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Suggestions Regarding Management Planning For Some Vertebrate & Invertebrate Resources of Narragansett Bay 52 pp

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Narragansett Bay Estuary Project

Suggestions Regarding Management Planning for Some Vertebrate and Invertebrate Resources of Narragansett Bay

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FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1984 , and the Narragansett Bay Project (NBP) was established in 1985. Narragansett Bay was designated an "estuary of national significance" in 1988. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP's mandate is to direct a program of research and planning focussed on managing Narragansett Bay and its resources for future generations.

The NBP will develop a draft Comprehensive Conservation and Management Plan (CCMP) by December, 1991, which will recommend actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven priority issues for Narragansett Bay:

- management of fisheries
- nutrients and potential for eutrophication
- impacts of toxic contaminants
- health and abundance of living resources
- health risk to consumers of contaminated seafood
- land-based impacts on water quality
- recreational uses

The NBP is taking an ecosystem/watershed approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among federal, state and local agencies, as well as with academic researchers, in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. The information in this document has been funded by the State of Rhode Island under the R.I. Clean Water Act Environmental Trust Fund (R.I.G.L. 46-12-24.2 (c)) as part of a Cooperative Agreement between RIDEM and the University of Rhode Island. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication as a technical report by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP.

Executive Summary

This report attempts to evaluate past history, present status, and projections for selected fish and invertebrate species in Narragansett Bay, with an overall goal of providing some suggestions and recommendations for management planning. The objectives, as defined, are impossible to adequately satisfy in practice, primarily due to severe limitations in available data—both for past, as well as future projections. The assessment of available data clearly indicated that specific causal factors related to individual fisheries are unassignable on the basis of available information. In spite of this, the following judgements, suggestions, and recommendations are put forth with a view toward providing management advice at a policy and planning level.

Suggestions for vertebrate resources management—

- The primary objective of fisheries management for Narragansett Bay should be to maintain the abundance of stocks for optimal benefit to users. The type of overfishing to be avoided is recruitment overfishing, wherein the reproductive capacity of the stock concerned is damaged.
- To preserve the spawning stock biomass a constant harvest rate policy is suggested to be superior to other policies.
- Management planning must involve steps toward controlling over-expansion by limiting the numbers of fishermen and their gear.
- Changes in the manner in which regulations are made should occur. Specifically, changes should be designed to prevent unreasonable delays in enacting or modifying management regulations and to permit sound resource conservation based on available scientific evidence.
- Marine sport fishermen should be subjected to an annual license fee.
- The management agency (RI DEM) should have adequate staff and funding to conduct stock assessments in Narragansett Bay and adjacent waters.
- Fishing effort and catch should be effectively monitored
- Degradation of habitat should be controlled.
- Close coordination among neighboring states and federal agencies is considered important for effective management action.

Suggestions for shellfish and invertebrate resource management—

- Conduct continuing stock assessments to provide reliable information on the population dynamics and biology of the resources.
- Design, implement, and evaluate programs to control entry into the shellfish fishery, such as individual transferable quotas.
- Evaluate hydrographic suitability of various parts of Narragansett Bay for the establishment of spawner sanctuaries. These are defined as sites containing fecund adult clams located such that larval setting will be maximized in selected growing areas.

- We also suggest that available hydrographic models of Narragansett Bay be utilized in an analysis of the potential effectiveness of refuge or sanctuary areas for quahogs. It is currently thought by some people that the present polluted (restricted) areas serve as a source for repopulating exploited areas. Exercising a suitable hydrographic model would permit an objective analysis of the value and location of refuge areas to assure adequate dispersion of larvae to exploited areas.

- Design, implement, and evaluate various alternative harvest strategies with clearly defined objectives.

- Enhance monitoring to detect trends in water quality and the levels and sources of pollutants. Also, evaluate impacts of sewage treatment improvements and disposal facilities on certification of shellfish harvest and growing areas.

- Another suggestion regarding the management of non-motile resources relates to systems of optimal rotation of harvest areas and the optimal thinning of dense beds of non-motile organisms.

- For future American lobster management in Narragansett Bay—as well as in the State of Rhode Island—it is suggested that the model of Shotton (1989) be given serious consideration.

- It is recommended that further study of shellfish mariculture as a cottage industry—as well as at a larger scale—be given priority in view of the global potential of this industry. Elimination of user conflict needs to be resolved.

- Reinvestigate depuration and relaying strategies—It has already been stated that there is a strong public health component in shellfish production and marketing in Narragansett Bay. One of the management procedures utilized in Rhode Island involves the relaying of quahogs from moderately polluted waters to clean areas for relatively long periods in order for the organisms to purge themselves of certain contaminants. We believe that this practice is feasible if the cost of collecting organisms from polluted areas is relatively low, the recovery of the organisms is high, the organisms are sampled for pollutants and contaminants, and transplant areas can be effectively monitored to prevent unauthorized harvesting. The cost-effectiveness of such activities should be carefully evaluated and various alternatives should be critically examined, including a determination of which pollutants to measure. Another procedure which may permit utilization of organisms from moderately polluted waters is the application of a process of depuration prior to marketing. A clear description of the depuration process as it relates to the quahog is provided by Zaharia (1979). Since this report, there have been significant improvements in various aspects of depuration—such as improved ultraviolet systems, ozone treatment, and other developments. These should be assessed in the light of current needs.

- Reassess current conservation and management legislation—The possibility of a well-managed fishery for the quahog and other non-motile invertebrates in Narragansett Bay is significantly affected by both the lack of adequate professional staff to conduct surveys and assessments—as well as the authority to limit effective fishing effort. It is our opinion that the value of the shellfish resources of the Bay justify substantially more effective monitoring and assessment, and additional staff for this program—as well as changes in legislation to permit more effective control of the fishery—are recommended.

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I. Overview

Introduction

Objectives of the Study—

This report attempts to evaluate past history, present status, and projections for selected fish and invertebrate species in Narragansett Bay, with an overall goal of providing some suggestions and recommendations for management planning. Primary attention is given to stocks of major commercial and/or recreational importance. No attempt is made in this report to provide species specific stock assessments nor to estimate vital statistics related to specific management actions. This latter activity is clearly very important, but it is considered to be within the domain of the Division of Fish and Wildlife of the Rhode Island Department of Environmental Management. The Division of Fish and Wildlife has been producing increasingly comprehensive management-related documents for major species in response to specific needs. An example includes recent reports related to winter flounder stock assessment and management (Gibson 1989a,b) and Powell (1988).

The objectives of this study as defined above are impossible to adequately satisfy in practice, primarily due to severe limitations in available data—both for past, as well as future projections. However, an effort has been made to assess the relevant material on the status and trends of important fisheries. See section on long-term trend analyses for examples. The assessment of these data clearly indicates that specific causal factors related to individual fisheries are unassignable on the basis of available information in most cases. In spite of this, some judgements, suggestions, and recommendations are put forth with a view toward providing management advice at a policy and planning level. These are based more on the past professional experiences of the authors than on available statistical evidence.

The organization of this report includes an overview of management objectives and their realizations, an empirical evaluation of status and trends of selected stocks and sections on shellfish and finfish management suggestions and recommendations. This document is designed to address both fish and shellfish management planning, since the two are under the jurisdiction of the same management agency. This arrangement is considered to be appropriate. However, there are some perceived differences in management strategies for motile versus non-motile organisms.

It should be made clear at the outset that this report is primarily a synthesis and evaluation of many reports, publications, and other documents related to the Narragansett Bay Project, reports and publications of the Rhode Island Division of Fish and Wildlife, and other publications related to fishery and shellfish management—as well as opinions of the authors. It is not possible to cite and acknowledge these sources of information adequately because they are too numerous. However, special mention is made of the *Status of the Hard Clam Fishery in Narragansett Bay* by S.A. Pratt and the draft *Winter Flounder, Pseudopleuronectes americanus, Species Profile* by C.L. Gray, because these contain extensive reference lists and detailed information of relevance which has been utilized.

Management Objectives—

Informal resource management plans for some Narragansett Bay and Rhode Island living marine resources have been developed from detailed scientific analyses by Rhode Island Division of Fish and Wildlife personnel. Examples include the winter flounder, the tautog, and the quahog. These management plans ultimately become the subjects of essentially political action and debate. The political action and debate occurs through the public hearing process and by actions of special interest groups, ultimately culminating with decisions by the Rhode Island Fisheries Management Council. The relative merits of this process are not addressed in this section. However, it is strongly recommended that in such debates, efforts by all concerned parties be made to carefully focus attention on well-defined fisheries concepts for use as standards of performance. One of these management objectives or measures of performance has been defined as maximum sustainable yield

(MSY). It has been recognized for some time that there is a relationship between resource population size and the sustainable rate of harvest. Low stocks produce low sustained yields in general, because not enough organisms are available to grow and reproduce to achieve the resource potential. Very high populations are also likely to be unproductive, because of competitive interactions which reduce performance of average organisms. It is assumed that there should exist some intermediate stock level that produces the greatest excess over maintenance needs. This excess is called the maximum sustainable yield (MSY). Models have been developed to determine what stock size provides MSY and what management (such as size limits) maximize capture success—such as the total weight of organisms harvested. This latter information is often provided by so-called yield-per-recruit (YPR) models, which are designed primarily to control growth overfishing. Growth overfishing occurs when the average size (age) of captured fish is substantially lower than the size (age) at which the weight yield-per-recruit or harvestable biomass is maximized. However, growth overfishing is not as serious as recruitment overfishing wherein the spawning stock biomass is reduced to less than acceptable levels.

It should be recognized that MSY is developed for application as a deterministic, equilibrium concept, in most instances. In practice it is virtually impossible to maintain MSY at a fixed quota for any length of time due to large random environmental disturbances, which affect recruitment and stock size. Also, the MSY rate of exploitation may be very near a point on the YPR curve where only a slight increase in exploitation may bring the stock to collapse. An alternative and more recent concept is $F_{.01}$, which is defined as the fishing mortality rate at which the slope of the yield-per-recruit curve is $^1/_{10}$ of the slope at the origin. In other words, $F_{.01}$ is the fishing mortality rate at which the gain in yield-per-recruit produced by adding one unit of effort to the fishery is only $^1/_{10}$ of the yield-per-recruit obtained by the first unit of effort introduced into a virgin stock.

Most harvest fishery management alternatives fall into three categories: 1) maintenance and/or restoration of the resource to some optimal level, 2) minimization (elimination or reduction) of conflicts, and 3) improvement of the economic performance of the fishery (a prohibited activity for the Rhode Island Marine Fisheries Council). Specific management models are almost exclusively based on a concept of equilibrium conditions.

It is suggested that the primary objective of fisheries management for Narragansett Bay—as well as for the State and nation—should be to maintain the abundance of stocks for optimal benefits to the users. Section 602 guidelines related to the Marine Fisheries Conservation and Management Act of 1976 promulgated by the Secretary of Commerce in 1989 were explicitly formulated to objectively define overfishing and to prevent its occurrence in the future. The type of overfishing to be avoided is recruitment overfishing, wherein the reproductive capacity of the stock of concern is damaged. This statement is thought to be appropriate for Narragansett Bay and Rhode Island fishery management planning. Therefore, the overriding biological concern should be to preserve the spawning stock biomass, to ensure that sufficient recruitment occurs to maintain the stock in perpetuity at levels which produce optimal yields. Contemporary thought in fisheries management, based on supporting population dynamics studies—as well as experience in fisheries management—indicates that a constant harvest rate policy is superior to other policies in terms of preventing population collapse, while maintaining adequate yields. This policy is not dependent upon equilibrium assumptions, which are being increasingly challenged by the scientific community at large and by contemporary ecologists in particular. The above policy is also defined as a risk averse policy, which is conservative. That is, it views nature as relatively responsive to moderate changes in exploitation rates or to other perturbations and attempts to minimize the risk of a catastrophe. In order to provide a rational way to deal with the reasonable objective of avoiding unnecessary risks, it is suggested that management agencies attempt to maximize a risk averse utility function. A utility function is defined as a way to measure the uncertain outcomes of alternative strategies on a single value scale. Walters (1986) has discussed this in a fishery context and Keeney (1977) has described the procedure from a decision theoretic point of view.

Although biological bases for management planning are emphasized in this report, it is recognized that most resource management decisions involve consideration of economic, political, social, and biological aspects of various management options. In addition, resource management involves evaluation of uncertainties, such as the consequences of changes in exploitation rates, environmental variations which affect resource recruitment and growth, stock size estimation uncertainties, other parameter estimation uncertainties, uncertain political and economic decisions, and probably others. It should be pointed out herein that analysis of uncertainties and techniques for aiding decision making in the face of risk and uncertainty have been developed and utilized in several disciplines. Even policy conflict resolution, policy projections, and evaluations of policy consequences are possible through sophisticated computer programs designed to use existing knowledge and informed judgements to build system models relatively easily and quickly. These models contain evaluation features suitable for resolving the conflicting preferences of many groups under many conditions. An illustration of one form of decision analysis software is provided by EZ-IMPACT, Biosocial Decision Systems, 1504 Brittany Drive, College Station, Texas 77840. A case example of the application of an early version of this software is provided by an undergraduate thesis at Brown University by M.B. Brown and M.E. Echavarria, 1987 entitled *Thinking Like an Estuary: Using IDA as a Tool for Problem-Solving in Narragansett Bay*. One of us (S.B.S.) has utilized the above program for preliminary assessment of alternative coastal zone management plans in Southeast Asia. There are several other available programs for decision analysis.

Although the primary emphasis of this report is on biological management criteria, the larger dimensions of living resource management planning are clearly recognized. To meet this broader need, we strongly urge that serious consideration be given to the application of multiple objective decision analysis techniques to obtain a systematic resolution of potential differences in the perceptions and preferences of various user groups, such as representatives of various types of fisherman, scientists, managers, and administrators. Mariculture, in particular, needs to be put into perspective with accomodations for limiting conflicts with other user groups (personal communication, RI Division of Fish and Wildlife). We believe that the current state of technology available is capable of providing substantial assistance to rational decision making regarding living resource management which is satisfactory to multiple user groups faced with risk and uncertainties. Our recommendation is for these techniques to gradually replace the public hearing and unstructured decision making process currently in operation.

Projections Related to the Narragansett Bay Environment and Its Users—

The briefing paper entitled *Sewage Contamination in Narragansett Bay* (Karp et al. 1990) nicely summarizes demographic trends in Rhode Island and other probable impacts on the Bay with special reference to sewage contamination. In summary, the population of the State is expected to increase by about 10 percent by 2010, and the rural and coastal communities are expected to experience most of this growth.

The following are some thoughts on the consequences of this growth and some projection of factors likely to affect resource planning in Narragansett Bay.

a) On a global scale the relative importance of aquaculture/mariculture is expected to double each decade to an average annual production of 32 million metric tons from the present 8-9 million ton volume according to the Food and Agriculture Organization of the United Nations. Clearly, there is some need to put mariculture into perspective with other Narragansett Bay planned activities. The study by Kassner (1988) clearly illustrates the political power of baymen (those who harvest hard clams) in affecting management decisions regarding mariculture—as well as in limiting fishing effort in New York. Resistance to mariculture and to limiting effort has effectively constrained both mariculture and rational management in New York. This seems very analogous to the Rhode Island situation, and this problem should be addressed and assessed in terms of the growth potential of mariculture and the potential sustainability of the quahog fishery of Narragansett Bay.

b) The relative importance of all recreational uses of the Bay is expected to increase dramatically in the future. Potential conflicts between recreational fishermen and commercial fishermen are expected to increase. The strategies for conflict resolution briefly mentioned in the previous section deserve careful evaluation for this problem area. The economic multiplier effects of the recreational fishery industry should be clearly recognized and reassessed at regular intervals. It is recognized that there are so-called multiplier effects obtainable from both the sport and commercial fisheries. That is, the capture and final processing of fish and shellfish involves several ancillary activities. In the case of sport fishing, these can extend to income generated from housing, fuel, tackle, bait, boats, etc. related to the fishing experience. Similarly, commercial fishing provides additional income through processing, distribution, gear, fuel, etc. Both of these multiplier effects should be carefully evaluated for Narragansett Bay fisheries and utilized in management planning. No user group should have an advantage over another user group, and both commercial and recreational uses are appropriate.

c) The public health component of bivalve mollusk production and marketing will remain a continuing problem area. Further reductions of sources of pollution in the Providence area do not necessarily assure an uncontaminated Upper Bay environment, because there is a significant river flow into the Bay which can include sources which are well outside the Providence area.

d) It is believed that most of the economically important living resources of Narragansett Bay are currently exploited at or above optimal levels. It is concluded, therefore, that additional sustained yields can only be achieved by limiting effective fishing effort and/or various measures to augment natural stocks such as enhancing the environment or artificial propagation through critical life history stages. These latter activities (determining ways to limit effective fishing effort and/or evaluating various measures to increment natural stocks by environmental enhancement or artificial propagation through suitable life history stages to insure high survival) should receive priority attention in management planning for the shellfish fisheries in Narragansett Bay.

e) The importance of various aesthetic uses of the Bay will continue to increase. Therefore, it seems desirable that some efforts be made by the Department of Environmental Management to monitor overall biodiversity and non-exploited—as well as exploited resources—in Narragansett Bay. The suggested management plan for non-commercial, ecologically or aesthetically important species is a carefully planned and executed annual or seasonal monitoring of biodiversity. If significant changes in species diversity occur, then specific investigations of the probable causes should be undertaken. Current trawl surveys (summarized in Jeffries et al. 1988) and invertebrate surveys—as well as bird censuses—can form a basis for the biodiversity monitoring program.

Recently Miller (1990) concisely documented some properties of a well-managed nearshore fishery, which are considered relevant to this report, especially for finfish. He provided a list of tools available for management which included the following which have been slightly modified for this report.

a) Fisheries regulations which can be enacted promptly and enforced effectively.
b) Fisheries scientists who can communicate well with participants in a fishery, or their representatives.
c) Fishing effort and catch which can be monitored effectively.
d) Controlling the amount of effective fishing effort for a given fishery.
e) Controlling the type of gear used.
f) Influencing the sizes and quality of fish and shellfish landed.
g) Controlling degradation of fish (and shellfish) habitat.

It is clear that the management agency in Rhode Island does not have access to all of the above-mentioned tools. Of particular relevance for the current problems related to finfish is the inability to control the amount of effective fishing effort. On the other hand, effective communication, monitoring of effort and catch—as well as cooperation in controlling habitat degradation—are evident at present.

II. Empirical Evaluation of Stocks

Introduction

Commercial and recreational finfisheries are important uses of Narragansett Bay. Recreational fisheries include: winter flounder, summer flounder, tautog, scup, bluefish, and striped bass, while commercial finfishing is currently restricted primarily to winter flounder and several other species seasonally. A large commercial shellfishery exists for hard clam—as well as smaller fisheries for lobsters, soft clams, surf clams, and conch (Desbonnet and Lee 1990). In earlier years both menhaden and oysters were significant fisheries in the Bay. The hard clam fishery, the state's largest, is estimated to generate $15 million (ex-vessel value) per year and supports 2,500 full- and part-time fishermen. Desbonnet and Lee (1990), in their review of historical trends in water quality and fisheries resources for Narragansett Bay, noted that the living resources of Narragansett Bay have changed dramatically over their recorded history. The Bay no longer supports large anadromous fish runs, extensive soft shell clam beds and oyster bars or major finfishing via fish traps, seines, and fyke nets. Hard clam populations have increased in areas closed to shellfishing. However, bay scallops and soft clams have generally declined throughout most of the Bay. Additionally, some of the productive hard clam beds in the upper Bay have been permanently closed because of pollution. Equally disturbing is the tendency for fish species to display an increased incidence of disease along a gradient which may be related to pollution (Wolke et al. 1989).

To realistically aid in management planning for fish and shellfish stocks in Narragansett Bay, it is considered necessary to attempt to determine the current status of the stocks and to attempt to uncover which natural environmental and anthropogenic factors may act in regulating stock abundance over an extended period of time. This is clearly a large undertaking, for which adequate personnel and funding are necessary. At present neither adequate funding nor staff are available in the Rhode Island Division of Fish and Wildlife for such an undertaking.

A primary shortcoming of historical data sets for evaluating stocks in Narragansett Bay and elsewhere is that the initial programs were not properly planned for critical evaluation of the relations between anthropogenic factors and indices of species abundance. Additionally, fisheries managers are currently united in regulatory matters due to fishing mortality, often leaving the resource harvesters at a disadvantage (personal communication, RI Division of Fish and Wildlife). Therefore, rigorous procedures for detecting trends or interventions in multivariate time series data are not applicable. Adequate procedures for critical monitoring of trends are currently available, and it is recommended that a comprehensive monitoring plan for the Bay be developed and executed.

Long-Term Trends—

An initial goal of this study was to document the status and trends of recreationally and commercially important fish and shellfish in Narragansett Bay by reviewing the existing data. Actual long-term data sources within the Bay proper are scarce—particularly finfish data pertaining to the Upper Bay or Providence River. Two major data sources were consulted to determine long-term trends in fisheries stocks:

1) The weekly trawl program conducted by The University of Rhode Island's Graduate School of Oceanography in the lower West Passage of the Bay and just offshore in Rhode Island Sound from 1959-present (Jeffries et al. 1988).
2) Commercial landings and licensing data for hard clams, compiled by Pratt (1988) from a variety of NMFS sources, and updated (1985-1989) with data compiled by Karp et al. (1990) from the Rhode Island Department of Environmental Management (RIDEM)

Some data from the Rhode Island Division of Fish and Wildlife trawl surveys are available, but these were not utilized for long-term trend analyses in this report because the data consisted of two separate survey designs, neither of which was considered long enough for long-term trend analysis. The Fish and Wildlife data are the only data which currently document survey tows north of Fox Island, in the East Passage, Sakonnet River, and upper Narragansett Bay. Details of these data and figures illustrating them are provided in Jeffries et al. (1988).

Jeffries et al. (1988) graphically presented yearly catch data for several major fish species occurring in the Bay and just offshore over 1959-1987. All species depicted showed fluctuating stock levels with both increasing and decreasing trends. To test for statistically significant trends over time, Jeffries et al. (in preparation) first regressed annual catch versus year for each station using least squares regression techniques (SAS 1985).

Examples of these regressions for some locally important species are shown in Figures 1-6, which illustrate temporal trends for three species (tautog, winter flounder, and lobster at two stations [Fox Island and Whale Rock]). The units on the ordinates of these figures represent yearly catch (the annual sum of mean monthly catch in numbers per 30-minute trawl tow). A high degree of scatter is evident in all the figures, with some indication of higher variability in the later years of the record. Such variability is sometimes associated with high fishing effort. It is also evident that other curves than a least square linear regression might be appropriate, but the analysis was restricted to a linear model. Nevertheless, it seems that the tautog shows a decline at both stations, whereas winter flounder show apparent differences in trend for the two stations. We caution the reader that these data should not be interpreted as anything more than suggestive evidence of trends. See Tables 1, 2, and 3—as well as the section of this report entitled *Long-Term Trend Analyses* for further interpretation of these data.

Stations with increasing or decreasing temporal trends were subsequently pooled and covariate models were developed for each species (Table 2). Attempts were made to develop models for all commercially and recreationally important fish and shellfish species collected in the trawls: winter flounder, summer flounder, scup, tautog, butterfish, bluefish, total finfish and lobster.

Pratt (1988) also graphically presented data for hard clam landings in Rhode Island—as well as the number of full-time clam fishermen over the 1951-1985 period. As noted above, these data were updated (1985-1989) using information compiled by Karp et al. (1990) from RIDEM sources. The shellfish licensing data presented by Karp et al. was first multiplied by 0.40 to estimate the number of full-time fishermen (Pratt 1988). We recognize that a multiplier used to estimate full-time fishermen is a variable which is subject to the state of the economy and even to publicity related to the opening of shellfish beds. Nevertheless, we believe it is a useful first-order approximation which has relatively wide confidence limits. Using the combined data, we similarly regressed hard clam landings, full-time fishermen, and landings adjusted for fishermen versus year over the 1951-1989 period. Figure 7 illustrates the trend in relative catch-per-unit-effort (CPUE) for hard clams (quahogs) for a relatively long time series. It is clear that the data show a downward trend which seems fairly consistent. This suggests that more effort is now required to catch a constant weight or volume of quahogs then has been required in the past. These data have not been corrected for changes in technology. Improved technology should enhance the CPUE, and its failure to do so suggests an even greater negative trend. Also, it should be recognized that size selection by the fishermen could bias this type of analysis if it is not corrected. No corrections have been made for these data.

Factors Controlling Stock Size—

The major factors thought to affect fisheries stock levels are overfishing, environmental factors (i.e., climatic change), habitat alteration, and pollution. These are not necessarily in decreasing order. Separating the effects of these factors—alone or in combination for a specific region such as Narragansett Bay—is a highly complex task, one which is virtually impossible to accomplish from existing information. Summers et al. (1987) have attempted such a task for several of the major fish and shellfish stocks in Narragansett Bay. We include a description of their approach and a summary of their findings below.

Summers et al. (1987) collected data for five major northeastern estuaries—including Narragansett Bay—to assess long-term relationships among hydrographic conditions, macropollution histories and fish and shellfish stocks. Macropollution variables were defined as aggregate variables which indirectly represented trends in pollution as either human-related activities or general water quality. For Narragansett Bay the macropollution variables considered were: human population, dredging activity, and municipal sewage discharges. Both the human population and sewage loading increased over time throughout the study period. Direct measures of specific pollutants (e.g., cadmium, lead) were not used since these data were generally unavailable over sufficiently long periods for historical assessments. Annual fish and shellfish stock sizes for Narragansett Bay—including Rhode Island Sound—were based on annual recorded landings and associated effort for shellfish and finfish for the period 1929-1980. Climate data for Narragansett Bay included air temperature, wind speed and direction, and freshwater discharge.

Categorical time series regressions were developed for each stock using lagged stock (i.e., a variable representing the time lag between spawning and recruitment), and hydrographic and macropollution conditions at the time of spawning to account for historical stock variations (Summers et al. 1987). The first step was to use a lagged stock component of abundance (i.e., based on life history of individual stock) to remove any cyclical component in stock size and perhaps residual fishing—pressure effects. Climatic variation in stock size was next removed to account for changes in annual climatic conditions. Finally, the potential relationship between stock size and pollution variables was investigated. In all cases relationships between macropollution and stock abundances were greatly improved when the residual variation related to climatic conditions was removed (Summers et al. 1987). This clearly suggests that environmental variation is a significant factor affecting stock abundances.

We illustrate for three species (tautog, winter flounder, and lobster) the figures and tables which show the derived relationships. It is evident from these figures (Figures 8, 9, and 10) that the overall fit to the data looks good. However, the models have no predictive power, and the fit to the data was somewhat arbitrarily established for each species. Tables 4, 5, and 6 relate to the details of the fit and the model coefficients for the figures mentioned above.

Long-Term Trend Analyses—

(Jeffries et al., in preparation). Preliminary regression analyses indicated that not all fish species behaved in the same fashion over the 1959-1987 period (Table 1). No significant linear trends over time were found for winter or summer flounder at either station (Fox Island, West Passage, or Whale Rock, Rhode Island Sound). Tautog abundance significantly declined at the Fox Island station; while scup, butterfish, and bluefish significantly increased either at the Bay station proper or at both stations. Total finfish catch also significantly increased over time at both stations (Table 1). Lobster, the only shellfish species examined, showed significant improvement in catch over time in the Lower Bay, and no significant trends just offshore. For the above trawl survey data, effort was considered constant over time so that catch is an actual measure of relative abundance. However, it is clear that increases in both effort and fishing power have taken place over this period in the commercial fishery.

Station data for species with significant increasing or decreasing temporal trends were subsequently pooled and covariate models developed for each of the following species: tautog, scup, butterfish, bluefish, total finfish, and lobster (Table 2). The final models used both station and year as predictors and included a term adjusting for year-by-station interactions. The results indicated that all models were significant ($P < 0.08$) with 12 to 74 percent of the variance in abundance explained by the model (Table 2). Using the combined station data, temporal trends (indicated by the year parameters) were significant for all species except lobster. The models for tautog, scup, butterfish, and lobster additionally revealed significant differences among stations indicating that average abundances for these species varied between stations. Significant differences among estimated slopes (year by station parameter) were found only for tautog, scup, and butterfish.

Long-Term Trend - Hard Clam—Linear regression analyses indicated that hard clam landings from 1951-1989 exhibited no significant linear trends (Table 3). Over the same time period the number of full-time fishermen significantly increased, while the catch-per-unit effort (CPUE) significantly declined (Table 3). The greatest percentage of variation (53 percent) in the data was explained by the CPUE model. The slope of the model indicated a decline in hard clam landings of greater than 100 pounds (wet weight) per year after adjusting for fishing effort. Based on these results, fishing pressure appears to be a significant factor in affecting the abundance of hard clams in Narragansett Bay, and particular efforts to avoid overfishing should continue to be considered in future management of the fishery.

Categorical time series regressions—Summers et al. (1987) evaluated 18 stocks for the Narragansett Bay/Rhode Island Sound region over the 1929-80 period. Models accounting for at least 55 percent of stock variation (after adjusting for effort) were constructed for nine species: menhaden, winter flounder, lobster, summer flounder, bluefish, eel, butterfish, scup, and tautog (Table 7). The results also indicated that stock abundances were significantly related to anthropogenic effects for nine species: striped bass, white perch, soft clams, winter flounder, lobster, summer flounder, weakfish, eel, and tautog (Table 7). In only four of the well modeled stocks ($R^2 > 0.55$) were anthropogenic influences not a major source of variation. The symbol R^2 refers to the projection of the total variation explained by this model. These were bluefish, scup, menhaden, and butterfish.

Categorical time series regressions provided particularly good fits for summer flounder ($R^2 = 0.89$), scup ($R^2 = 0.84$), tautog ($R^2 = 0.71$), winter flounder ($R^2 = 0.78$), lobster ($R^2 = 0.68$), and bluefish ($R^2 = 0.70$). Summer flounder abundance was best predicted as a function of lagged stock, June temperature, July river flow, and sewage loading. A positive relationship to sewage loading and June temperature and an inverse relationship with July flow were noted to primarily control stock variability. Scup were significantly related to lagged stock, May wind speed and direction, and July temperature. High values for wind speed and temperature tended to produce greater than average future recruitment. Tautog were best modeled as a function of lagged stock, June river flow, and sewage loading with stock variation inversely related to sewage. Both hydrographic and anthropogenic factors were equally important in explaining variation in tautog stocks. Four categorical variables (lagged stock, March temperature, March flow, and sewage loading) were significantly related to winter flounder CPUE (catch-per-unit-effort), with hydrographic variables of primary importance. Lobster abundance was best modeled by March river flow and temperature, lagged stock and human population, with both anthropogenic and hydrographic factors of primary importance. Bluefish harvest was best modeled as a function of lagged stock and August temperature with no anthropogenic factor tested significantly related to abundance. Only one of the 18 species, windowpane flounder, could not be modeled for Narragansett Bay over the time period.

The relative strength of anthropogenic factors was at least as important as hydrographic variables in explaining variation in stock size for 8 of the 16 Narragansett Bay stocks (Summers et al. 1987). The statistical evidence for Narragansett Bay thus suggested existence of significant relationships between historic stock abundance and gross indicators of pollution for many species. Regrettably, the form of the relationship between sewage loading and stock abundance (i.e., positive or negative) was unreported for most species examined. A second drawback of the analyses was the use of commercial stock data for regions outside of the Bay proper (i.e., Rhode Island Sound) thus weakening our understanding of relationships directly within the Bay.

The results from both the long-term trend analyses and the categorical regression analyses indicate that tautog are declining in numbers in the Bay. The categorical regression further suggests that tautog stock size was inversely related to pollution variables. Other species examined from the GSO trawl survey (i.e., scup, butterfish, bluefish, Table 1) were increasing in abundance in the Bay, suggesting no negative effects of pollution at least at the lower end of West Passage. As noted above, Summers et al. (1987) failed to report the form of the relationship between pollution variables and stock abundance for many species. They did note, however, that summer flounder was positively related to sewage loading levels, indicating that low level pollution effects may not be detrimental to this species, which is primarily a summer visitor to the Bay area.

In summary, the existing finfish data for the relatively polluted portions of Narragansett Bay (i.e., Upper Bay) are too sparse for any strong conclusions to be drawn about the effects of high levels of pollution on fisheries abundance. The dramatic decline in some anadromous fish runs, oyster beds, and other shellfish occurred during a period of declining water quality, high fishing pressure, and excessive habitat alterations, make a post facto assignment of cause impossible with available data and analyses. The results of the statistical analyses should be treated with caution. No causal inferences are possible with the methodology utilized. Furthermore, some of the postulated associations may be spurious. The form of analysis and the nature of the data do not permit any inferences about causality.

III. Invertebrate Fishery Management Planning

General—

A comprehensive and recent reference on the assessment and management of invertebrate fisheries is found in Caddy (1989) who edited an important volume on crustacean, molluscan, and other invertebrate fisheries. Some of the specific reports within the volume are considered potentially relevant to Narragansett Bay planning although none deal specifically with the Bay. The material which follows represents an initial effort to provide more specific management planning suggestions and recommendations dealing with invertebrate resources in Narragansett Bay and vicinity. The following topics are considered important for this purpose. Although some of these topics are covered in more detail in other reports, we believe they deserve attention in this context. They are not listed in any order of importance.

Public Health Component of Bivalve Mollusk Production and Marketing—Canzonier (1988) has provided an excellent review of this problem. We concur with his overall conclusion that the primary requisite for assessing a wholesome product is the prevention of the contamination of the shellfish at the source (i.e., production and harvesting in clean waters). However, we clearly recognize that is not possible in the short term, and may be prohibitively expensive in the long term. Other alternatives must at least be carefully examined. For example, even when water samples meet currently accepted criteria of public health safety, the shellfish harvested frequently carry large numbers of indicator bacteria, and/or pathogens, including Hepatitis A and Norwalk viruses. Grimes and Colwell (1990) make the following sobering statements.

> "Obviously, consumption of contaminated seafood and recreational contact with polluted water provide opportunities for infections, accounting for the majority of cases of human disease derived from polluted estuaries. Shellfish rank as the number one cause of water-borne disease in the United States, with the most frequent etiological agent being viruses—notably the Norwalk virus. In 1986, there were

> 103 outbreaks recorded in New York alone, and these involved 1,017 cases of shellfish derived gasteroenteritis caused by the Norwalk agent. There is no doubt that contaminated shellfish pose a significant health risk for humans."

The above-mentioned report emphasized shellfish quality assurance and suggested support of newly developed tests—including gene probes for bacteria, viruses, and other pathogens—as well as monoclonal/polyclonal antibody direct detection methods and phasing out of the use of coliforms as indicators of fecal pollution. We strongly endorse an active program of evaluating methods for improving shellfish quality assurance. The authors do not consider themselves qualified to evaluate the relative merits or costs and benefits of the various alternatives. However, it is our understanding that the use of viral indicators of sewage shows promise, and that alternative indicators to the coliform indicators are already accepted practice in some areas. Testing and evaluation of alternatives for Narragansett Bay seems highly desirable.

With specific reference to current conditions in Narragansett Bay, we note that as of May 1990, 41 percent of the Bay is restricted to shellfish harvest for at least part of the year (Karp et al. 1990). Studies by Bean and Sutinen (1990) in a draft report state that 13 percent of the Rhode Island quahog industry are frequent violators of existing regulations, with about 260 frequent violators responsible for about 1.5 million dollars of illegal product annually. The typical violator fishes for uncertified (polluted) clams 44 days/year, averaging about $300 per trip. The taking of clams from polluted water seems to peak in April and May, which are months of warming water. This report suggests that illegal shellfishing in polluted waters occupies about 11,500 man days of effort resulting in approximately 870,000 pounds of polluted organisms. It seems clear to us that this amount of potentially contaminated product poses a significant health threat. Although this draft report is subject to revision and the estimated extent of violation is subject to a large error term, we still conclude that the health threat posed is a real one, which should not be ignored or minimized. Continuing efforts at better quality assurance of the harvested product and continued pollution abatement are required Our suggestions for management-related planning include better and more comprehensive quality control of the harvested product and improved strategies for enforcement with more severe penalties for violators.

We fully recognize that the data reported above is subject to various interpretations, including challenges to its validity. We believe, however, that an important problem area has been identified which should receive immediate attention from both the quality assurance and enforcement points of view.

Suggestions Regarding Shellfish Resource Management—The report of a study by the Coastal Ocean Science and Management Alternatives Program of the Marine Science Center of the State University of New York (1985) entitled: *Suffolk County's Hard Clam Industry: An Overview and an Analysis of Management Alternatives, 1985* and a later report entitled *Strategies and Recommendations for Revitalizing the Hard Clam Fisheries in Suffolk County, New York, 1987* by the Suffolk County Planning Department (1987) have been suggested as excellent models for the development of plans for hard clam (quahog) resources in Narragansett Bay. We believe that such studies are valuable, but they are site specific—not only with respect to the environment but also with respect to the nature and extent of specific management recommendations. However, we find that there are some elements of the enhancement strategies and recommendations which seem relevant, and others which are either already implemented in Narragansett Bay or are not applicable to it. We endorse the following strategies as being potentially useful in the management of Narragansett Bay shellfish resources.

- Conduct continuing stock assessments to provide reliable information on the population dynamics and biology of the resources.
- Design, implement, and evaluate programs to control entry into the shellfish fishery, such as individual transferable quotas.
- Evaluate hydrographic suitability of various parts of Narragansett Bay for the establishment of spawner sanctuaries. These are defined as sites containing

fecund adult clams located such that larval setting will be maximized in selected growing areas.

- We also suggest that available hydrographic models of Narragansett Bay be utilized in an analysis of the potential effectiveness of refuge or sanctuary areas for quahogs. It is currently thought by some people that the present polluted (restricted) areas serve as a source for repopulating exploited areas. Exercising a suitable hydrographic model would permit an objective analysis of the value and location of refuge areas to assure adequate dispersion of larvae to exploited areas.
- Design, implement, and evaluate various alternative harvest strategies with clearly defined objectives.
- Enhance monitoring to detect trends in water quality and the levels and sources of pollutants. Also, evaluate impacts of sewage treatment improvements and disposal facilities on certification of shellfish harvest and growing areas.

Clearly, recommendations, such as the above, require adequate research staff and authority by the management agency to implement results of studies. These are not considered to be adequate at present, and increased staffing at a professional level for invertebrate fisheries is recommended.

The three commercially important bivalve species—the soft clam, hard clam or quahog and the eastern oyster—share certain life history characteristics, and we believe that management plans and actions can be similar for the harvest fisheries for these resources. Specifically, we endorse the theoretical evaluation of shellfish resource management reported by Malinowski and Whitlatch (1988) in which it is suggested that the greatest return will be realized in the production and management of these organisms if efforts are directed primarily toward increasing juvenile survivorship and the quality and/or quantity of the juvenile habitat. Present management practices are based largely on these concepts.

Research by Brousseau and Baglivo (1982) is using matrix models for soft clam management is an example of a similar approach.

- Another suggestion regarding the management of non-motile resources relates to systems of optimal rotation of harvest areas and the optimal thinning of dense beds of non-motile organisms.

  We believe that optimization methods applied to forest rotation and forest thinning may have useful applications in pelecypod management. We do not know of any application of optimization methods involving the quahog industry. However, Rice et al. (1989) have recently indicated associations between density of quahogs and growth in Narragansett Bay. This suggests that a management scheme—such as that suggested above—is feasible, although with potential difficulties in limiting access to the "closed areas" being rotated.

Available information on the American lobster indicates that the stock of lobsters in the Bay is maintained by recruitment from areas outside of the Bay, probably to the west in Long Island Sound. The present management regime is considered to be rational, and the status and trends in the fishery deserve continuing careful monitoring in view of its value.

- For future American lobster management in Narragansett Bay—as well as in the State of Rhode Island—it is suggested that the model of Shotton (1989) be given serious consideration.

  The model enables various management options to be evaluated in terms of fishery landings and future (discounted) revenues. This is one of the few operational management models which explicitly considers time discounting. It is a discrete-difference model, which is appropriate to the lobster fishery.

The fishing for conch in the Bay has been studied and enough seems to be known of the vital statistics of these animals to permit rational management (Davis and Sisson 1988). There is clearly a conflict between optimization of the conch fishery and effective management of the hard clam fishery since the conch is a predator on juvenile clams.

- It is recommended that further study of shellfish mariculture as a cottage industry—as well as at a larger scale—be given priority in view of the global potential of this industry. Elimination of user conflict needs to be resolved.

  Species of special relevance for Rhode Island include the eastern oyster, the bay scallop, and mussels. It is believed that the quahog can be grown to maturity in a more cost-effective manner in the South Atlantic region. The recent review by Siddall (1988) is considered an appropriate basic model for development of small-scale mariculture for Narragansett Bay. It should be noted that several Atlantic coastal states (examples include New York, Connecticut, and Maine) have published aquaculture development plans and strategies. It seems that these plans were developed by commissions or institutions and involved active participation by individuals with diverse interests. These documents clearly describe the current industry profiles, research, and technological development areas, regulation and enforcement problems, economic potential, and relations with traditional fisheries, and impediments to development. A comprehensive aquaculture-mariculture development plan, organized along the lines of the three mentioned above, would provide Rhode Island with much needed guidelines for development of this industry. It is our perception that Rhode Island lags considerably behind its sister states in this form of planning, which has had a negative impact on development of a mariculture industry in Narragansett Bay.

- **Reinvestigate depuration and relaying strategies**—It has already been stated that there is a strong public health component in shellfish production and marketing in Narragansett Bay. One of the management procedures utilized in Rhode Island involves the relaying of quahogs from moderately polluted waters to clean areas for relatively long periods in order for the organisms to purge themselves of certain contaminants. We believe that this practice is feasible if the cost of collecting organisms from polluted areas is relatively low, the recovery of the organisms is high, the organisms are sampled for pollutants and contaminants, and transplant areas can be effectively monitored to prevent unauthorized harvesting. The cost-effectiveness of such activities should be carefully evaluated and various alternatives should be critically examined, including a determination of which pollutants to measure. Another procedure which may permit utilization of organisms from moderately polluted waters is the application of a process of depuration prior to marketing. A clear description of the depuration process as it relates to the quahog is provided by Zaharia (1979). Since this report, there have been significant improvements in various aspects of depuration—such as improved ultraviolet systems, ozone treatment, and other developments. These should be assessed in the light of current needs.

- **Reassess current conservation and management legislation**—The possibility of a well-managed fishery for the quahog and other non-motile invertebrates in Narragansett Bay is significantly affected by both the lack of adequate professional staff to conduct surveys and assessments—as well as the authority to limit effective fishing effort. It is our opinion that the value of the shellfish resources of the Bay justify substantially more effective monitoring and assessment, and additional staff for this program—as well as changes in legislation to permit more effective control of the fishery—are recommended.

IV. Vertebrate Fishery Management Planning

General—

This section deals primarily with the so-called finfisheries, although it is not possible to keep the two groups (vertebrates and invertebrates) entirely separate with regard to management plans or suggestions.

The importance of estuarine-related species in commercial and recreational fisheries has been emphasized by McHugh (1984). He optimistically estimated that about two-thirds of the total fish and shellfish landings of the United States are estuarine-dependent at some life history stage. More recently, Day et al. (1989) have attempted to summarize information on estuarine fisheries—including management—in a chapter of their book entitled *Estuarine Ecology*. However, we do not find this review chapter to be very useful in terms of management planning for the purposes at hand. Specific shortcomings in both the general literature review and the management sections include the fact that most of the recent methodologies for estimating secondary production are not described, and the information on stock production modeling is inadequate. Recent management methodologies—such as the use of matrix models—are totally ignored.

Oviatt and Nixon (1973) have summarized the occurrence of demersal fish of Narragansett Bay which included 44 species. The draft report by Desbonnet and Lee (1990) entitled *Historical Trends in Water Quality and Fisheries Resources in Narragansett Bay, Rhode Island* provides a historical study of trends in anadromous fisheries, migratory fisheries, and Bay fisheries, with an attempt to link them to water quality changes. This report is a useful compilation, but we challenge some of the inferences drawn in it. The statement (page 195) that "Population fluctuations of winter flounder seem to be linked to cycles of predators, and to other physical variables that are driven by climatic changes in the Bay" is considered to be somewhat misleading. There is considerable scientific evidence from stock assessment work (Gibson 1989a, b) and the figures shown in Gray

(1990) that the winter flounder is currently subjected to growth overfishing and that recent declines in catch and catch-per-unit-effort indicate overexploitation as a major cause for recent declines in the stock. This does not mean that environmental variables are unimportant, but it does suggest that the weight of evidence at hand points to overfishing as a major cause of current declines in some selected fisheries.

We also suggest that the general conclusion of Desbonnet and Lee (1990) (page 195) "that each reported Narragansett Bay finfishery, except for winter flounder, was apparently overfished historically" is not valid based on evidence at hand. We also do not agree that fishing effort in Narragansett Bay has declined tremendously in the past 30-50 years for certain non-sport species. In fact fishing effort has probably continuously increased for virtually all species. Although the number of fish traps in Narragansett Bay was substantially greater in 1910 then now, it must be recognized that fish traps are passive gear, which operate only during the migratory period of the fish. They can be treated for management purposes as so-called "gauntlet" models in an effective manner. See, for example, Argue et al (1983) for an application to the Pacific salmon. Although it is not possible to completely dismiss the above statement in Desbonnet and Lee (1990), we argue that the offshore trawl fishery for anadromous fishes and other Narragansett Bay migrants was at least as important as the fixed gear fishery in preventing recovery of stocks. From a management point of view, it is easier to effectively control a gauntlet fishery by allowing periodic escapement of returning adults to the spawning grounds. Control of the offshore fishery is only possible by limiting effective fishing effort.

It seems clear that for estuarine vertebrate fisheries (and for invertebrate fisheries, as well), the matters of conflicting uses, time discounting, and uncertainty apply in full force. At present there are few ways to adequately deal with these in an effective manner. Good programming as illustrated by Weithman and Ebert (1981) is one approach to complex decision making (see below).

The existing models used for management of fishery resource usually have an economic component, the objective being the optimization of sustained yield. It has been demonstrated by Gordon (1954) that unregulated fishing effort will increase until net revenues become zero—because the existence of any positive net revenues will always attract additional fishermen. Subsequent increases in the price of fish, or a decrease in the cost of effort, both of which result in increased profits at the optimal level, lead to further increases in effort and further reduction of the fish stock.

The above brief description of Gordon's simple model clearly indicates that this unfortunate situation results from open-access use of the resource. The current concept of minimizing government interference with the fishermen, when applied to common property resources, makes matters even worse. The only responsible course of action is for continuing careful monitoring of resource condition and improving management regulatory power and institutions, with a view toward maintaining long-term stability of the resources. With response to time discounting, it seems that fishermen frequently use the argument of a current economic crisis as the basis for pleading for increased quotas or more relaxed regulations, than those suggested by the management agency. These pleas are often made with little regard for projected impacts on future resource productivity. Unfortunately, this is not totally irrational on the part of the resource user. Present survival is a prerequisite to future existence, and the economic reflection of this is time discounting—namely, "a bird in the hand is worth two in the bush." That is, the present value of the resource is high relative to any future value. However, this is clearly not in the best interests of the state, which should adopt schemes to assure sustained high productivity of all renewable marine resources.

With respect to uncertainty, conservation of resources implies a concern for the future. However, uncertainty in our projections is high because we cannot observe wild fish populations directly. We must, therefore, adopt conservative, or risk averse strategies.

With specific reference to Narragansett Bay finfishery resources, it seems safe to state that most capture fisheries of the Bay are suffering simultaneously from overexpansion of the fishing capacity and declining catch-per-unit-effort and/or catch resulting in the ultimate impoverishment of the fishermen. It is suggested that management planning must involve steps toward controlling overexpansion by limiting the numbers of fishermen and their gear. The details of the methods for doing this must be worked out at the management level. However, the concepts of individual transferable quotas or other means for controlling effective fishing effort must receive early consideration—both at the management and administrative/legislative levels.

In summary, a major concern at present is the rational management of renewable commercially-exploited resources in Narragansett Bay. It seems clear that current pollution problems are slowly being addressed. This abatement of pollution should continue. However, without continued monitoring and effective regulation of the fishery resources, the potential for collapse and non-optimal control is very real.

The recreational fisheries of Narragansett Bay have received attention in recent years (Marine Recreational Fishery Statistics Survey conducted by NMFS and RI Division of Fish and Wildlife). However, in order to permit effective estimates of the significance of the fishery, increased monitoring effort is recommended. It is suggested that an approach somewhat similar to that proposed by Agnello (1989) be initiated in order to put this important fishery into perspective with current commercial efforts. Clearly, the objectives of fishery management in Narragansett Bay should not only include sustained use of renewable resources, but also consideration should be given to maximizing social and economic benefits to the state as a whole. There is an apparent increase in the amount of recreational fishing activity in Narragansett Bay, and the relative importance of this in contrast to commercial fishing should be carefully evaluated in management planning. This work has already been proposed and may begin in late 1991, pending approval by funding agency (personal communication, RI Division of Fish and Wildlife). An example of an approach (i.e., Agnello 1989) has been suggested.

Vertebrate Management Suggestions/Recommendations—

- Management of the marine fisheries of Rhode Island (including Narragansett Bay) under the present system of management decision making by the Rhode Island Marine Fisheries Council (RIMFC) is considered to be less than ideal, and alternatives should be carefully evaluated.

  An example of such sub-optimal management is provided by the winter flounder. This species was clearly manifesting signs of overfishing based on a 1987 study by the Rhode Island Division of Fish and Wildlife. However, the RIMFC yielded to outside pressures and did not act promptly and decisively by enacting measures to reduce fishing mortality to acceptable levels. The history of the council's actions is well documented by G. Allen (*The Fisherman*/April 12, 1990). The responsibility of the RIMFC is restricted to actions directly related to the biological conservation of the marine resources. However, virtually all marine resource management decisions have strong economic and social implications. These are not adequately addressed by the staff of the management agency nor by the RIMFC due to lack of qualified personnel. In addition the approved chain for enacting or modifying regulations is thought to be long and tenuous at present. The number of people currently influencing fisheries management decisions is believed to be too large for effective action. It is our opinion that statutory changes in the manner in which marine resource management regulations are made are in order. These changes should be designed to prevent unreasonable delays in enacting or modifying management regulations and to permit sound resource conservation based on available scientific evidence. They should also provide flexibility to make changes at intervals as required. The commercial fishermen of Narragansett Bay are given the right, at minimal cost, to harvest common property resources belonging to the state. Future sustained yields of these resources should not be jeopardized by their short-term interests and economic desires. The management agency (RIDEM) is responsible to future generations of resource users, and the agency should have the power to effectively manage.

- Marine sport fishermen should be subjected to an annual license fee.

It is regrettable that the marine recreational fishery does not even pay nominal direct fees for their use of Narragansett Bay resources. A user fee—in the form of a marine fishing license for all marine recreational fishermen—should receive serious consideration in future legislative actions. This form of fee is already in practice in some states, such as Alabama and Florida. Receipts should be utilized exclusively for sport fish management and enhancement.

- The management agency (RIDEM) should have adequate staff and funding to conduct stock assessments in Narragansett Bay and adjacent waters to provide continuing reliable information on the population dynamics of the major species of commercial and recreational interest.

Clearly, this information is required for objective analyses of trends in abundance and for determining the effects of management regulations. The quality of the current level of assessment is considered to be high, but the demands on the existing staff are believed to be sufficient to preclude significant additional work without additional staffing.

- Close coordination among neighboring states and federal agencies is considered important for effective management actions regarding the finfish resources of Rhode Island and Massachusetts.

It is virtually impossible to separate assessment and management at state and regional levels from those of Narragansett Bay, due to the motile nature of the fish resources. Very few are confined exclusively to Rhode Island waters.

- Increased investigations of various forms of fish attraction devices, artificial habitats and reefs—as well as stock enhancements in these areas—should be conducted.

Recent development in marine habitat improvement should be assessed with a view toward enhancing the yields or fishing opportunities in Narragansett Bay. These investigations are contingent upon funding and staff, and measures, such as a marine recreational license, are important in implementing them.

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Table 1. Linear regression analyses of annual catch versus year over the 1959-1987 period for the Graduate School of Oceanography's trawl survey data at Fox Island and Whale Rock (Jeffries et al., in preparation).

Species	Station	N	M	(± SE)	R^2	P
Finfish						
Winter flounder	Fox Island	29	9.4	(25.8)	0.01	N.S.
	Whale Rock	29	-4.9	(5.7)	0.03	N.S.
Summer flounder	Fox Island	29	0.2	(0.4)	0.01	N.S.
	Whale Rock	29	-0.07	(0.2)	0.01	N.S.
Tautog	Fox Island	29	-1.5	(0.3)	0.46	0.0001
	Whale Rock	29	-0.03	(0.02)	0.03	N.S.
Scup	Fox Island	29	71.2	(22.3)	0.29	0.004
	Whale Rock	29	12.7	(4.1)	0.27	0.004
Butterfish	Fox Island	29	10.8	(2.3)	0.44	0.0001
	Whale Rock	29	32.2	(6.4)	0.49	0.0001
Bluefish	Fox Island	29	0.68	(0.19)	0.32	0.002
	Whale Rock	29	0.79	(0.56)	0.07	N.S.
Total finfish	Fox Island	29	121.3	(29.1)	0.39	0.0003
	Whale Rock	29	80.5	(41.9)	0.12	0.06
Shellfish						
Lobster	Fox Island	29	3.1	(0.5)	0.55	0.0001
	Whale Rock	29	-0.5	(4.1)	0.01	N.S.

Table 2. Analyses of covariance using annual species abundance as the dependent variable and station and year as predictors for the Graduate School of Oceanography's weekly trawl program (Jeffries et al, in preparation) over the 1959-1987 period.

Source	DF	SS	MS	F	P
Species: Tautog R^2 = 0.74					
Model	3	16,091	5,364	51.67	0.0001
Error	54	5,606	104		
Station	1	2,421	2,412	23.32	0.0001
Year	1	11,452	11,452	110.32	0.0001
Year x Station	1	2,218	2,218	21.37	0.0001
Species: Scup R^2 = 0.27					
Model	3	24,823,775	8,274,591	18.17	0.0001
Error	52	23,684,528	455,472		
Station	1	7,188,952	7,188,952	15.78	0.0002
Year	1	14,335,303	14,335,303	31.47	0.0001
Year x Station	1	3,299,520	3,299,520	7.24	0.0095
Species: Butterfish R^2 = 0.53					
Model	3	2,862,836	954,278	20.4	0.0001
Error	54	2,525,179	46,762		
Station	1	1,877,982	1,877,982	40.1	0.0001
Year	1	522,310	522,310	11.1	0.001
Year x Station	1	462,542	462,542	9.9	0.003
Species: Bluefish R^2 = 0.12					
Model	3	2,583	861	2.37	0.08
Error	54	19,631	364		
Year	1	2,232	2,232	6.14	0.02
Station	1	338	338	0.93	N.S.
Year x Station	1	14	14	0.04	N.S.
Species: Total Finfish R^2 = 0.23					
Model	3	43,040,249	14,346,749	5.4	0.0002
Error	54	142,390,052	2,636,853		
Year	1	41,289,705	41,289,705	15.66	0.0002
Station	1	66,234	66,234	0.03	N.S.
Year x Station	1	1,684,310	1,684,310	0.64	N.S.
Species: Lobster R^2 = 0.20					
Model	3	234,194	78,065	4.59	0.006
Error	54	918,529	17,009		
Year	1	7,026	7,026	0.41	N.S.
Station	1	213,749	213,749	12.57	0.0008
Year x Station	1	13,418	13,418	0.38	N.S.

Table 3. Linear regression analyses of hard clam landings (pounds, wet weight), full-time fishermen, and catch-per-unit-effort (i.e., landings/fishermen) versus year over the 1951-1989 period for the data compiled by Pratt (1988) and Karp et al. (1990)

Dependent Variable	N	(M ± SE)		R^2	F	P
Hard clams landings	40	-13545.1	(16557.0)	0.02	0.67	N.S.
Full-time fishermen	39	13.4	(3.6)	0.27	13.50	0.0008
CPUE	39	-113.4	(17.5)	0.53	41.68	0.0001

Table 4. Effects of climate and macropollution on abundance of tautog in Narragansett Bay. From Summers et al. 1987.

Regressor Variables	Number of Categories	Adjusted R^2	Comparisons	
			Models	F-Value
A) Lagged stock	2	0.4399	---	33.99*[(a,b)]
B) Lagged stock June flow	4	0.5137	B to A	4.11*
C) Lagged stock Sewage	4	0.5528	C to A	6.17*
D) Lagged stock Dredging (TOTVOL)	4	0.4515	D to A	NS
E) Lagged stock June flow Sewage	8	0.7086	E to B E to C	4.81* 3.72*
F) Lagged stock June flow Dredging (TOTVOL)	8	0.5353	F to B F to D	NS 2.76*

(a)Model F-value rather than comparative F-value
(b)* = significant at $\alpha = 0.05$

Table 5. Effects of climate and macropollution on abundance of winter flounder in Narragansett Bay. From Summers et al. 1987.

Regressor Variables	Number of Categories	Adjusted R^2	Comparisons: Models	Comparisons: F-Value
A) Lagged stock	2	0.3441	---	23.04*(a,b)
B) Lagged stock March temperature March flow	8	0.6558	B to A	13.88*
C) Lagged stock Sewage	4	0.5525	C to A	10.55*
D) Lagged stock Dredging (TOTVOL)	4	0.3149	D to A	NS
E) Lagged stock March temperature March flow Sewage	16	0.7757	E to B E to C	3.67* 4.53*
F) Lagged stock March flow March temperature	16	0.6746	F to B	NS 4.59*

(a)Model F-value rather than comparative F-value

(b)* = significant at $\alpha = 0.05$

Table 6. Effects of climate and macropollution on abundance of lobster in Narragansett Bay. From Summers et al. 1987.

Regressor Variables	Number of Categories	Adjusted R^2	Comparisons	
			Models	F-Value
A) Lagged stock	2	0.1986	---	10.44*(a,b)
B) Lagged stock March temperature	4	0.4810	B to A	10.27*
C) Lagged stock Human population (POPULATE)	4	0.5525	C to A	15.23*
D) Lagged stock Dredging (TOTVOL)	4	0.2858	D to A	NS
E) Lagged stock March temperature Human population (POPULATE)	8	0.6806	E to B E to C	6.31* 4.41*
F) Lagged stock March temperature Dredging (TOTVOL)	8	0.4803	F to B F to D	NS 4.18*

(a)Model F-value rather than comparative F-value

(b)* = significant at $\alpha = 0.05$

Table 7. Results (R^2 values) for the categorical times series analyses for Narragansett Bay stocks (Summers et al. 1987)

Stock	Stock Alone	Model Hydrographic Variables[1]	Anthropogenic Variables[2]
Anadromous species			
Striped bass	0.005 (NS)	0.102 (T)	0.380
Smelt	0.000 (NS)	0.110 (T)	None
Alewife	0.018 (NS)	0.193 (T)	None
Estuarine species			
White perch	0.066	None	0.300
Oyster	0.068 (NS)	0.297 (T)	None
Hard clam	0.179	0.303 (F)	None
Soft clam	0.011	0.097 (T)	0.259
Estuarine developers			
Menhaden	0.311	0.545 (W)	None
Winter flounder	0.344	0.656 (F,T)	0.776
Lobster	0.199	0.481 (T)	0.681
Windowpane flounder	0.106 (NS)	None	None
Summer flounder	0.008 (NS)	0.411 (T,F)	0.892
Weakfish	0.177	0.323 (T)	0.485
Bluefish	0.346	0.703 (T)	None
Eel	0.282	0.425	0.608
Butterfish	0.152	0.550	None
Ocean developers			
Scup	0.535	0.840 (W,T)	None
Tautog	0.440	0.514 (F)	0.709

[1]Significant additions to the stock alone model with F = river flow, T = temperature, and W = wind.

[2]Significant addition to the best stock and hydrographic model.

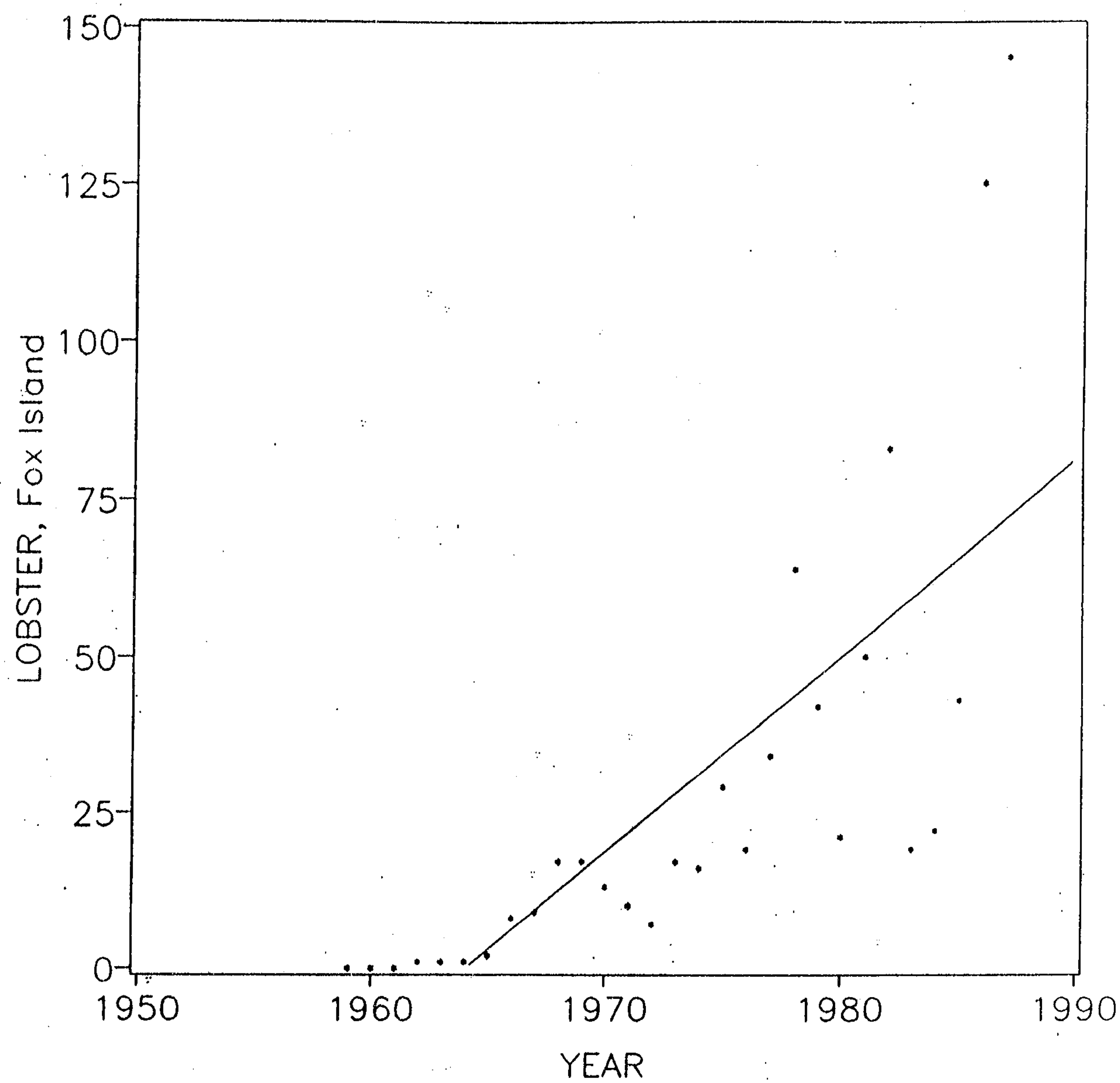

Figure 1. Trend in relative abundance of the American lobster from trawl survey data in the vicinity of Fox Island (from Jeffries et al., in preparation)

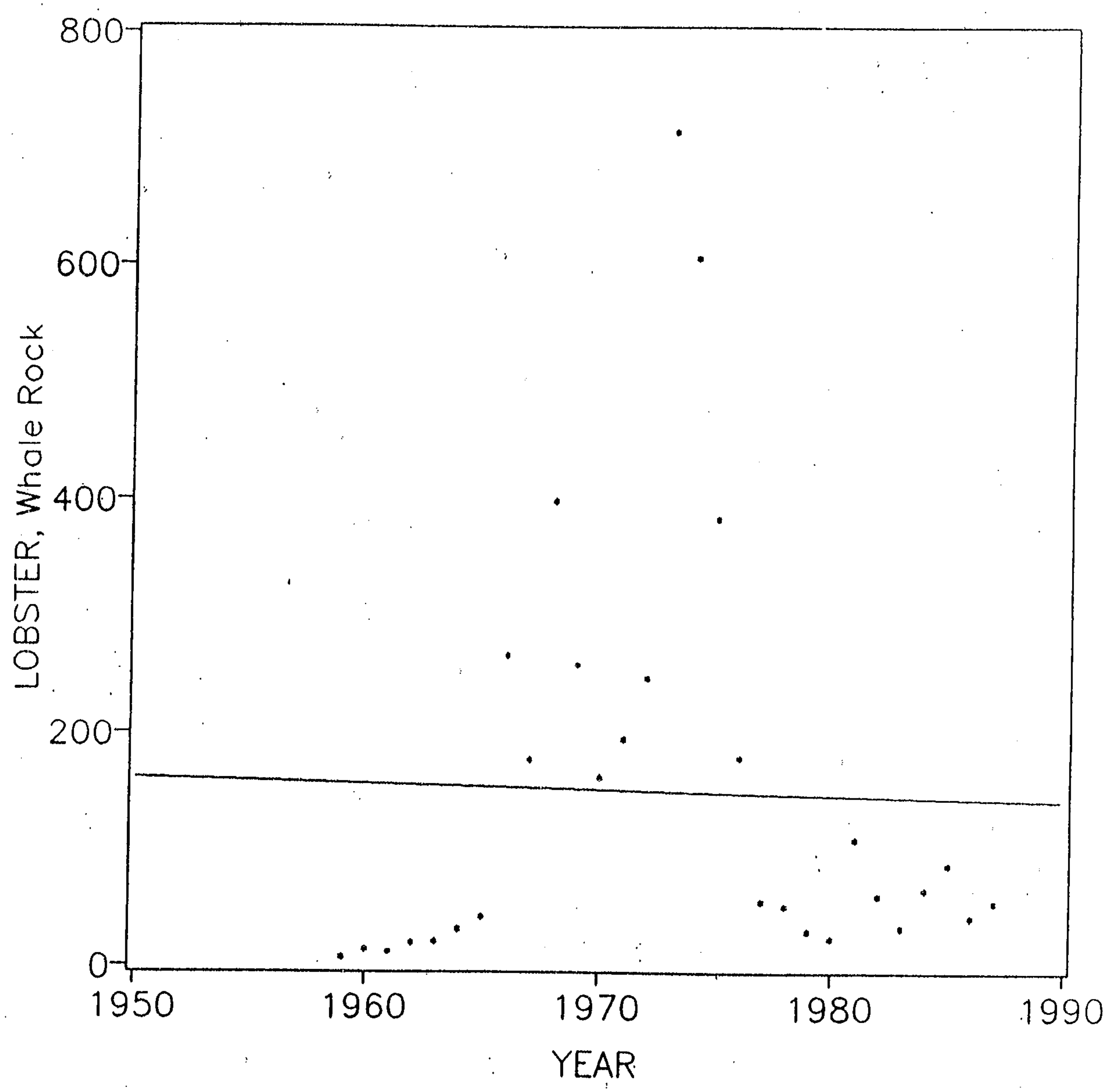

Figure 2. Trend in relative abundance of the American lobster from trawl survey data in the vicinity of Whale Rock (from Jeffries et al., in preparation)

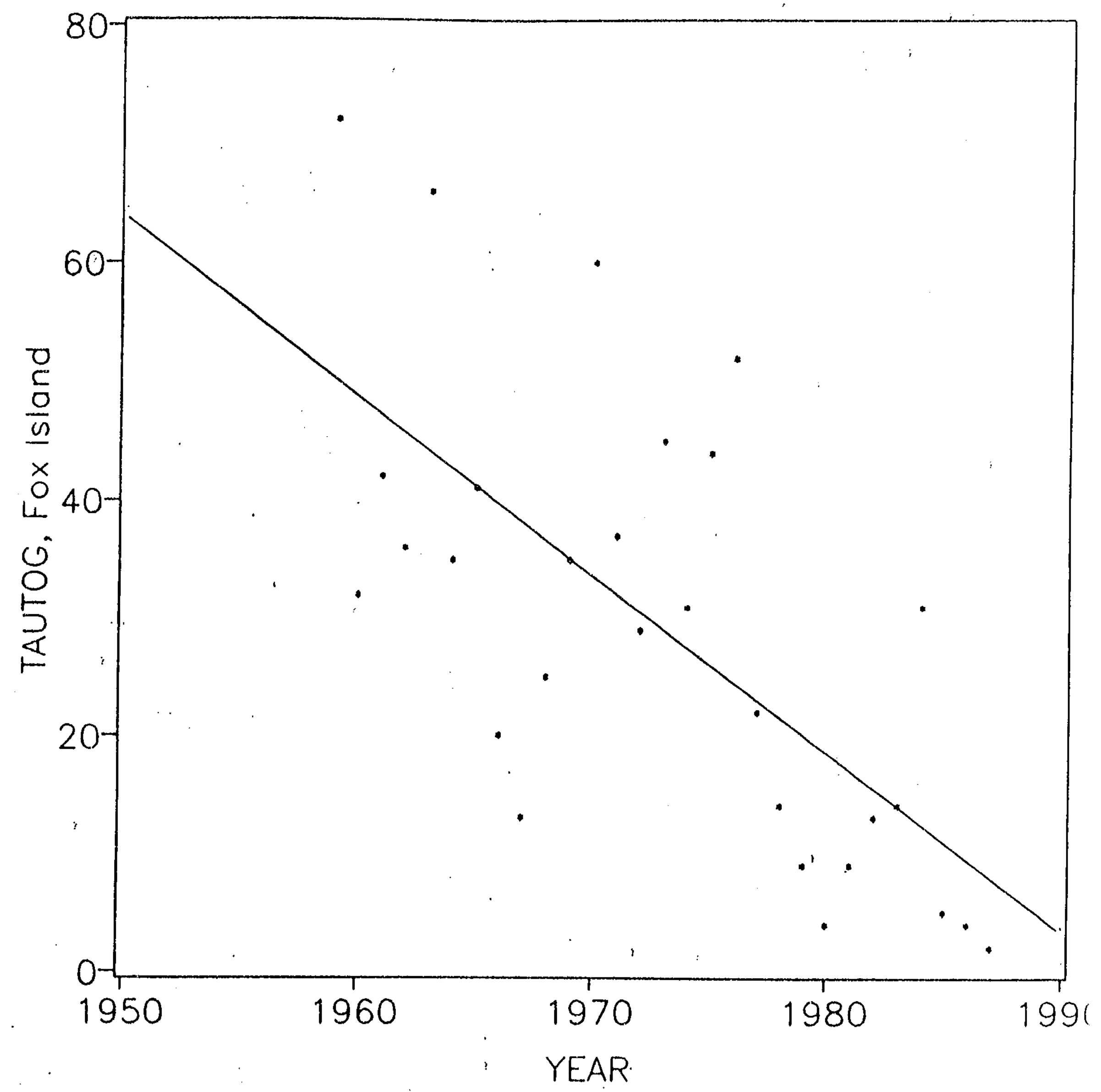

Figure 3. Trend in relative abundance of the tautog from trawl survey data in the vicinity of Fox Island (from Jeffries et al., in preparation)

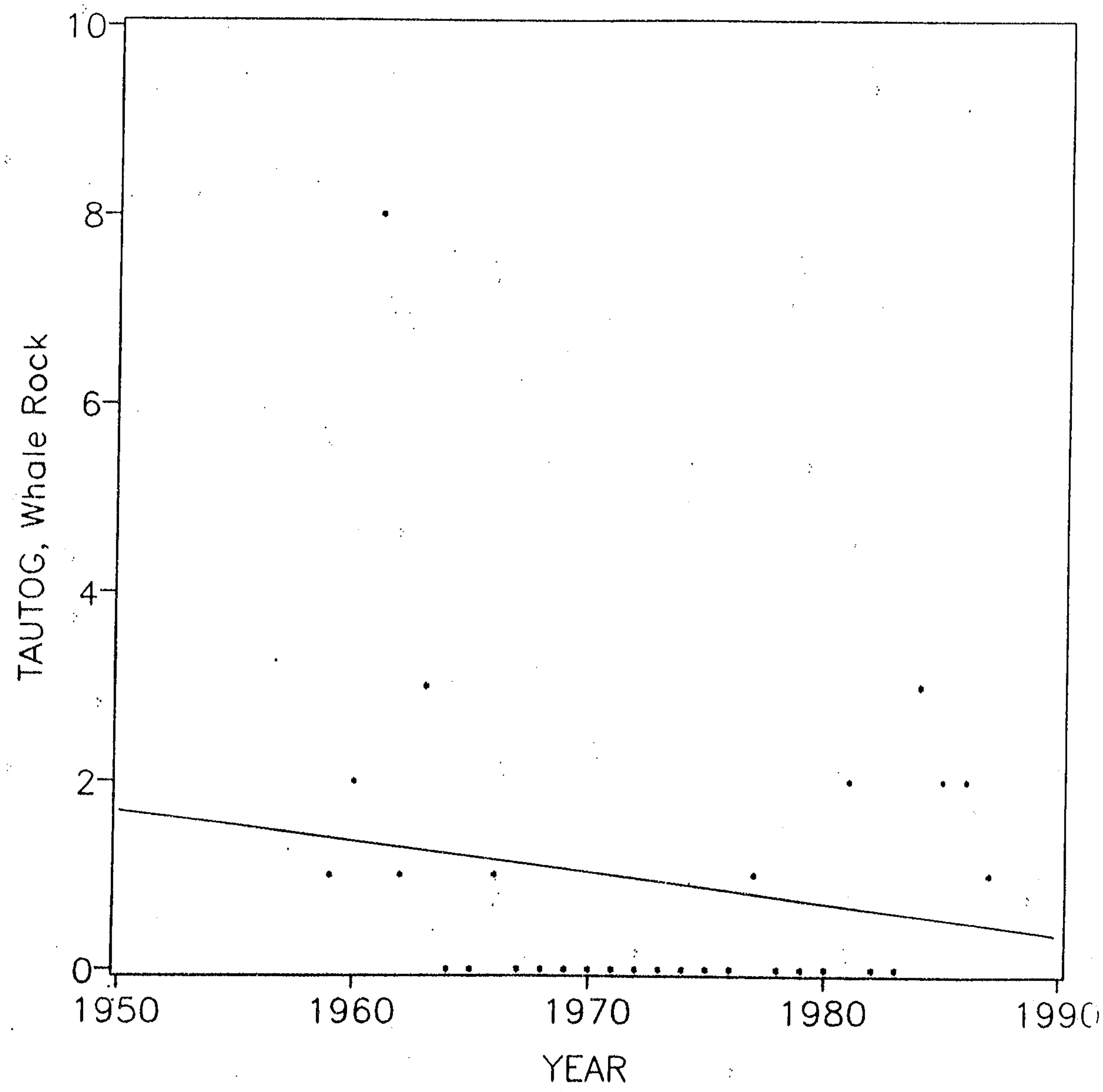

Figure 4. Trend in relative abundance of the tautog from trawl survey data in the vicinity of Whale Rock (from Jeffries et al., in preparation)

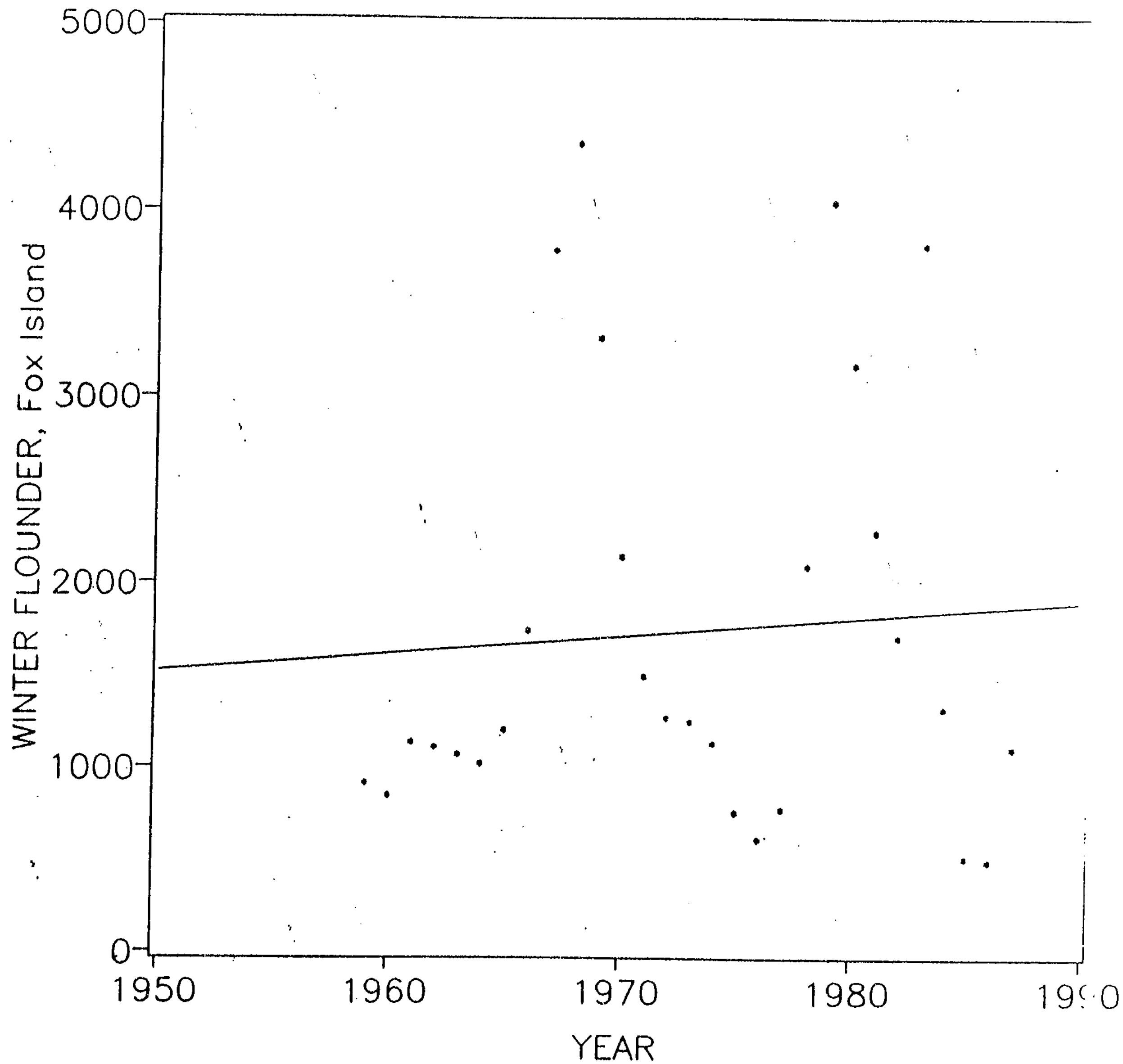

Figure 5. Trend in relative abundance of the winter flounder from trawl survey data in the vicinity of Fox Island (from Jeffries et al., in preparation)

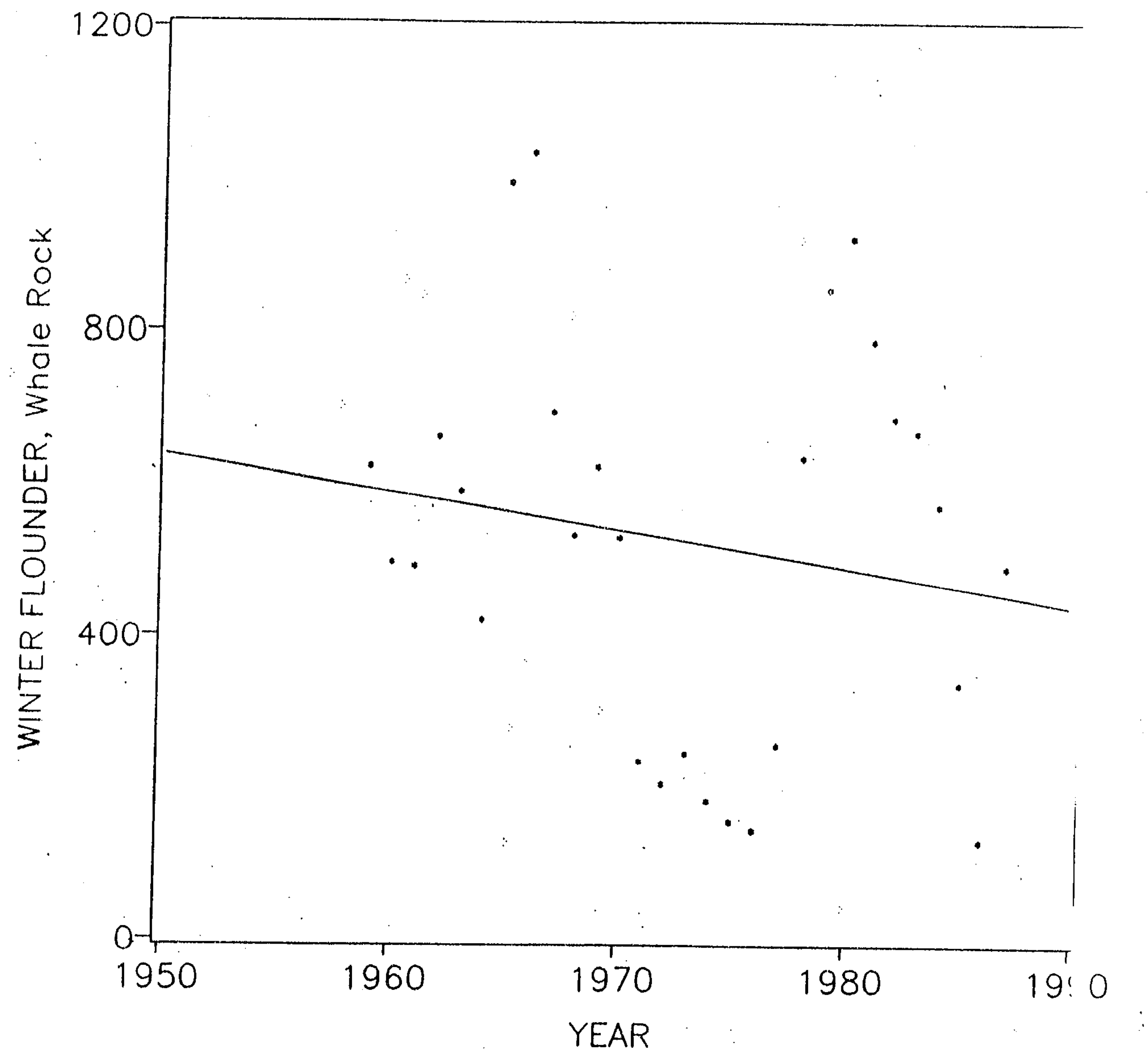

Figure 6. Trend in relative abundance of the winter flounder from trawl survey data in the vicinity of Whale Rock (from Jeffries et al., in preparation)

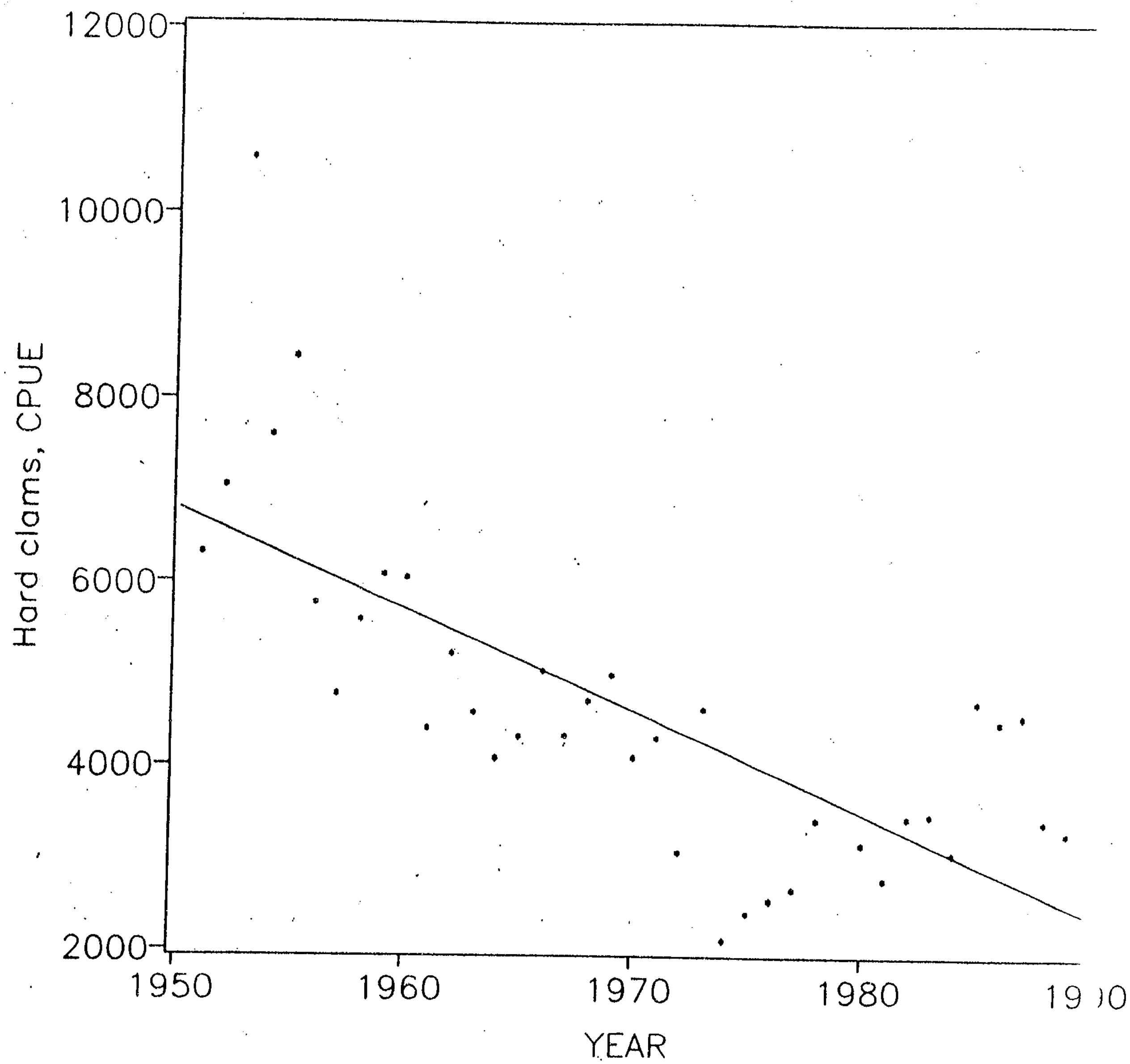

Figure 7. Trend in relative abundance of the hard clam (quahog) based on available catch and effort data (from Jeffries et al., in preparation)

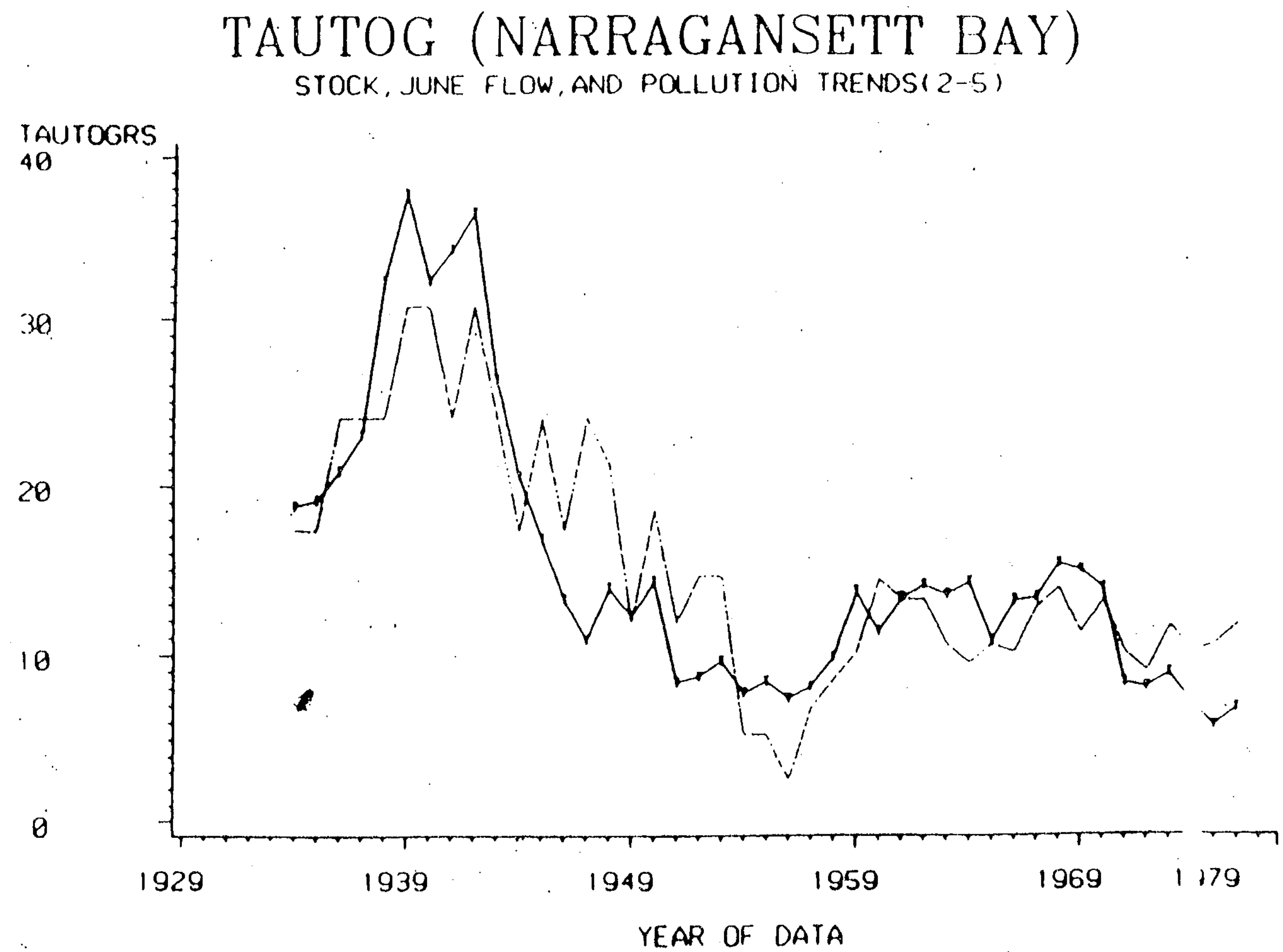

Figure 8. Model of stock variation (1935-1977) in Narragansett Bay (including RI Sound) tautog.
Key: T-T = observed, --- = predicted.
Stock, June river flow and sewage loadings lagged 2-5 years.
From Summers et al. 1987.

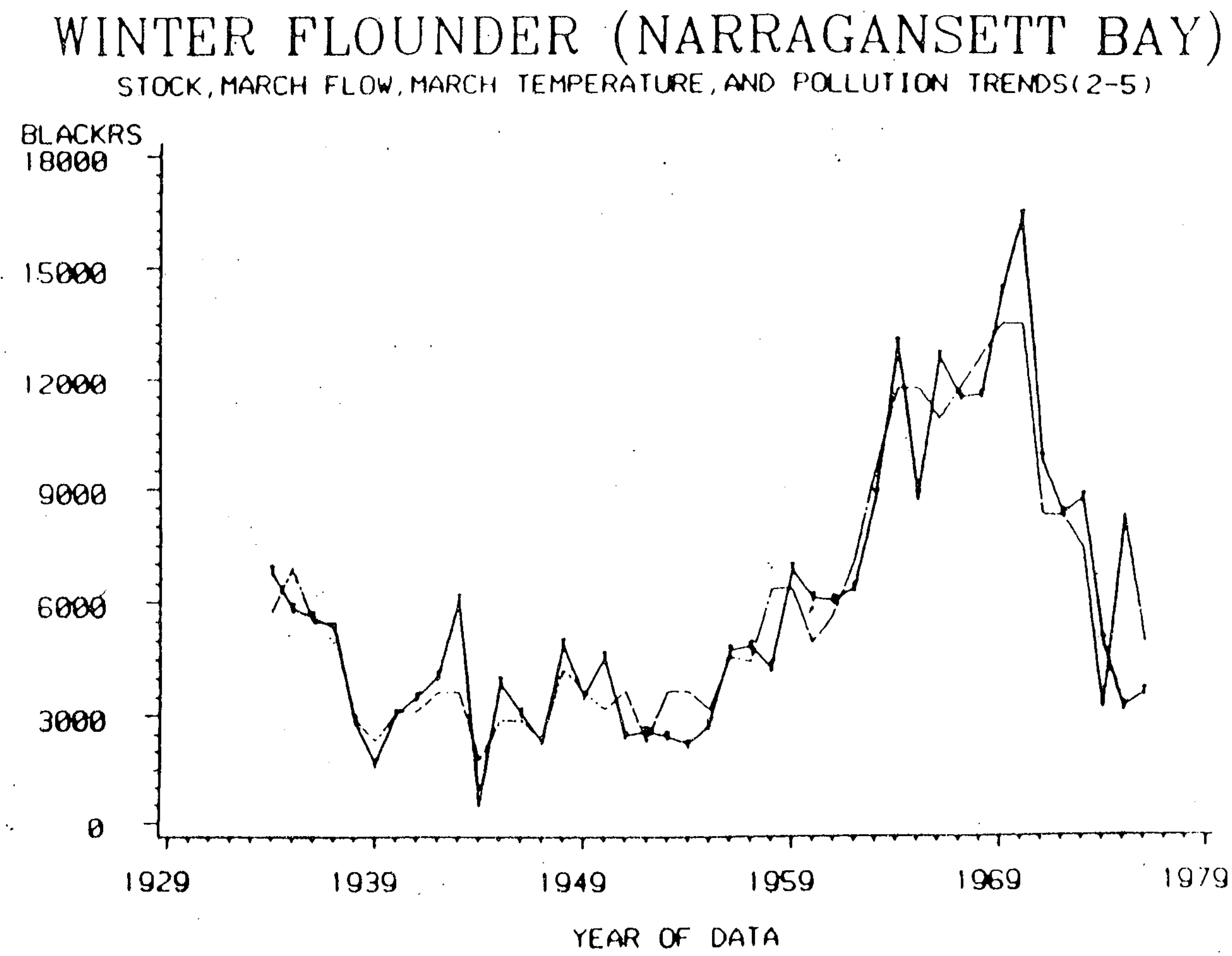

Figure 9. Model of stock variation (1935-1977) in Narragansett Bay (including RI Sound) winter flounder.
Key: T-T = observed, --- = predicted.
Stock, March river flow, March temperature, and human population lagged 2-5 years.
From Summers et al. 1987.

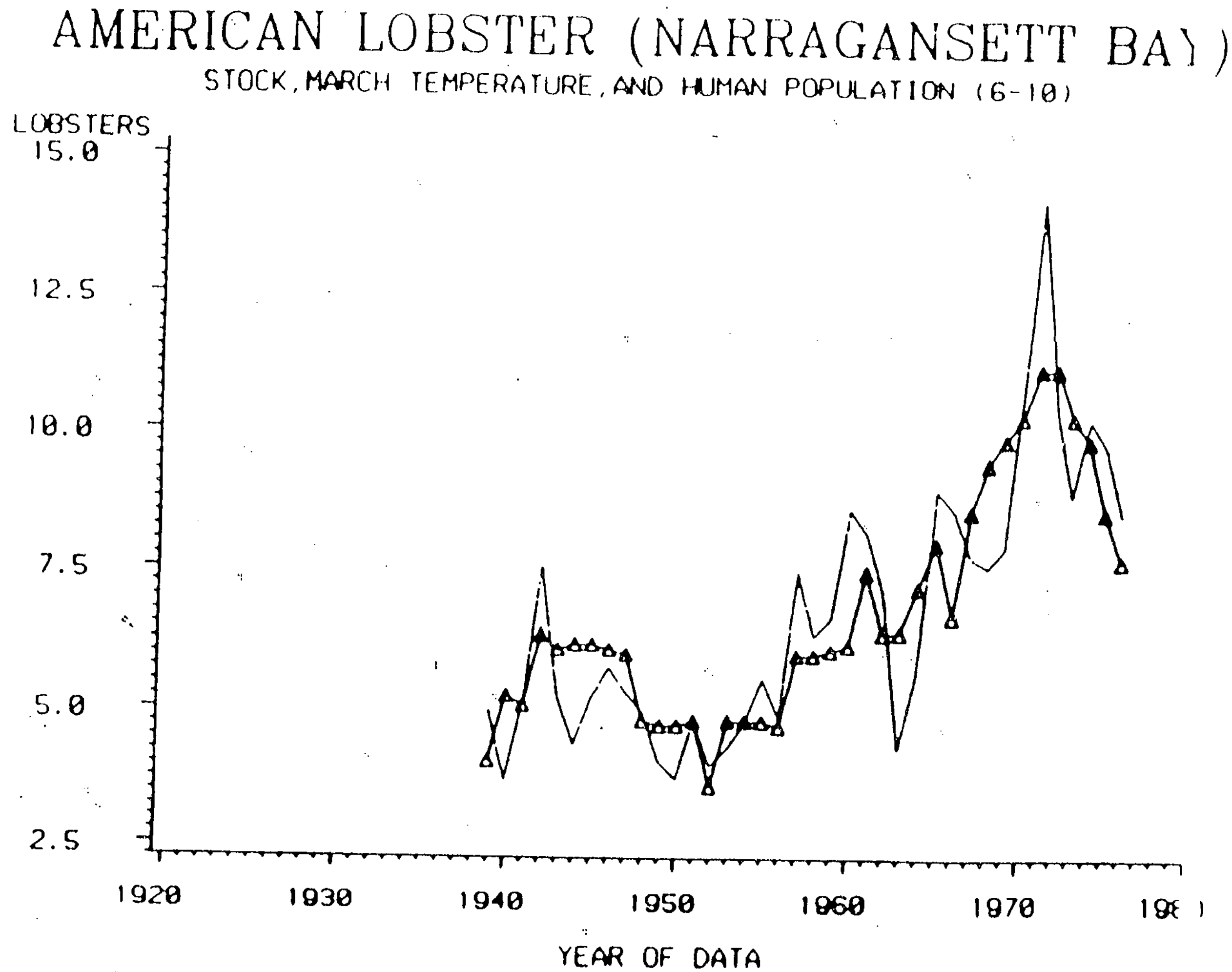

Figure 10. Model of stock variation (1938-1977) in Narragansett Bay (including RI Sound) lobster.
Key: T-T = observed, --- = predicted.
Stock, March temperature, and human population lagged 6-10 years.
From Summers et al. 1987.