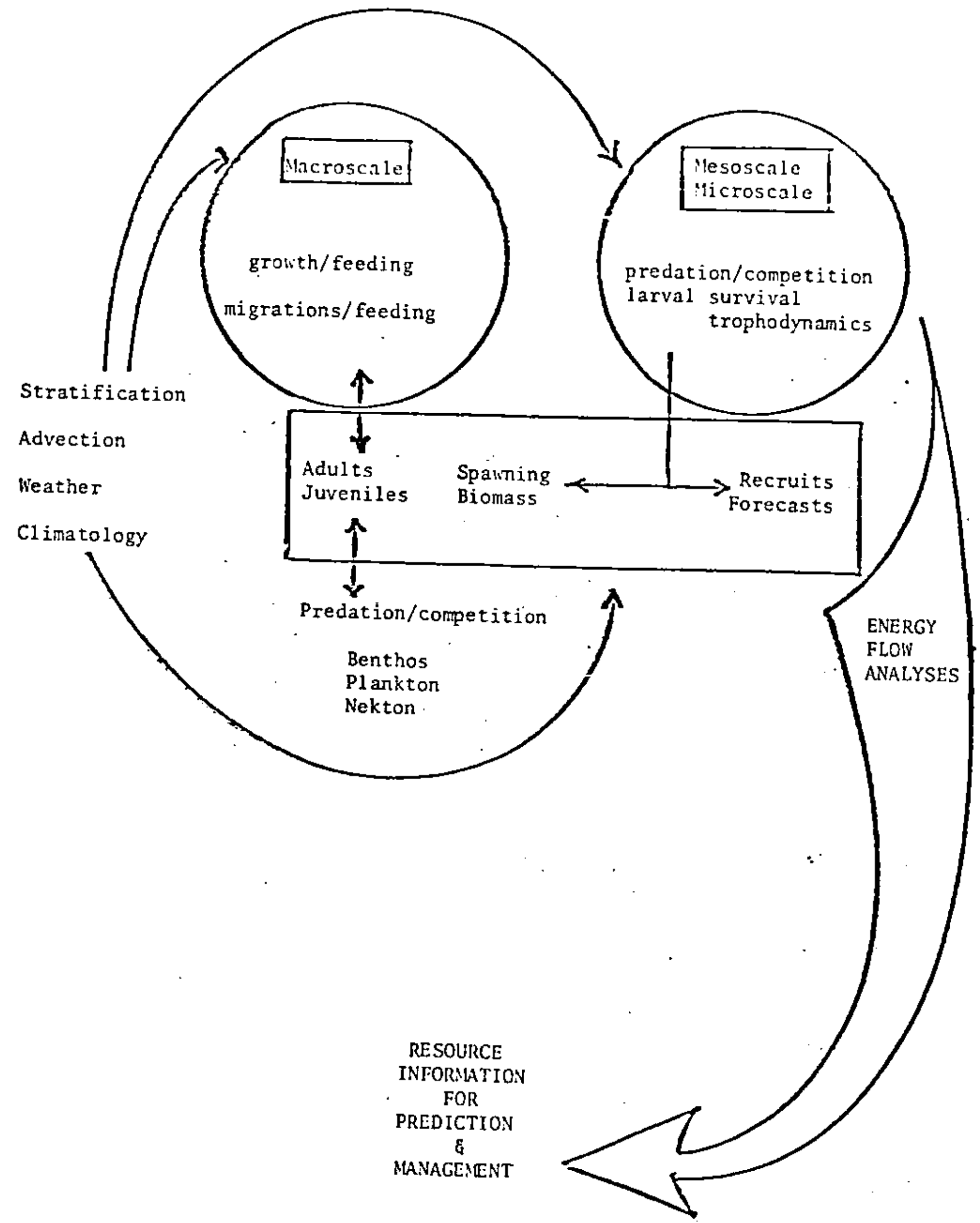

Fig. 8. Schematic outline of the principal focus of the MARMAP ecosystem study of the Northeast Fisheries Center. The rectangle depicts the interactions under investigation to obtain a better understanding of the relationship between the size of a spawning biomass of fish and subsequent year-class recruitment. Studies are underway on the larval, juvenile, and adult fishes within the context of measuring energy flow through the system, and the effects of fishing, pollution, and environmental changes on the flow. Macroscale surveys are made up to 6x/yr to monitor changes of fish, plankton, and hydrography. Mesoscale surveys are conducted from the onset of larval hatching up to juvenile development on target species. Herring has been the target species since 1971 in studies of recruitment processes off the northeast coast. Microscale studies of larval herring growth and predator-prey studies are planned for 1979.