PROCEEDINGS OF THE 1996 NEWFOUNDLAND ASSESSMENT-ENVIRONMENT-ECOSYSTEM MEETING, JANUARY 23-26, 1996

edited by

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Table of Contents

Abstract

The Newfoundland Assessment-Environment-Ecosystem (AEE) meeting was held on January 23, 25, and 26, 1996. The three sessions were devoted to 1) environmental, ecological and stock overviews; 2) the effect of environment on maturation and the timing of spawning of various species; and 3) the issue of using environmental data in assessments. These proceedings contain summaries of working papers presented at the meeting as well as relevant discussion.

Two major recommendations were made. The first indicated the importance of compiling all available environmental information together with all available data on stock size, condition, recruitment, etc. for both commercial and non-commercial vertebrate and invertebrate species as the initial step in formulating hypotheses on interactions between environment and stocks. The second stressed the importance of providing a "half-way house" where environmental and assessment scientists could work together to formulate hypotheses. It is recommended that the individual assessment meetings be used for this purpose.

Résumé

RÉSUMÉ

La réunion d'Évaluation-Environnement-Écosystème (EEE) de Terre-Neuve a eu lieu les 23, 25 et 26 janvier 1996. Les trois journées ont été consacrées à 1) des survols de l'environnement, de l'écologie et des stocks; 2) la question d'utiliser des données sur l'environnement dans le processus d'évaluation; 3) l'effet de l'environnement sur la maturation et la date de frai de diverses espèces. Le présent rapport réunit des résumés de documents de travail présentés à la réunion, ainsi que des observations connexes.

Deux recommandations principales ont été formulées. La première a décrit l'importance de conjuguer toutes les informations connues sur l'environnement à toutes les données en main sur les stocks d'espèces de vertébrés et d'invertébrés tant commerciales que non commerciales (envergure, conditions, recrutement, etc.) comme première étape à la formulation d'hypothèses sur les interactions entre l'environnement et les stocks. La deuxième a relevé l'urgence d'offrir une «place publique» où spécialistes de l'environnement et de l'évaluation puissent oeuvrer ensemble à formuler des hypothèses. Il est recommandé que les réunions d'évaluation particulières soient utilisées à cette fin.

1.0 INTRODUCTION

The second Newfoundland Assessment-Environment-Ecosystem (AEE) meeting was held on January 23-26, 1996. The terms of reference for the AEE Committee were designed to help broaden the scope of regional assessments to incorporate potentially relevant environmental and biological information. This annual meeting is open to Northwest Atlantic Fisheries Centre (NAFC) Science Branch staff as well as others from university, industry, and other DFO branches. Its timing prior to the start of the year's assessments serves several purposes. First, the meeting provides a broad overview in which apparent trends in various commercial and non-commercial vertebrate and invertebrate stocks, marine mammals and seabirds can be discussed in conjunction with trends in the physical and biological oceanographic environment. The overviews eliminate the need to present the same information to each assessment meeting. Second, the meeting provides a forum in which individual stocks can be discussed in relation to variations in the Northwest Atlantic ecosystem and environment. The diversity of participants and the meeting's global perspective are designed to encourage discussion and stimulate new view points. Third, the meeting addresses the issue of how what has heretofore been considered "peripheral" information can actually be assimilated into assessment methodologies and processes.

The terms of reference require that the meeting proceedings be available to participants during forthcoming assessments. This report contains summaries of each presentation and any significant discussion. Figures are included in the summaries of those presentations which have not been published elsewhere. All summaries were provided by the authors and have undergone only minor editing. As well, a number of the presentations will be published as DFO Research Documents. From the abstracts that follow, it might appear that some of the overviews were considerably more thorough than others. This impression is illusory. At last year's inaugural meeting (February, 1995), thorough overviews were presented in most, but not all, subject areas. In these cases, the Committee requested that only brief updates be provided and that these address questions concerning what was new or unusual regarding stock size, condition or distribution and if any potential environmental or ecological concerns were evident. Presentations on the state of the biological and benthic environments and the ecology of seabirds were given for the first time.

This year, management instructed the Committee to select a specific topic for detailed discussion each year that is multi-disciplinary and addresses some aspect of ecosystem-stock and/or environment-stock interactions. The topic chosen for 1996 was the effect of environment on maturation and the timing of spawning. The meeting contained three distinct sessions. The first included environmental, ecological and stock overviews; the second addressed the issue of using environmental data in assessments, and the third was devoted to the special topic on maturation and spawning.

2.0 Session 1 (January 23) ENVIRONMENT, ECOSYSTEM, and STOCK OVERVIEWS

2.1 State of the Ocean Report - physical oceanography. (Res. Doc. 95/98, WP AEE 96/1) - E. Colbourne

Oceanographic observations from the Grand Bank, northeast Newfoundland and southern Labrador shelves during the summer (July) of 1995 were presented and compared to historical (1961-1990) data from the area. In addition, meteorological and ice cover data from the winter and spring were also presented. The analysis indicated that the colder than normal air temperatures experienced in Atlantic Canada during the winter and early spring had moderated to near normal by the spring of 1995. The above normal ice coverage during winter and early spring along the east coast of Newfoundland and Labrador had returned to near normal conditions by mid-May except for some isolated patches in the inshore regions. At Station 27, water temperatures were normal during the winter months but had cooled to 0.5-1.0 deg C below normal during the spring and early summer of 1995, except in the depth range of 15-70 m in July when temperatures were up to 1.0 deg C above normal. Salinities were near normal during early winter and from January to July near the bottom but up to 1.0 psu (potential salinity units) fresher than normal in the upper water column during spring and early summer. The cold-intermediate-layer (CIL) volume was above normal along the Flemish Cap transect (20%) and up to 28% below normal along the Bonavista transect and 32% below normal along the Seal Island transect. The cross sectional area of sub-zero deg C water on the Northeast Newfoundland and southern Labrador Shelves was the lowest in about 10 years. Minimum CIL core temperatures were above normal along the Seal Island transect, about normal along the Bonavista transect but still slightly below normal on the Grand Bank along the Flemish Cap transect,

2.2 State of the Ocean Report - biological oceanography. (WP AEE 96/2) - P. Pepin & M.A. Paranjape

This study provided a preliminary description of temporal and spatial patterns in the variation of nutrients, phytoplankton and zooplankton in the Newfoundland region based on data from directed and ship-of-opportunity collections (1993-94) as well as using information from the CPR series (1959-1978, 1991, 1992) and from the Mobil Oil survey of the Grand Banks (1980-81). The principle objective was to describe and contrast the depth-dependent seasonal cycle in nutrient and phytoplankton abundance from a single site (Station 27) with observations taken in the northern region of the Grand Banks (NAFO Div. 3L).

All nutrients as well as chlorophyll concentrations exhibit strong seasonal cycles. Overall nitrate and phytoplankton concentrations are higher along the shelf edge, in correspondence with the offshore arm of the Labrador current. Phytoplankton concentration appears to show a peak in late April-early May but the precise timing of the spring bloom is uncertain because of the unavailability of data for the period preceding April. Maximum phytoplankton concentrations occur at depths of 30-50 m. It is apparent that there is a strong seasonal cycle at all depths with the greatest overall variability occurring at intermediate depths (10 and 50 m). The seasonal cycle in integrated (0-100 m) fluorescence levels from all CTD observations in NAFO area 3L shows a pattern that is similar to that observed at Station 27 as is the cycle in temperature. After taking into account the seasonal cycle, the residual fluorescence levels show a marked regional pattern which is similar to that of temperature residuals but is shifted further south along the shelf, possibly indicating advection of tracers.

The seasonal cycle in the abundance of *Calanus finmarchicus* at station 2 is not as marked as that of *Calanus glacialis* or *Calanus hyperboreus*. The abundance of *Pseudocalanus sp* and *Temora longicornis* show higher levels during mid-fall. The seasonal cycles for these five species are similar to those observed from the CPR surveys conducted in NAFO Div. 3K and 3L but differ substantially from those for NAFO area 3NO. Differences in the seasonal cycle at station 27 with other parts of NAFO area 3L may be due to local features or processes (e.g., mixing, mixed layer depth, nutrient sources, advection). However, it is also possible that the variability in the level of some elements on the time scale of less than 30 days limits the degree of comparison possible from ship-of-opportunity collections.

There are important questions pertaining to the sampling frequency and spatial resolution that would be essential in order to detect the "climatic" variability. However, the nature of the sampling program required to supply "adequate monitoring" requires extensive evaluation and discussion because ship-of-opportunity based collections require substantial assumptions in the interpretation of data analysis. The current sampling resolution of biological oceanographic variables severely limits the comparison of available observations because of the possible influence of short-term and small-scale variability on the description of the seasonal cycle and in the measurement and understanding of interannual fluctuations about that mean cycle.

Discussion

The discussion turned on three issues: 1) What is the linkage between the benthos and primary and secondary production in the upper water column? 2) What questions should be addressed with plankton data? and 3) What sampling scales are required in order to provide the data needed to answer the questions we pose.

Although the amount of phytoplankton that sinks to the bottom is unknown, it was speculated that because about 90% of the annual biomass production is at the sea floor, production in the upper water column may be a way of feeding the benthos. Indeed, the formation of a subsurface chlorophyll maximum may be a step in the overall export of matter to the bottom. It was mentioned that R. Thomson (Ocean Sciences Centre) may have data relevant to determining how much matter sinks.

There was considerable difference of opinion on the need for biological data relative to assessments. On the one hand it was felt that the need for such data was self-evident, as one could not manage any stock without adequate knowledge of its habitat. The analogy was given of the absurdity of trying to manage a herd of elephants without considering the vegetation on which they feed. Similarly, it was argued that more species specific information was required. For example, it could be useful to have information of the temporal/spatial distribution of euphausiids and amphipods which serve as prey for capelin. On the other hand, the opinion was expressed that one can always argue for more information. In the present climate of budgetary restraint, one must first try to quantify the potential effects on assessments before one requests additional resources. The issue was not resolved. It was clear, however, that the knowledge of biological oceanographic processes in the Newfoundland region is meagre indeed.

It was also clear that present efforts to map the space and time scales of plankton distribution is hampered by inadequate sampling. At present, the questions that can be addressed must be tailored to available cruises. However, it was recommended that the collection of fluorometer data at Station 27 should be enhanced so as not to introduce gaps in the times series there.

2.3 State of the Ocean Report - benthic ecology. (WP AEE 96/3) - P. Schwinghamer

The benthos of the Grand Banks and the Northeast Newfoundland Shelf is species rich and high in biomass and abundance. Its role in the productivity of the historically rich fisheries of the region has neither been appreciated nor taken into account in deliberations on the relative effects of human versus natural perturbations on commercial fish stocks. Calculations presented here indicate that biomass and heterotrophic production of benthic metazoans are greater than total water column values by factors of greater than 10. The total biomass of commercial finfish in 2J3KL during the 1970s and early 1980s has been calculated as less than 10^7 t, while benthic macrofauna and epifauna totalled approximately 2-3 x 10^8 t for the same area. Production of the benthos is probably higher than what the biomass proportion would indicate owing to the generally smaller modal size of benthic fauna and their consequently high production to biomass ratios relative to water column fauna. Therefore, the consequences of fishing practices on benthic fauna and the bottom habitat are important factors to take into account when planning management schemes for fisheries whose prosecution may impact the benthos. Also, natural variations, both spatial and temporal, in benthic production are most likely of great importance to the production system which results in commercial fish species on the continental shelf. A program of benthic ecological studies has therefore been initiated in the Newfoundland Region to meet the need for this information in stock status and trend assessments of commercial species. Preliminary data from this program and from experiments on the effects of otter trawling on sandy bottom epifaura were presented. They indicate significant effects of trawling on several benthic invertebrates and on the structure of the sandy bottom habitat. In addition, they illustrate large spatial variations in biomass of several epibenthic species, both commercial and prey, related to depth and other factors.

Discussion

It was noted that there were many areas on the continental shelf in which more that 8% of the area per year was scoured by trawls when the groundfish fishery was prosecuted. Because much of the trawling effort probably occurs in region of high productivity, the potential impact on the benthos is magnified.

2.4 Recent developments in salmonid stocks and environment - D.G. Reddin, M.F. O'Connell, and C.E. Bourgeois

In this presentation, the following topics were discussed:
1) provision of catch advice for Greenland salmon fishery;
2) recent developments for marine thermal habitat and salmon abundance; and,
3) variability in salmon runs and spawning time.

Catch advice was provided for the West Greenland salmon fishery through the use of regression techniques to forecast the abundance of the two-sea winter component of the North American stock complex of Atlantic salmon prior to fisheries in Greenland and North America (Rago et al. 1993a&b). The historical abundance of this stock component was determined empirically from constrained ranges of catches and escapements by area and sea age. The approach was guided by recent findings relevant to factors controlling post-smolt survival of North American salmon (Reddin & Friedland 1993; Friedland & Reddin 1993; Friedland et al. 1993). Winter indices of potential salmon habitat, weighted by research vessel catch rate data, were tested as independent variables (Fig. 1). The index for winter habitat was found to be the best predictor and was used to forecast the pre-fishery abundance of two-sea winter salmon (Figs. 2a&b). The analysis was enhanced by the use of stochastic prediction methods. The method gave a forecast for 1995 of about 242,000 at the 95% probability level. These estimates provide the basis for fishery catch allocation in North America and Greenland and two-sea winter escapement in Canada.

Correlation techniques are used to examine the relationships between spring salmon catches in several rivers in Newfoundland and Labrador, in the UK (Scotland and Wales) with indices of potential salmon habitat (termed thermal habitat) in the Northwest Atlantic (Fig. 3). The approach was guided by recent findings relevant to factors controlling post-smolt survival of North American salmon. Several causal relationships are explored using thermal habitat as an independent variable. Spring rod catches were modelled with catches of European salmon and their mean weight at Greenland, thermal habitat, and pre-fishery abundance. The results indicated that only thermal habitat was related to declines in Scottish rod catches.

Salmon survival rates provide us with estimates of habitat suitability for surface dwelling species. Survival rates are calculated as counts of smolts leaving a river divided by the numbers of adults returning one year later. Survival rates for salmon stocks on Rocky, Northeast Trepassey, and Conne rivers declined from 1986 reaching low values in 1991 (Fig. 4). Since 1991, survival rates have increased. This indicates that for salmon stocks habitat reached a low in 1991 and has subsequently improved. The impact of environment on timing of river entry and spawning was examined for the salmon stocks of Terra Nova and Exploits rivers (Narayanan et al. 1995). Time of entry into Terra Nova River was significantly correlated with the day that sea surface temperature at Station 27 exceeded 4 deg C. (Fig. 5).

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2.5 Status of seabird populations: Trends in seabird populations and feeding ecology in the Northwest Atlantic (WP AEE 96/4) by W. Montevecchi and R.A. Myers

Long-term fluctuations in seabird populations, reproductive success and diets exhibit robust associations with oceanographic and climatic changes. Examples from seabirds in the Northwest Atlantic of decadal increases in breeding populations, decreases in reproductive success and shifts in parental diets are associated with changes in oceanographically- and fishery-induced changes in prey conditions. Analyses of the foods delivered to gannet chicks on Funk Island, Newfoundland from 1977 through 1995 indicate that diversity of prey increased through this period and shifted from migratory warm-water to resident cold-water pelagic prey. These changes are indicative of large-scale shifts in pelagic food webs associated with recent cold-water perturbations in the Northwest Atlantic. Data derived from seabirds complement fisheries research assays, enhance multi-species approaches and often supplement traditional survey techniques by providing information on noncommercial and hence unstudied species. As easily accessible, wide-ranging marine predators, seabirds are also extremely useful in monitoring human-induced perturbations associated with pollution and habitat change.

Discussion

Although murres take primarily female capelin, it is not known if they are selective toward the sex of their prey, or if the availability of female capelin is higher in the areas and depths where they forage. Female capelin, especially gravid ones, may also be easier to catch than males. Selective consumption of female capelin by seabirds should be incorporated into trophic consumption models.

Fishers in Bonavista Bay noted that in recent years gannets were more common near shore than they had been in the past. It may be that the gannets not only had difficulty finding large, lipid rich prey, such as mackerel and herring, but also had to forage to a greater extent in relatively shallow coastal water in order to find concentrations of capelin. Finally, it was mentioned that the dominant component of the diet of gannets has been many small prey (especially capelin) in recent years instead of large prey (notably mackerel and squid), and it was postulated that this may be bioenergetically disadvantageous. It appears that during the 1990s, the gannet's diet has shifted from large warm-water migratory species (mackerel, squid) to cold-water pelagic fishes (capelin, herring).

2.6 Larval and juvenile fish distributions - J. Anderson

Summary

In 1994 and 1995, a two-ship survey of the plankton and nekton was conducted throughout NAFO Divisions 2J3KLNO, including inshore areas. These surveys were done from August 22 to September 3 and from September 5-22, respectively. Both small (61 cm bongo) and large (IYGPT, International Young Gadoids Pelagic Trawl) gears were used.

Abundances

In the plankton, the smallest size range (0.3-5 mm) was dominated by copepods, while the larger size range (5-25 mm) was dominated by capelin (Mallotus villosus) larvae. In the nekton, the smallest size range was dominated by euphausiids and amphipods were an important component of the nekton. The remaining nekton was dominated primarily by juvenile Arctic cod (*Boreogadus saida*) and juvenile Arctic squid (*Gonatus fabricii*). The predominant size range for these species was 40-60 mm. Other important species in the lower size range of the nekton included juvenile Atlantic cod (*Gadus morhua*), redfish (*Sebastes* sp.) and herring (*Clupeus harengus*). In 1995 turbot (*Reinhardtius hippoglossoides*) occurred throughout much of the Northeast Newfoundland Shelf, while it was noticeably absent in 1994. The largest size range of the nekton (> 60 mm) was dominated by one-year-old capelin. The largest species caught in our surveys was two-year-old capelin, although these were always in low abundance.

Distributions

In 1994, the smallest size fraction of copepods (< 1 mm) occurred most abundantly over the Northeast Newfoundland Shelf, and within the Notre Dame Bay and Bonavista Bay, while biomass was lowest over the Grand Bank. Similarly, the middle size range (1-2 mm) and largest size range (> 2 mm) were most abundant over the NE Newfoundland Shelf compared to the Grand Bank. As a composite, the copepod biomass was most abundant over the NE Newfoundland Shelf, lower within the inshore areas and lowest over the Grand Bank.

Distributions of capelin larvae were similar each year, being highest within the inshore and decreasing to zero abundance on the outer shelf and on the Grand Bank. These distributions are expected, given the inshore spawning locations of capelin. Notable was the absence of larval capelin on the southern Grand Bank. This contrasted with surveys carried out on the southern Grand Bank in the mid-1980's (Frank and Carscadden 1989).

Juvenile Arctic cod (*Boreogadus saida*) was the dominant fish species caught each year. In 1994 and 1995 they were most abundant both over the NE Newfoundland Shelf and inshore. Both years Arctic cod was notably absent from the Grand Bank. The second dominant species which occurred in the nekton were juvenile squid. They were most abundant over the NE Newfoundland Shelf each year, and off southern Labrador in 1995. In both years squid also occurred on the Grand Bank, although in lower abundances. Examination of a limited number indicated that the dominant species was Arctic squid (*Gonatus fabricii*). These are juvenile stages of squid, ranging in size from approximately 25-60 mm in mantle length.

Juvenile Atlantic cod (*Gadus morhua*) was the second most dominant fish species sampled in 1994. They ranged in size primarily from 30-60 mm in 1994 and from 35-70 mm in 1995. In 1994 Atlantic cod were distributed broadly over the NE Newfoundland Shelf and throughout the inshore area. There was also a distinct concentration sampled on the southern Grand Bank. In 1995, Atlantic cod only occurred sporadically offshore on the NE Newfoundland Shelf and were mostly absent on the southern Grand Bank. However, they occurred throughout the inshore in 1995, being most abundant in Notre Dame Bay.

Juvenile redfish occurred over Funk Island Bank and the southern Grand Bank each year, as well as a small concentration on the eastern slope of the northern Grand Bank in 1995. Redfish are oceanic spawners and their distributions on the outer shelf areas each year may reflect advection onto the shelf in these areas.

The largest size range sampled in the nekton (> 60 mm) was dominated by one-year-old capelin. They were distributed most abundantly over the northern Grand Bank and throughout the inshore area each year and were notably absent on the outer part of the NE Newfoundland Shelf and the southern Grand Bank. The largest capelin caught (>115 mm) were two and three years old.

Sampling across three orders of magnitude in size has created a unique data set that ranges from copepods to large planktivorous fish. Some observations become immediately obvious. For instance, larval capelin were most abundant inshore, coincident with their spawning grounds, but were clearly being dispersed to the offshore areas. At one and two years of age, capelin occurred both inshore and offshore, although their highest concentrations occurred on the northern Grand Bank. Where one and two year old capelin occurred abundantly on the northern Grand Bank, Arctic cod and Arctic squid were notably absent. Where Arctic cod and squid were most abundant, and Atlantic cod in 1994, the zooplankton biomass was highest, indicating the planktivorous juvenile gadoids co-occurred with their food.

As a preliminary step in exploring the spatial relationships among the different species and parameters measured during these surveys, we ran a simple rank correlation analysis among all variables for the 1994 data. Among the dominant fish species and squid, there were positive correlations on the order of 0.4 to 0.5. Larval capelin were correlated with surface chlorophyll, which tended to be higher within the inshore area. Arctic cod and, to a lesser extent, Atlantic cod were correlated with total zooplankton biomass. Chlorophyll was strongly negatively correlated with zooplankton biomass, demonstrating significant differences between inshore and offshore areas. Finally, Arctic cod was negatively correlated with surface water temperature, which typically ranged from 6-8 deg C in the north to 15-19 deg C in the south.

Discussion

Distribution patterns were not shown for American plaice because plaice catches displayed a strong diel pattern which has not yet been taken into account. It was also noted that sampling was conducted too late in the year to collect larvae of shrimp and crabs.

0-group Arctic cod is a major component of the catch during the 0-group surveys. It was noted that the Campelen trawl now being used during the groundfish biomass surveys seems to be much more efficient at catching 0-group Arctic cod than was the Engels High-rise trawl. This opens up the possibility of exploring more thoroughly the ontogenetic changes in distribution of this important species.

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2.7 Recent developments in groundfish stocks: by B. Atkinson

Information pertaining to the assessments and status of all of the various groundfish stocks that we reviewed last year can be found in the Canadian Stock Status Reports (95/4; 95/8) or the NAFO Scientific Council Report (95/19). For the most, they remain at or near record low levels and most of the fisheries remain closed. The only ones still open, at least of the traditional species, are redfish in 3LN, 30 and Unit 2, Greenland halibut, and 3Ps witch flounder. There are also ongoing fisheries for other groundfish such as lumpfish, skate, white hake, monkfish and wolffish. Most of the work done in conjunction with the stock declines has been related to cod, specifically northern cod. Some advocate that the decline of this stock can be wholly explained by fishing. Others, while acknowledging that fishing has been a contributor, believe that there are other factors related to the environment that have played a role. In fact, it is this latter belief that prompted the special Cod Mortality Project.

Less work has been carried out on other commercial species, but arguments with regard to cause (either fishing, environment or both) have frequently been extended from cod to these as well although much less work has been done to support the points of view.

One area of interest is that of offshore commercial fishing effort, and how this relates to trends in research vessel biomass estimates. Figure 6 shows the nominal offshore effort and research vessel biomass estimates for cod, redfish and flatfish (excluding Greenland halibut - i.e. American plaice, witch and yellowtail) for Division 3L. Effort increased during the late 1980s and this was tracked by a decline in estimated biomass. This looks like what might be called a 'typical' response to increasing fishing effort - a decline in biomass. In other words, a 'cause-effect' situation. When we look at 3K, however, the picture is not so clear (Fig. 7). The effort was consistently less than in 3L, and it did not increase substantially during the biomass decline.

The 2J situation is even more interesting (Fig. 8). Fishing effort was lowest in this area, yet the declines in biomass were earliest and most dramatic over the entire period. The ratio of applied effort per unit of biomass is, by far, the lowest in this area.

Examination of catch rates in the different areas would be necessary to determine if the impact per unit of effort was greater in the north with respect to fishing mortality. Also, an examination of the ratio of catch to research vessel biomass would be interesting. Nonetheless, these results raise once again the question as to whether other factors besides fishing came into play, particularly in the north.

Analyses of this type are useful in indicating whether parallels exist in different areas and helping to determine the scales which should be used in any analyses. This may be best illustrated by examination of the picture when divisions 2J3KL are treated together (Fig. 9).

Discussion

The question of whether the proper spatial scale is being used to subdivide cod stocks was raised. Although there are many genetic studies ongoing, the question of stock structure hasn't been looked at seriously since 1986 from a management viewpoint. In fact, the lack of evidence supporting a homogeneous stock led to the 1/3-1/3-1/3 rule where the quota was equally allotted to 2J, 3K and 3L to spread out effort.

Although the figures refer to assemblages of species, individual species show similar distributions, albeit in a noisier fashion. It was suggested that one should look at other stocks besides cod to see changes in distribution, particularly American plaice. However, if one examines stocks that were not actively fished, one sees exactly the same trends. This suggests a common factor is playing an important role and that not all changes in distribution can be attributed to fishing activity. Turbot distributions are a bit different as the stock has shifted into deeper water. If this shift was environmentally driven, we may not have adequate information to investigate it until the environment returns to more normal values.

2.8 Recent developments in pelagic and invertebrate stocks: - G. Winters

1. Snow Crab

Landings in 1994 reached an all-time high of 28,000 t (Fig. 10). Recent increases in landings are a result of increased quotas in traditional areas and the initiation of fishing activity in previously unfished areas. Research vessel survey data indicate that the current fishery is supported by good recruitment which entered the legal size range in the early 1990s (Fig. 11). It is noted, however, that survey catch rates of sub-legal sized crabs in 3L appear to be declining since 1991 and, therefore, CPUEs are expected to decrease over the next several years.

2. Shrimp

The assessment of shrimp relies heavily on commercial CPUE data (Fig. 12). These data indicate an expansion in the range and abundance of shrimp in recent years. Female shrimp (largest and oldest) are well represented in catches from all areas indicating a healthy spawning biomass is being maintained and high catch rates of smaller, male shrimp indicate good recruitment to the fishery in the short term.

3. Capelin

Annual trends in abundance, integrated from a variety of research and commercial data indicate that abundance increased steadily during the 1980s to relatively stable levels in the 1990s (Fig. 13). The year-class structure (Fig. 14) indicates that year classes produced in the 1990s have been relatively good. Trends in abundance of capelin and shrimp have shown similar trajectories since the mid-1970s (Fig. 15). These have similar factors in common viz. in that being subarctic-boreal, they are well adapted to cold water and both species are important prey for groundfish on the Newfoundland Shelf area. The recent increases in both of these species occurred during a period of environmental cooling coinciding with major declines in groundfish abundance. The relative role of these two factors, if any, in shrimp/capelin abundance changes cannot yet be determined.

4. Herring

There are five herring stock complexes distributed along east and southeast Newfoundland. Survival of young herring in these stocks is largely influenced by environmental conditions, principally overwintering, water temperature, and salinities. Large year classes of herring produced in the late 1960s supported these stocks through the 1970s. The White Bay-Notre Dame Bay stock is typical of these recruitment fluctuations (Fig. 16). There has been poor survival of all year classes until 1982 and since then only the 1987 yearclass has been of moderate strength. Consequently, nearly all of these herring stocks are now at a point where spawning stock size may be insufficient to take maximum advantage of favourable survival conditions.

Discussion

With respect to capelin, there was some scepticism expressed about standardized abundances which show more capelin now than in the past 20 years.

2.9 Recent developments marine mammal stocks: - G. Stenson

Analysis of the 1994 harp seal (*Phoca groenlandica*) pup production surveys was completed. Using visual and photographic surveys production off the coast of Newfoundland, in the northern Gulf and in the southern Gulf of St. Lawrence were estimated to be 446,700 (SE=57,200), 57,600 (SE=13,700) and 198,600 (SE=24,200), respectively, for a total pup production in the Northwest Atlantic of 702,900 (63,600; Stenson et al. 1995a). Incorporating this estimate of pup production along with data on the catch-at-age (Sjare et al. 1995a) and reproductive rates (Sjare et al. 1995b) into a population model resulted in an estimate of total population in 1994 of approximately 4.8 million (Shelton et al. 1995a). The 95% confidence limits were estimated to be 4.1 - 5.5 million (Warren et al. 1995).

The most recent estimate of pup production of hooded seals (*Cystophora cristata*) born off the coast of Newfoundland was made in 1990 (Stenson et al. 1996). Using a combination of photographic and visual surveys, pup production at the Front was estimated to be 83,100 (SE=12,700).

The diet of harp seals, estimated by reconstructing the wet weight of prey ingested using hard parts recovered from the stomachs and intestines, shows considerable annual, geographic, and seasonal variation (Lawson and Stenson 1995, Lawson et al. 1995). Comparing the stomach contents of seals caught in nearshore areas in 1982, 1986 and 1990-1993 indicated that the major prey consumed changed from capelin in 1982 to Arctic cod in the subsequent years (Lawson and Stenson 1995). Capelin is still the most common prey of harp seals sampled from offshore areas while Arctic cod remains the major prey in nearshore areas. It is unknown if the change in nearshore diet observed in the mid 1980s is due to a change in the relative availability of capelin and Arctic cod or due to a change in preference by the seals. Quantifiable data on the distribution and abundance of Arctic cod will be necessary to address such questions. The entire diet data set is currently being reanalyzed to provide finer resolution of variation and estimates of variance in the proportion of each prey species in the diet.

In order to determine the seasonal distribution and diving behaviour of harp seals, 12 satellite linked time-depth recorders were deployed on newly moulted seals during May and June 1995. Data on their movements, dive depths and dive durations were obtained from 11 seals during their northward migration in the spring/summer and their fall return.

Preliminary analysis of the data obtained during the first 7 months of this study indicate that offshore areas of greater importance to harp seals than historically assumed. Also, individuals travelled great distances relatively quickly, with some seals moving between Newfoundland and the Arctic more than once in a year. Data from the animals released in 1995 will continue to be obtained for the coming months and the study will be repeated in 1996 with the planned release of 10 additional harp seals.

A model incorporating age-specific estimates of energy requirements, population size, seasonal distribution and diets was constructed to estimate the consumption of major fish prey by harp seals in the Northwest Atlantic (Stenson et al. 1995b). Total prey consumption was estimated to have increased from approximately 3.6 million to 6.9 million tonnes between 1981 and 1995. The proportions of prey obtained in the Arctic and Newfoundland areas were similar (46% and 40% respectively), while 14% was consumed in the Gulf. The major prey off Newfoundland was Arctic cod and capelin. Based on an average diet, harp seals consumed an estimated 1.2 million tonnes (95% C.I. 735,000 - 1.7 million) of Arctic cod, 620,000 tonnes (95% C.I. 288,000 - 1.0 million) of capelin and 88,000 tonnes (95% C.I. 46,000 - 140,000) of Atlantic cod in Newfoundland waters during 1994. In the Gulf, harp seals consumed an estimated 445,000 tonnes (95% C.I. 208,000 - 727,000) of capelin, 20,000 tonnes (95% C.I. 0 - 48,000) of Arctic cod, and 54,000 tonnes (95% C.I. 14,000 - 102,000) of Atlantic cod. Incorporating seasonal, geographic and annual variation in the diet provide additional information on trends in consumption. This model was considered preliminary since it was necessary to use assumed values from some parameters and changes in the energetic costs of activity and growth, abundance, residency period, or the proportion of energy obtained from offshore areas can affect estimates of total consumption significantly.

A number of studies are underway to modify the consumption model by improving our estimates of some of the important parameters and to quantify the uncertainty associated with the estimates. Studies are being carried out by Drs. E. Miller and J. Lawson at Memorial University to estimate the assimilation efficiency for the major prey species consumed in this area, while researchers in the Laurentian Region (M. Hammill and co-workers) are constructing a daily energy budget for harp seals. Preliminary results of the energy model suggest that the total annual requirements are similar to those used in the original consumption model, but that seasonal differences occur which may change the estimates of consumption for individual prey species.

Using Monte-Carlo methods, Shelton et al. (1995b) estimated uncertainty in the consumption estimates of Arctic cod, capelin and Atlantic cod by varying the major parameters of the model. The parameters were grouped into the 4 major components - those related to the population estimates, the energy requirements of individuals, distribution or residency in the study area, and diet. If quantitative data were available, they sampled the parameter from within the estimated variances. If only qualitative data were available, however, they assumed a range for the parameter based on their understanding of the potential variance. Generally, they found that the uncertainty associated with the population estimate resulted in very little change in the consumption estimates (COV 4%) while changes in parameters used to estimate energy requirements and residency resulted in equal amounts of variance (12%). The later were the greatest sources of uncertainty in the estimates of consumption of both capelin and Arctic cod.

For Atlantic cod, however, changes in the proportion of cod in the diet was the source of the greatest uncertainty in the estimates of consumption, resulting in a COV of almost 19%.

Although preliminary, this study shows that consumption models contain considerable uncertainty which should be accounted for when considering the results of such models and that the importance of each assumption to the overall uncertainty differ depending upon the prey species being considered. The uncertainty associated with the consumption estimates will be incorporated into the revised consumption model along with the new data on the distribution and diet of harp seals. Once this is finished, questions concerning the impact a given level of consumption may have on a prey species and the functional response between a predator and its prey will be considered.

A study of the reproductive rates of harp seals indicated that late-term pregnancy rates increased from 85.5% in the 1950s to 95.2% in the mid 1960s and then declined steadily to 69.0% in the early 1990's (Sjare et al. 1995b). The mean age of sexual maturity decreased from 5.8 years in the mid 1950s to 4.6 years in the early 1980s and then increased to 5.4 years in the early 1990s. Data on size-at-age and body condition (fatness) for harp seals collected from 1979-1994 was analysed by Chabot et al. (1995). The growth rate (in both length and mass) of female seals 1-4 years of age was lowest in the early 1990s while older seals, regardless of sex, were in poorer condition in 1992 than in the early 1980s. Given the dynamics of the seal population, these variations in reproductive parameters, growth rates and body condition are consistent with a density-dependent response. However, coinciding with the increase in seal abundance in recent years, there have been changes in the availability of prey taken by seals, particularly capelin and Arctic cod, which may have influenced the changes observed in growth, condition and fertility. Recent studies suggest that the energy content and assimilation efficiency of Arctic cod by harp seals is lower than for capelin (Lawson, pers. comm). It is unknown if these differences, along with possible differences in the energetic costs of feeding may result in lower energy available from Arctic cod than from capelin.

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3.0 Session 2 (January 24) EFFECTS OF ENVIRONMENT ON MATURATION AND THE TIMING OF SPAWNING IN THE NEWFOUNDLAND REGION

3.1 Correlations between age at maturity in American plaice and temperature (WP AEE 96/5) - J. Morgan and E. Colbourne

American plaice in the Newfoundland region are managed as three stocks, 2 + 3K, 3LNO and 3Ps. Age (A50) and size at 50% maturity have been declining in recent years in all three stocks. At the same time, there have been large changes in abundance in the three stocks. Coincident with the declines in A50, bottom temperatures on the continental shelf have experienced a general cooling trend since the 1970s. These colder than normal conditions are highly correlated with recent atmospheric and sea ice anomalies in the Northwest Atlantic. The purpose of this study was to investigate relationships between trends in temperature and abundance and changes in age at 50% maturity in the three American plaice stocks.

To investigate the spatial variability in the bottom temperature on the Newfoundland Shelf over time, the historical data set for the region was grouped into five areas. The average water depths in these areas ranged from 70 - 80 m in 3LNO, 250 - 300 m in 3K, 150 - 200 in 2J, 176 m at Station 27 and 75 - 100 m in 3Ps. These areas were selected based on the local bathymetry and on the available data, and they cover most of the NAFO Divisions in the Newfoundland Region. They also have a general correspondence to the three main stocks of American plaice in the area. To examine relationships between the variables, simple Pearson product moment correlations were conducted, sometimes incorporating time lags. For comparisons involving 2J + 3K A. plaice and oceanographic variables, data were examined separately for 2J and 3K since this provided a better match between the areas from which the biological and oceanographic data were collected. Biological data from 2J were examined relative to oceanographic data from the 2J temperature block and to the cross sectional area of the Seal Island (Hamilton Bank) CIL. For 3LNO, relationships were examined between the biological data and oceanographic data from Station 27, the 3LNO temperature block and the cross sectional area of the CIL on the Grand Bank. Biological data from 3K and from 3Ps were examined relative to the oceanographic data from the 3K and 3Ps temperature blocks.

There appeared to be a positive correlation between the temperature anomalies in a given year and A50; i.e. as temperatures became colder, A. plaice matured at an earlier age. There were significant negative correlations between A50 in 3LNO and the cross sectional area of the CIL on the Grand Bank. There were also correlations between temperature anomalies and abundance with declines in abundance mirroring declines in temperature. Finally, stock abundance and A50 were also positively correlated with fish maturing at a younger age as population declined.

A50 may be directly effected by low temperature in some way or the effect of temperature may be indirect. Abundance appears to be related to low temperature and the effect of temperature on A50 could be indirect through an effect on abundance. However, it must be remembered that all three variables have shown the same trend (downwards) over the time period examined and any correlations may be spurious.

Discussion

It was noted that fish which had already matured would not show an age-at-maturity response to an environmental signal and it was suggested that one could consider maturity changes by age group rather than 50% maturity. The suggestion was also made that other species be examined to see if they respond in a similar fashion.

3.2 Growing degree days and cod (WP AEE 96/6) - E. Colbourne J. Morgan and C. Taggart

The physiology of most fish species, as in most poikilotherms, exhibits sinusoid-like cycles in body condition and maturing that is repeated each year. The phase and amplitude of these cycles can vary interannually in relation to feeding cycles and the environmental cycle as represented by the seasonal accumulation of heat of the water column above freezing. This approach is analogous to the growing-degree-days (GDD) concept often used in agriculture and insect research and is hypothesized to apply to cod since their metabolic rates are, in part, determined by the environment. Since the phase and amplitude of the GDD cycle exhibit significant interannual variability it can be expected that physiological cycles affected by GDD will also vary. The purpose of this paper is to establish the normal GDD cycle and the normal cod maturing, spawning and spent cycles and to investigate the interannual deviations from these cycles from the available data.

The GDD cycle (as calculated here) reaches its maximum in late December while the depth integrated temperature cycle reaches its maximum in early October, a phase difference of approximately 3 months. Minimum condition is reached 2 to 3 months before the minimum in the GDD cycle and both climb together throughout the fall. The cod maturing cycle reaches a minimum at about the same time as the GDD cycle with the fish maturing for the next spawning season as the GDD cycle climbs through the fall. The spawning cycle and GDD cycle show opposite phases with peak spawning estimated to be at about day 165, just before the minimum of the GDD cycle. The spent cycle peak occurs slightly later than the minimum in the GDD cycle. Anomalies from the normal GDD cycle and normal maturing, spawning and spent cycles were compared to determine if deviations from the GDD were consistent with deviations in the reproductive cycles.

The anomalies for the spawning cycle seemed to be mainly negative during the period in the 1970s when the GDD anomalies were negative. Although more variable from 1980 on than in the previous period, there is a tendency for more positive anomalies during this period, matching the positive anomalies in the GDD cycle. When the spawning residuals for April - July are plotted against the GDD residuals there is a slight tendency for positive spawning residuals to be associated with positive GDD residuals, although this relationship is not significant. This may indicate earlier spawning (and so a higher proportion of fish in spawning condition) when the GDD is higher than normal. There was no apparent relationship between the maturing cycle anomalies and the GDD anomalies. The spent cycle residuals appear to be more negative during the period of positive GDD anomalies since the 1980s with a slight negative (although not significant) relationship between proportion spent cycle residuals and GDD cycle residuals.

A number of steps will be taken which may improve the relationships found here. First, the reproductive cycle time series presently ends at 1992, data from 1993 and 1994 will be added. Also, an attempt will be made to remove the effect of age from the data. Younger fish are making up a higher proportion of the spawning population in recent years as age at 50% maturity decreases. It is known that younger fish spawn earlier in the season than older individuals. However, the failure to find strong relationships may be a result of too low a frequency of reproductive data. Ideally, one would produce both reproductive and GDD cycles for each year and determine if the cycles shifted together. The reproductive data does not exist in sufficient detail to construct such annual cycles.

Discussion

The GDD was criticized on the grounds that it gives too much weight to the past. For example, current values of the GDD are strongly negative despite the general turnaround of temperatures over the past two years. On the other hand, it was argued that it is the past history of temperature, not just its current value, that affects fish. Perhaps a weighted temperature average taking into account the physiology of cod or other species will be the ultimate index. Some concern was also expressed that the average temperature over the full water column was used to form the GDD index. Since cod spend most of their time near the seafloor, a more depth specific temperature might be more appropriate.

It was also suggested that data other than spawning condition could be used to overcome the paucity of offshore data, and the author indicated that condition might be a better variable. It was also suggested that the authors eventually compare areas, since Myers and Hutchings found the opposite results in 3Ps.

3.3 Effect of environment on spawning and maturation of herring - G. Winters and J. Wheeler

A simple technique based on seasonal changes in gonad weights was used to describe key events in the spawning and maturation cycle of spring-spawning herring in the Northwest Atlantic. Analysis showed that there were quite large interannual variations in the timing and duration of the maturation and spawning periods. The initial maturation process, which begins in the fall, is controlled mainly by pheno-typic factors related to the size composition and condition of the adult population. The final maturation process, which begins in the spring and whose trajectory determines spawning times, is cued by January sea temperatures. The results contradict the general opinion that herring have a relatively fixed spawning season that is restricted to a brief 4-6 week period. Rather, the plasticity in spawning and maturation cycles of spring-spawning herring suggests that herring recruitment may not be a passive affair but an adaptive process in which Atlantic herring modify their reproductive activities to match expected environmental conditions during larval emergence.

(This presentation summarized the paper: Winters, G.H., and J.P. Wheeler. 1995. Environmental and phenotypic factors affecting the reproductive cycle of Atlantic herring, ICES J. mar. Sci., 52. In press)

Discussion

The question was asked that if herring are so good at adapting to changes in the seasonal environmental cycle, why do they exhibit so few good yearclasses. The answer was that although herring maximize their reproductive chances, other factors are important. The identity of these factors remains elusive, but some analyses show a correlation between recruitment and temperature and salinity.

There is no evidence that herring show an age-at-maturity response to temperature like cod, but the data have not been thoroughly analysed.

3.4 The Effects of Fish Length and Water Temperature on the Timing of Capelin (*Mallotus villosus*) Spawning - J. Carscadden, B.S. Nakashima, and K.T. Frank

Beginning in 1991, capelin (*Mallotus villosus*) spawning on beaches in Newfoundland were later than observed during most years in the 1980s and individual fish were smaller. This later spawning occurred during a period of below normal water temperatures in the Northwest Atlantic. Single variate correlation analysis indicated that spawning time was negatively related to mean monthly water temperatures February to June, 0-20 m from Station 27. Spawning time was also negatively related to mean fish length. Fish length and integrated temperatures (February to June) explained about 80% of the spawning time variation. The integrated temperatures (February-June) probably reflect most accurately the physical processes acting on maturation, since historical data indicate that maturation is most rapid during the spring. We suggest that maturation and migration are closely linked to the seasonal spring warming and zooplankton cycle.

(This presentation summarized the following paper which is now in press: The effects of fish length and water temperature on the timing of capelin (*Mallotus villosus*) spawning, CJFAS, in press.)

3.5 Cold-blooded strategies in an environment fluctuating in time and space: harvested invertebrate species in the Gulf of St. Lawrence - Gerard Y. Conan

Three water layers are encountered in the Gulf of St Lawrence. A surface layer forms in spring and reaches a depth of 40 m in the fall before disappearing in the winter. An intermediate layer reaches the surface in winter and in its lower extent, down to 100-150 meters. A deep layer is essentially only found in the Laurentian trench, below the intermediate layer and down to the bottom or approximately 500 m. The upper layer is warm and hyposaline, it may reach 20 deg C and 20 psu in summer. The intermediate layer remains cold all year round around -1 to + 1 deg C and 32 psu salinity. It is basically not affected by seasons, but slight variations in temperature and salinity are found from year to year. The deepest layer is quite stable with temperatures of about 6 deg C and high salinities of about 35 psu. The interfaces between these water masses vary from a well marked thermocline to a thick mixing layer. The depths of the interfaces also vary geographically.

Lobster and giant sea scallop are found in the top layer; when this layer disappears in winter they remain in a low metabolic state. Lobsters do not actively penetrate the intermediate water layer, explaining why no deep lobster stocks are found in the Gulf of St Lawrence. Icelandic scallop is found in the intermediate layer. Snow crab is found exclusively in the intermediate water layer, it eventually moves into shallow water when the surface layer disappears in winter, but moves down again as the upper thermocline forms in the spring. In summer, concentrations of snow crab can still be found in certain shallow water basins which retain cold intermediate water throughout the summer. Multiparous berried female snow crab concentrations are found at the limit of the surface and deep layers in waters reaching up to 3 deg C. It is thought that by remaining in warmer water these females may boost the development of their broods from the normal two-year period to a one-year period. Northern stone crab (*Lithodes maja*) is found in the deep water layer. Little is known about its life history.

In order to investigate the environmental effects on recruitment in the context of the water layer system, a stock of snow crab has been monitored over a period of 11 years inside the fjord of Bonne Bay. The fjord system is particularly convenient because a shallow sill at the entrance isolates in summer a deep pocket of intermediate water containing a little harvested snow crab stock. Commercially-harvested snow crab stocks are located at several steaming hours from harbour, are not accessible under winter pack ice, and are composed of many geographic sub-stocks which intermix. The fjord snow crab stock can be studied as a unit, close to shore and all year round; the environmental effects on the stock can be dissociated from fisheries effects.

Continuous monitoring has led to several breakthroughs in understanding how snow crab use environmental clues to best fit their poikilotherm metabolism to external seasonal variations. Once the mechanisms have been identified, it is possible to test experimentally their robustness and forecast, if not remedy, annual recruitment failures related to peculiar environmental conditions.

Egg production by individual female snow crab appeared stable from year to year and did not appear to be a major factor affecting recruitment under usual environmental conditions. The survival of the eggs in a brood, however, can vary geographically and possibly from year to year; it should be regularly monitored in commercially-harvested stocks.

The most opportune time for hatching of the eggs is met when the larvae are liberated shortly after the spring phytoplankton bloom. The signal detected is the rain of organic particles resulting from the bloom. Occurrence of blooms may locally vary in time. Over the period studied there was no evidence of failure for this mechanism which was also tested in laboratory. Therefore, the match-mismatch theory proposed by Cushing for explaining fluctuations of recruitment does not seem to apply. The author recommends it should be checked on the commercial fishery grounds whether unusual years with no well marked blooms would offset the mechanism.

During the period studied there was no marked difference in the seasonal stratification of water masses. The thermoclines, however, could be well marked or change into an important mixing layer. Snow crab appear to be very sensitive to changes in water temperature and follow the movements of the intermediate water layer. On fishing grounds which are quite flat towards the interface of the surface-intermediate, and intermediate-deep layers, annual fluctuations in the thickness of the layers would generate considerable differences in the area available for the species. This may affect area available for the adults, and also for the early benthic stages. The author recommends that fluctuations in thickness and stratification of the water masses should be monitored on the fishing grounds.

Snow crab larvae were almost always found below the surface layer, at the top of the intermediate layer, throughout the period studied. It is therefore unlikely that wind-driven circulation would affect the dispersion of the larvae. However, unusual circumstances with deep mixing after heavy storms may create disfunctions. It would be worth monitoring the evolution of the top stratification on fishing grounds during the period of pelagic larvae, from May to August. The duration of the period of sea ice cover did not appear to be related with the success of recruitment despite a wide range of variation.

The age structure of the population of snow crab *per se* appears to generate recruitment fluctuations. Dominant morphometrically-mature terminal moult males prey on molting juveniles and immatures. Juveniles prey on early benthic stages and immatures. This results in the occurrence of a short series of 2 to 4 successful age groups followed by almost complete gaps in recruitment until the successful age groups start to disappear. It is hypothesized that selective removals of stock components by a fishery may stabilize the fluctuations. The author recommends that such an experiment be conducted in an isolated fjord area.

The main factors generating oscillations in the snow crab stock appear to be relevant to the population itself. Environmental factors appear to be well buffered or taken advantage of under standard conditions, but should be monitored in case of a major modification resulting from changes in the water mass stratification. The synchrony of the recruitment fluctuations all over the Gulf of St Lawrence would indicate that from time to time a major environmental effect re-phases the population induced recruitment fluctuations.

The present work illustrates the difficulty of using global historical data on environmental conditions and attempting to relate such global observations to a commercially harvested stock. Global linear correlations are weak, sometimes present over a sequence of years, sometimes absent, sometimes reversed. If the life history of the species and the methods it has developed for matching the environmental fluctuations are not known from previous experience, it is doubtful that global correlation studies will bring any useful information, despite their very high cost. The environmental effects on a population are seldom linear, but generate feed back and oscillations; the responses are shifted in time over a scale of time varying from hours and days to years. The oscillations are not necessarily damped with time, and the survival of the stock may actually rely on a naturally oscillating system as shown by chaos modelling. A single sea survey limited in time to a few days and extending over geographically different sub-stock components is unlikely to bring the type of information which is required for understanding phenomena varying on a short range in time and space.

The author recommends a small scale, long term, year-round comprehensive monitoring specifically targeted at the recruitment fluctuations and environmental conditions of a single species, preferentially without a commercial fishery. The observations and mechanisms identified should be confirmed experimentally. Given this background and only then should global stock surveys be conducted. Global stock surveys should be designed for monitoring feed back mechanisms previously identified for single species, rather than for sampling a collection of multispecies parameters.

The fjord systems encountered on the Newfoundland coast are particularly amenable to thorough monitoring and experimental studies. They simulate quite well on a small scale conditions found off shore in the Gulf of St Lawrence, or on the Grand Banks. For instance, a surface and intermediate layer system can be found in Bonne Bay down to 200 m, while a complete three layer system can be found in Bay d'Espoir down to 600 m.

This team work was co-directed by Gerard Y. Conan and Jean Claude Therriault. Please refer to the first authors cited in the references for further information.

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Discussion

The hypothesis that stocks may exhibit chaotic behaviour was challenged, and it was pointed out that growth rates are not large enough to support chaos in simple models. The author has replied that any nonlinear system of iterative equations with built in feedback is a good candidate for generating chaos. The logistic model is a simplistic system familiar to most biologists that was used in the presentation to illustrate, after Robert May, how chaos can be generated from an apparently simple deterministic situation. The parameter is an artificial concept that can be rewritten as r = (b-m), b is an instantaneous birth rate which can be as high as 10^3 to 10^7 per year for most of the animals we work with; the behaviour of m is basically unknown for young individuals, but most likely involves lagged feed backs. It is inadequate to assume that a fixed model is right and try to force reality within this model for the purpose of analysis and forecasting, a model should be adapted to fit observed facts. Non-cyclic oscillations are a fact in all biological populations.

It was noted that large crab populations exist on the edge of the Grand Bank where there is little thermal structure in the water column during part of the year, and it was suggested that the mechanisms that hold in the Gulf of St. Lawrence may not work on the Grand Banks. The author responded that variablity in bottom temperatures is often overlooked when data are presented as a vertical section along a transect. A more revealing presentation would contour near bottom or sediment temperatures in a horizontal plane.

3.6 Annual Variation in Spawning Activity in the Lobster Population at Comfort Cove in Relation to Temperature Conditions During Spring and Early Summer (WP AEE 96/7) - G. Ennis

From 1975, tagging, biological sampling and fishery monitoring have been carried out annually along with year-round bottom (9 m) temperature monitoring since 1980 at Comfort Cove, Notre Dame Bay. Data series are examined for factors contributing to variation in spawning activity in the population. Among pre-recruit females (71-80 mm CL), percentage molting during summer was reduced only when spring temperature conditions were very low. Among recruit females (81-90 mm CL), in which percentage molting is lower and more variable than among pre-recruits, there was a positive correlation between temperature and percentage molting. In both the pre-recruits and recruits there were negative correlations between estimated percentage molting during summer and percentage ovigerous observed in fall sampling. There were no correlations, however, between temperature and percentage ovigerous for either group,

Percentage ovigerous at size is influenced by a number of factors in addition to those associated with the relative strength of adjacent cohorts moving through the population size structure. These include differences in direction and magnitude of variations in percentage molting between adjacent size groups; variability in the extent of deviations from the normal, alternate year molt/spawn sequence; and, for recruited females, variation in the exploitation rate during the spring fishing season.

The highest percentage ovigerous among recruit females was in 1991 when the percentage molting among pre-recruits was lowest. This high value is also associated with the lowest exploitation rate estimated over the period. There was a direct relation between exploitation rate and temperature at the low end of the range in temperature conditions.

Spawning activity increases in the Comfort Cove lobster population in years of exceptionally low bottom temperatures during spring and early summer. This results from a reduced level of molting activity in the population during summer and a lower exploitation rate during the spring fishery which allows an increased proportion of ripening females a chance to spawn.

Discussion

The question was asked if the apparent temperature effect observed could be due to ice cover. This possibility has not been investigated in detail, but ice cover could have had an effect in several years, especially 1991 which is an outlier in the time series. The effect of temperature on catchability is seen only in extreme years like 1991. In fact, all of the lobster are generally taken before the end of the season, sometimes as much as four weeks earlier. Much remains unknown about the effect of environment on recruitment in populations operating at such low annual egg production.

4.0 Session 3 (Jan. 25) ASSESSMENTS AND THE NEED FOR AND UTILITY OF ENVIRONMENTAL AND ECOLOGICAL DATA

4.1 Spatial and temporal distribution patterns in groundfish assessments in the Newfoundland Region - W. Warren

This presentation considered the change in spatial pattern of northern cod as determined by research vessel surveys in Divisions 2J3KL under different time scales and brings together results contained in Warren (1993, 1993, in press). Initially, the change in pattern between years was considered, followed by an examination of how the spatial pattern varied within a survey. The time period covered was from 1985 to 1992.

The first stems from a study of the viability of using fixed stations (or a combination of fixed and re-randomized stations) for the research vessel surveys. If, between years, the catch at all locations increased by the same absolute or relative amount then fixed stations would be highly efficient for estimating change. Such a pattern can be described as persistent and a measure of persistence can be constructed which reflects how far the actual situation departs from this ideal. Since in the research vessel surveys stations differ in location from year to year, trawls were regarded as being at the same location if they were within 2.5 or 4 nm of each other (one wants this distance to be as small as possible but yielding a sufficient number of "same locations"; hence the two choices). It was found that in Division 2J there was relatively strong persistence between adjacent years but the persistence weakened as the number of years between surveys increased. In contrast, in Division 3L, there was relatively strong persistence over the whole period. The results for Division 3K appeared to fall somewhere between these two situations.

The second stems from an attempt to account for the movement of fish during a survey by separating the variation into spatial and temporal components thereby generating spatial and temporal variograms. After removal of the temporal component, the spatial variograms were remarkably well defined, however, the range (i.e. the distance at which spatial correlation disappears) progressively decreased from 1985 to 1992 to the extent that in 1992 the variograms were not far removed from those of random noise. The temporal variograms showed a semi-oscillatory behaviour, apparently reflecting fish or school movement, however from 1985 to 1992, these also moved towards random-noise patterns. These trends were also strongest in Division 2J and weakest in Division 3K.

In summary, the spatial distribution of northern cod at both scales shows trends from 1985 to 1992 that are stronger in the north and weaker in the south and, in the case of the within-survey variation, appear to indicate a breakdown in "social structure", coincident with the decline in abundance. The factors causing this breakdown are unclear, however, the study does suggest that the spatio-temporal variation of distribution of research-vessel catches is, perhaps, a more sensitive measure of the health of a stock than its abundance per se.

References

Warren, W.G. 1993. More on persistence and the potential of sampling with partial replacement. ICES C.M. 1993/D:56

Warren, W.G. 1994. The potential of sampling with partial replacement for fisheries surveys. ICES J. Mar. Sci. 51:315-324.

Warren, W.G. Changes in the within-survey spatio-temporal structure of the northern cod population 1985-1992. Proceedings of the Symposium on the Biology and Ecology of Northwest Atlantic Cod. (in press)

Discussion

The suggestion was made that a fish stock that didn't move much (e.g. flatfish) should be examined and the results compared with those for cod. Other suggestions included looking at age dependence, especially since the age structure of the northern cod stock has changed. The possibility that the switch to more accurate location devices over time may contaminate the time series was also mentioned. Finally, the author asserted that little would be lost in survey precision by adopting a fixed station strategy.

4.2 The role of environmental and ecological data in assessments - R. Myers (summary provided by editor)

Summary

Several perspectives were presented in the application of environmental data in the assessment process. First, all data must be analyzed: the researcher must not be selective. Second, a baseline must be established for each stock. Data must be gathered as far back in time as possible. Third, workers must realize that the ability to predict recruitment may always be low notwithstanding the amount of environmental information available. Fourth, workers should perform experiments, if possible, in order to eliminate the confounding effects of fishing mortality on stocks. One possibility would be to establish protected zones closed to commercial activity for specified periods. Fifth, researchers should ask if there are other, non-environmental factors that may be more important to the size and health of fish stocks. These could include discarding, mesh size, or habitat degradation, to name a few.

Discussion

An objection was made to the contention that the ability to predict recruitment may always be low, as it was emphasized that our environmental/biological data base is inadequate to address the question. The concept of designing small-scale experiments to test hypotheses was advanced.

The notion of the importance of predictability was raised, and it was emphasized that we must distinguish between what has happened in the past and what we may predict in the future about the condition of various stocks.

Group Discussion

This session was devoted to an open discussion of the issue of including environmental and ecological information in the assessments carried out at the Northwest Atlantic Fisheries Centre. Of foremost interest to the meeting was what action management had taken on last year's recommendation that a project be initiated to assemble and analyze all biological and environmental time series relevant to species-species and species-environment interaction. Because no formal action had been taken, the meeting directed the Chair to submit a fortified recommendation for consideration prior to the 1996-97 budget allocations. The group retained the opinion formed last year that such a project is a necessary step in identifying stock-environment interactions and in possibly differentiating between effects due to environmental or ecological interactions and those due to over-fishing. The recommendation is given in the next section.

Beyond this, a variety of opinions were advanced on the question of using environmental and ecological information in assessments, but no common positions were agreed. It was pointed out that the meeting was not convened to discuss all environmental research, but only whether research carried out at NAFC has the potential to reveal relationships that could assist assessments. Because environmental effects are difficult to demonstrate, we must be cautious in accepting early indications that linkages between environment and stocks exist. In fact, it was argued that science is quite explicit about taking the opposite approach: if one sees something that appears to work then one must try hard to disprove it and only accept it into common practice when it does not fail.

To date, few obviously useful relationships have been discovered. One good example is the salmon thermal habitat index, although it has not been used long enough to discover where its utility breaks down. Work on the temperature dependence of the intrinsic growth rate of cod stocks is potentially a second successful example, as it has set preliminary bounds on how fast we can expect northern cod to recover. Participants were interested in knowing how the salmon index had come to be used in assessments. Although the history could not be provided at the meeting, the development of this index followed a path which will probably serve as a model for most future advances. It relied on the initiative and persistence of a single researcher (D. Reddin) in pursuing a well-founded hypothesis on the link between fish and environment, namely that salmon at sea prefer a certain temperature range (4-8 degrees C). This link was investigated over a period of a dozen years, and as better quality environmental data (sea surface temperature) became available, the relationship became clearer. Notwithstanding the success of this index, however, the salmonids group recognizes the inherent danger in drawing conclusions from a short time series (20 years), and is vigilant to the potential failure of the index.

Concerning the process of integrating environment research with assessments, it was emphasized that some sort of "half-way house" should be constructed where environmental and assessment scientists could work together to describe things that one side thinks it could produce given enough support, and that the other side would begin to use were they available.

Other viewpoints advanced included the position that research should focus on relationships based on postulated mechanisms rather than simply searching for empirical correlations, because the former are likely to degrade less severely under extrapolation. A similar argument was made that researchers should propose experiments to carry out within small, controlled areas to determine those mechanisms which would then be extrapolated to a larger scale. Further research would then be directed to see if the extrapolations are robust.

In the sense of carrying out limited area experiments, it was suggested that the meeting consider calling for the closure of certain areas to outside activity. The objection was made that the establishment of closed areas was a complex issue that lay outside the scope of the meeting. It is a topic that could be considered at future meetings, however.

RECOMMENDATIONS AND COMMENTS

Much of the discussion during the 1995 meeting centred on the apparent coincidence in timing of declines in various measures of stock status, production or condition (most notably, groundfish and salmon) or in shifts in geographic distribution (e.g. capelin and American plaice). Some of these observations involved commercially-exploited species, and other were made on species that were under relatively little fishing pressure. Consequently, the participants recommended that:

> "Management consider assigning high priority to a new project designed:
> 1) to assemble all biological and environmental data of relevance to species-species and species-environment interaction; 2) to look for commonalities in the various assembled time series; 3) to identify the time and length scales of interactions between species and environment with special regard to the timing of season cycles; and 4) to identify conceptual models capable of explaining observations. Although the discussion focussed on the period beginning in about 1988, the Committee recommends that the analysis be extended to all available historical data as the project participants find appropriate. This recommendation was originally formulated prior to the cod mortality special project, which presumably has accomplished part of the assembly and analysis, but not all and it might be possible to build on that project."

The above recommendation clearly identifies a necessary first step in addressing environment-species and species-species interactions. However, the problem of unraveling the environmental and ecological influences remains an extremely vexing one as evidenced by the general discussion in Session 3. From the variety of opinions expressed and from the general lack of progress made toward formulating any systematic procedure for resolving these influences, the Committee concludes that a broadly focused, open forum addressing environment-stock and multispecies interactions is unlikely to achieve much success. A finer scale approach seems to be required and the Committee recommends that this be attempted within the individual assessment meetings. The Committee chair should meet with the chairs of each assessment group to encourage that potential environmental/ecosystem effects be discussed, and that questions such as: "What type of environmental information would be useful in determining migration routes, condition, stock aggregation, etc.?" and "How could we use such information if we had it?" are considered.

ACKNOWLEDGEMENTS

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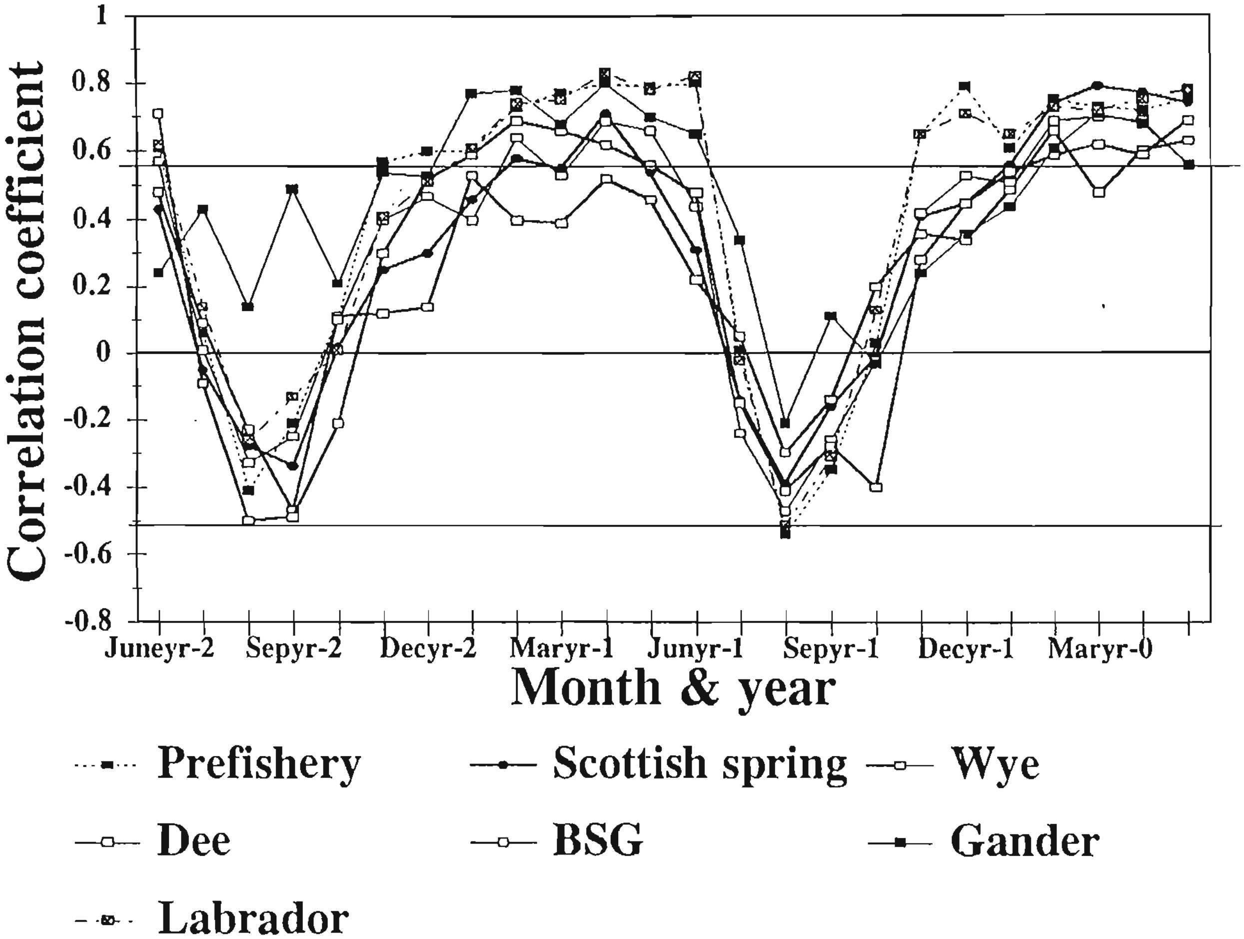


Fig. 1 Correlation summaries for abundance indices and thermal habitat. (Reddin, O'Connell, and Bourgeois)

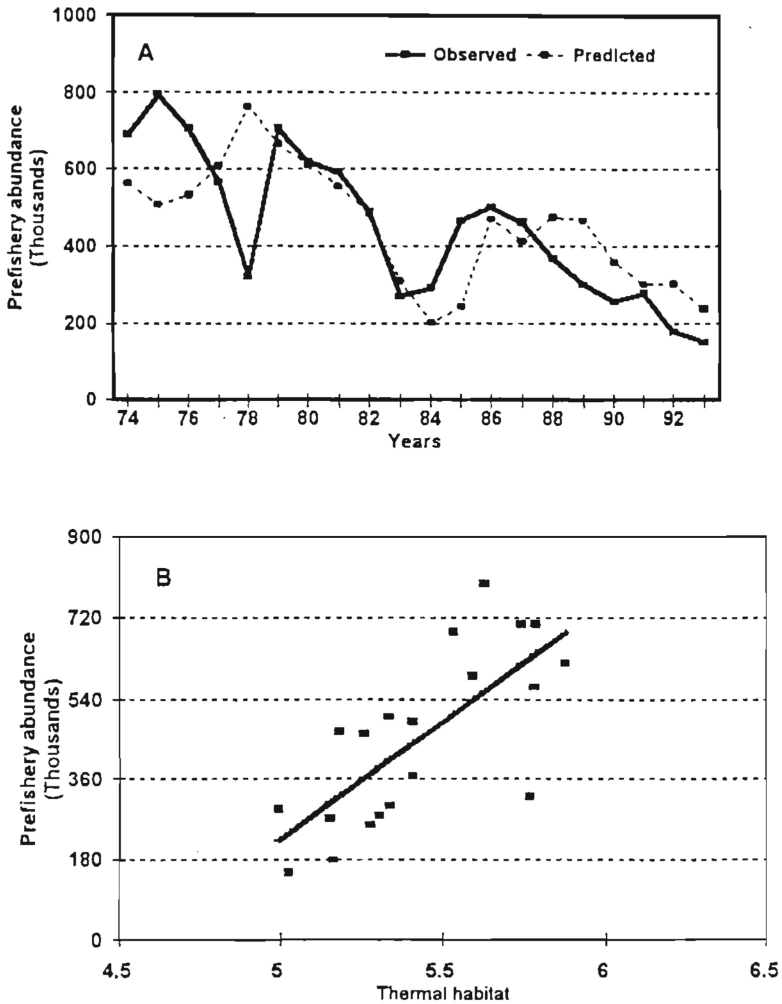


Fig. 2. Pre-fishery abundance and predicted values based on habitat area (A). Relationship of pre-fishery abundance on weighted habitat area (B). (Reddin, O'Connell, and Bourgeois)

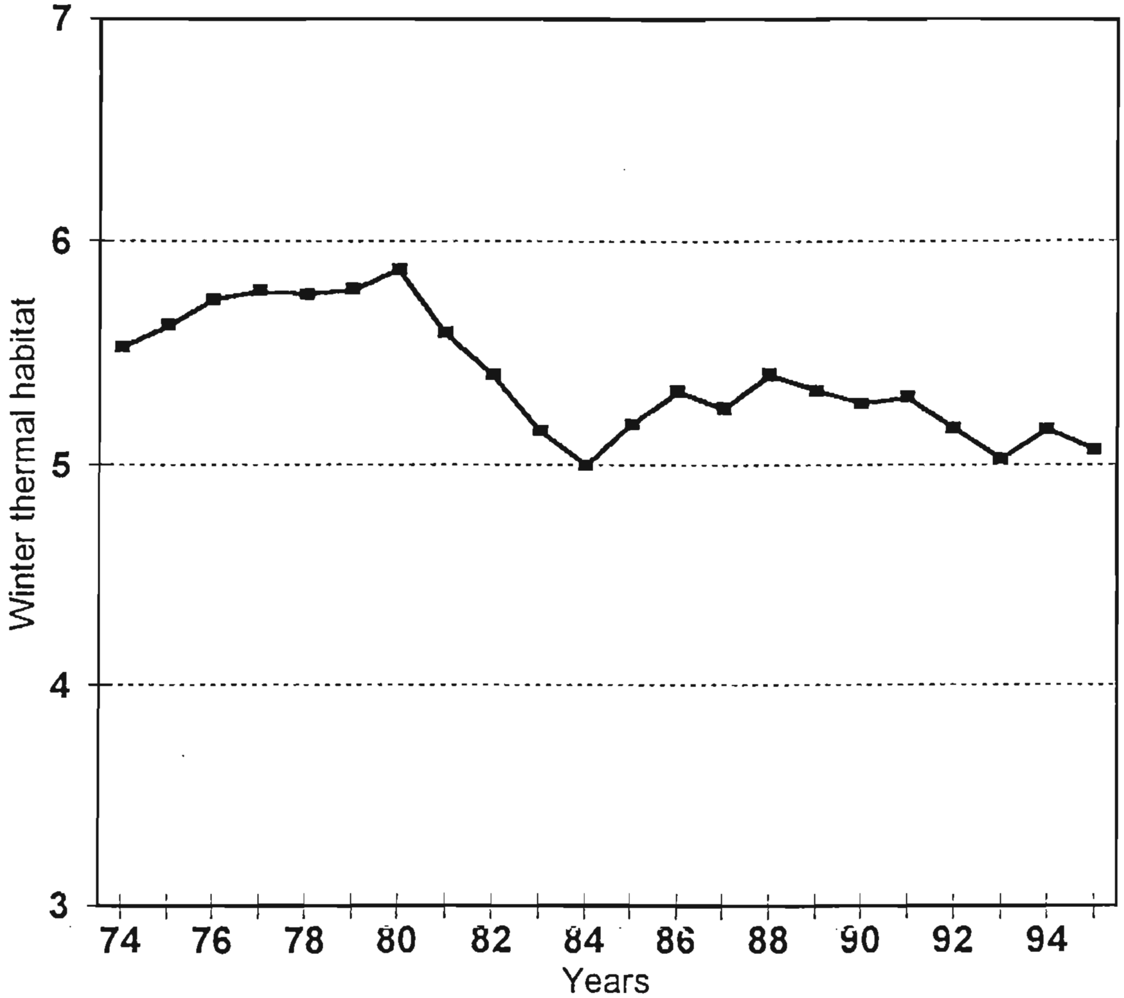


Fig. 3. Thermal habitat for winter in the Labrador Sea from 1970-95. (Reddin, O'Connell, and Bourgeois)

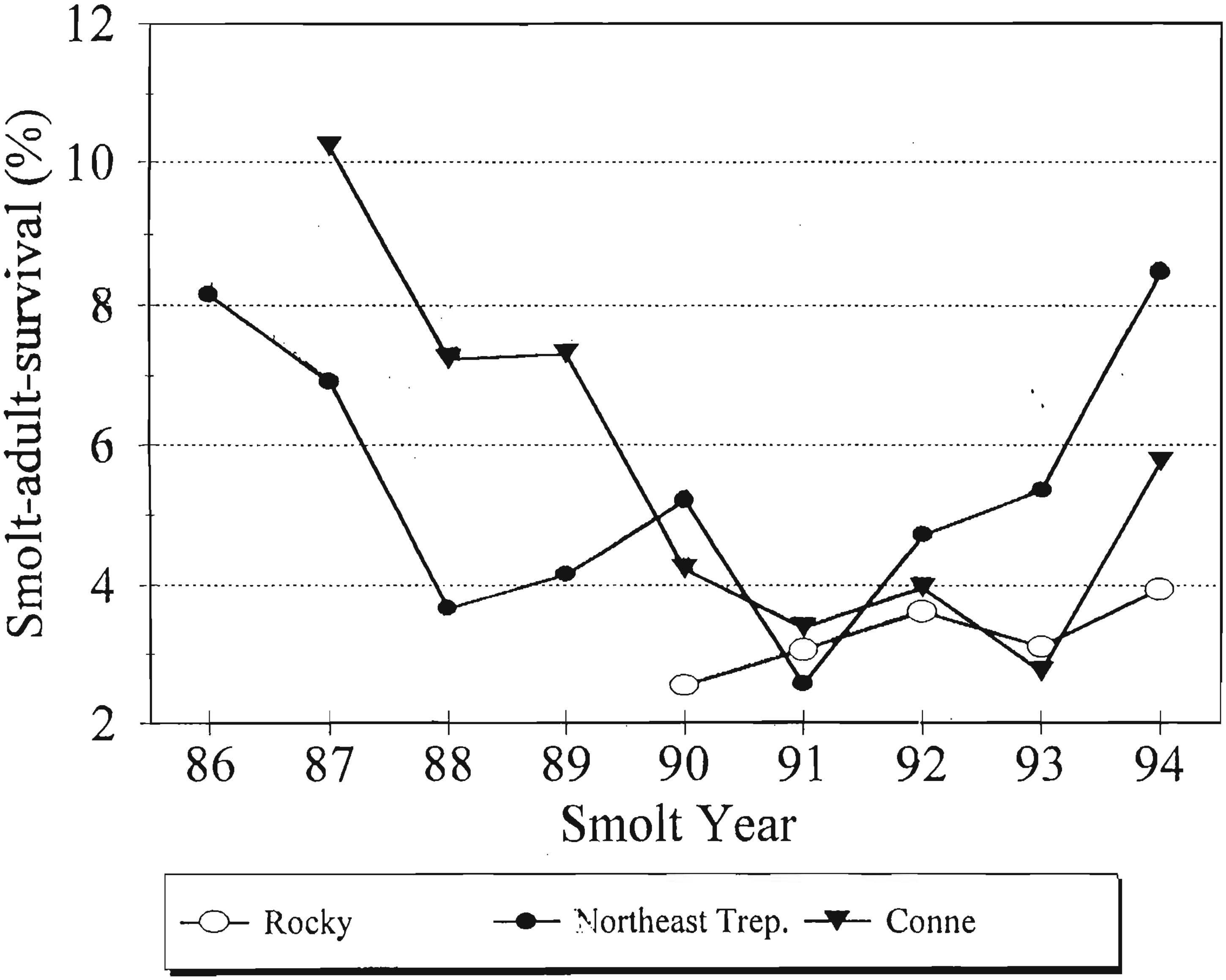


Fig. 4. Salmon survival rates versus year. (Reddin, O'Connell, and Bourgeois)

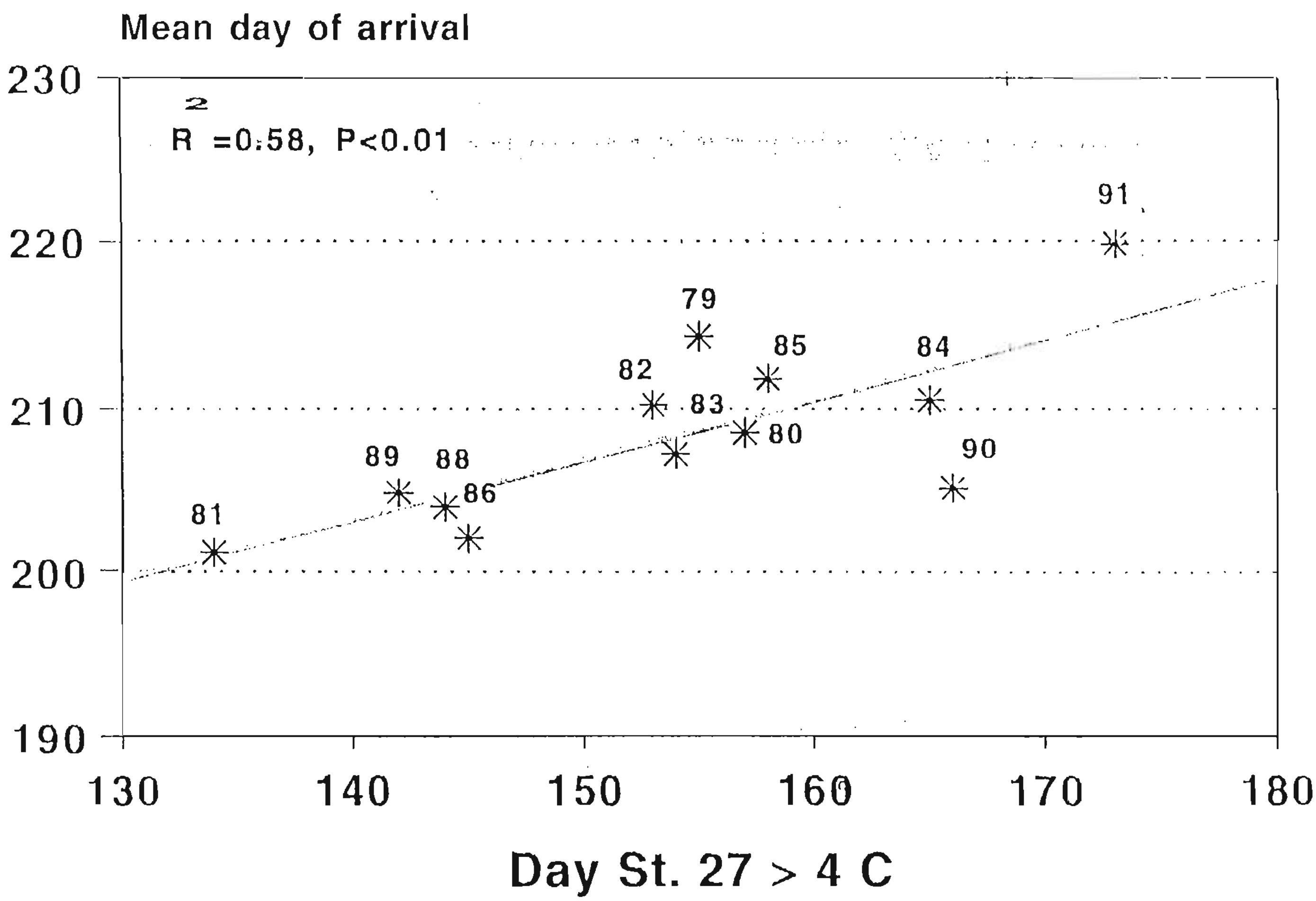


Fig. 5. Salmon arrival time at Terra Nova R. fishway versus sea surface temperature at Station 27. (Reddin, O'Connell, and Bourgeois)

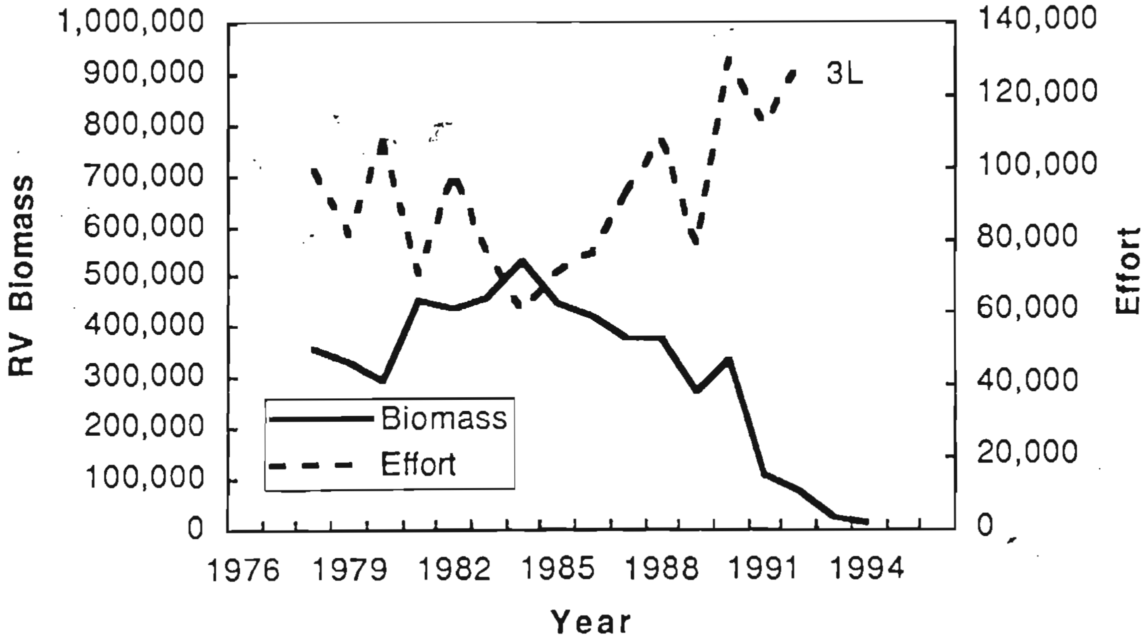


Fig. 6. Nominal offshore effort and research vessel cod, redfish and flatfish biomass for Division 3L. (Atkinson)

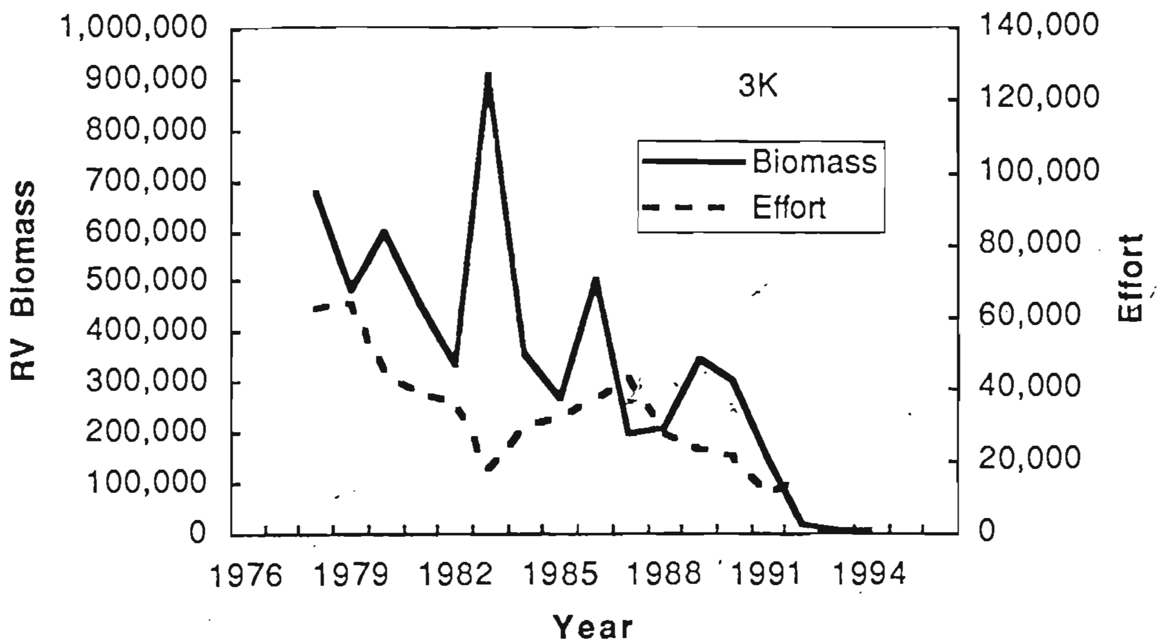


Fig. 7. Nominal offshore effort and research vessel cod, redfish and flatfish biomass for Division 3K. (Atkinson)

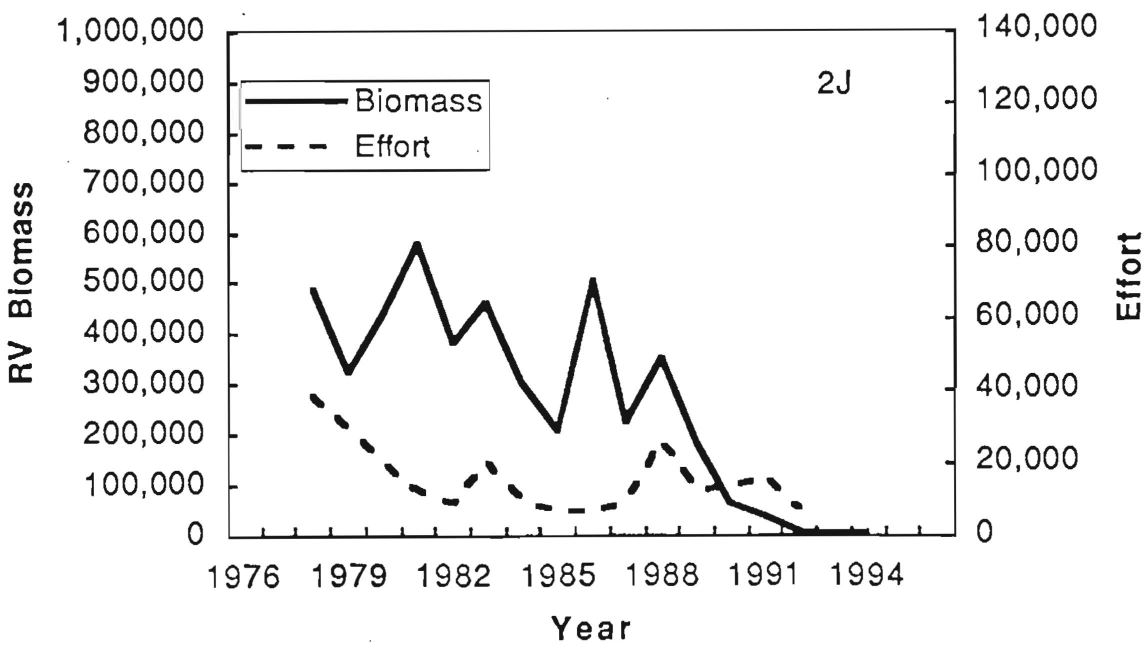


Fig. 8. Nominal offshore effort and research vessel cod, redfish and flatfish biomass for Division 2J. (Atkinson)

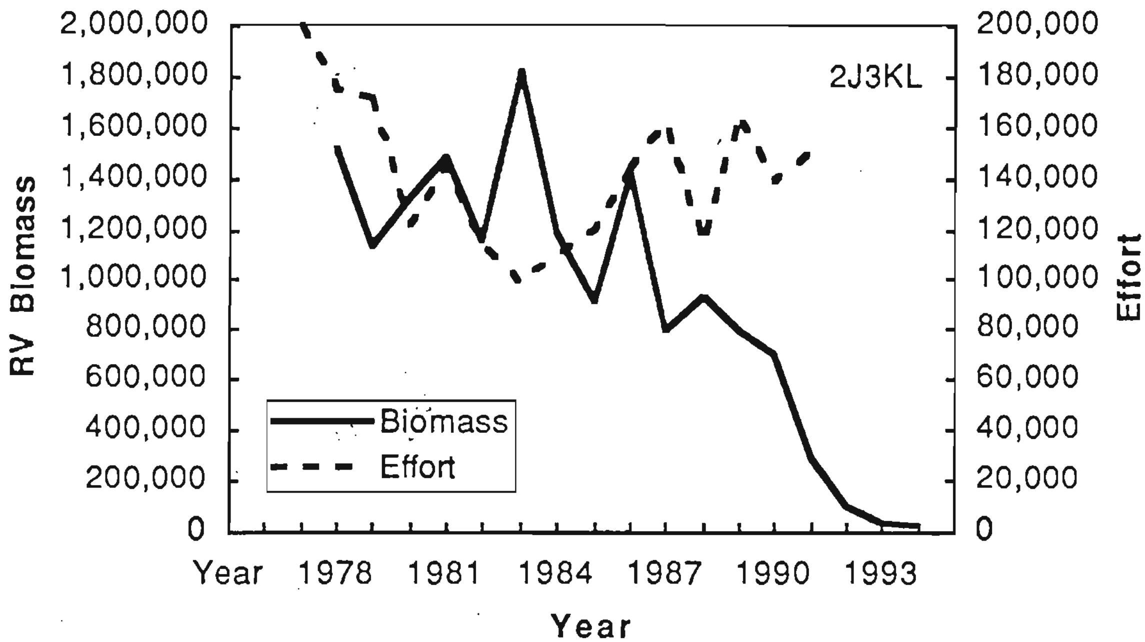


Fig. 9. Nominal offshore effort and research vessel cod, redfish and flatfish biomass combined for Divisions 2J3K3L. (Atkinson)

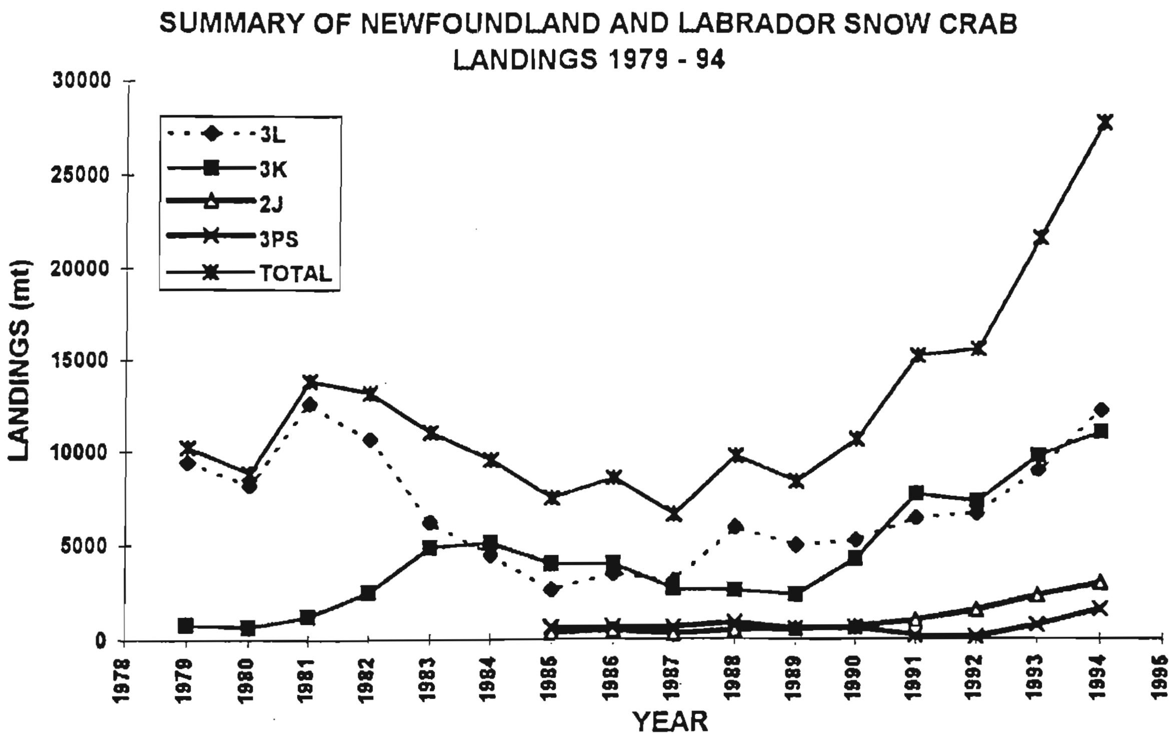


Fig. 10. Summary by NAFO division of landings for the Newfoundland and Labrador snow crab fishery. (Winters)

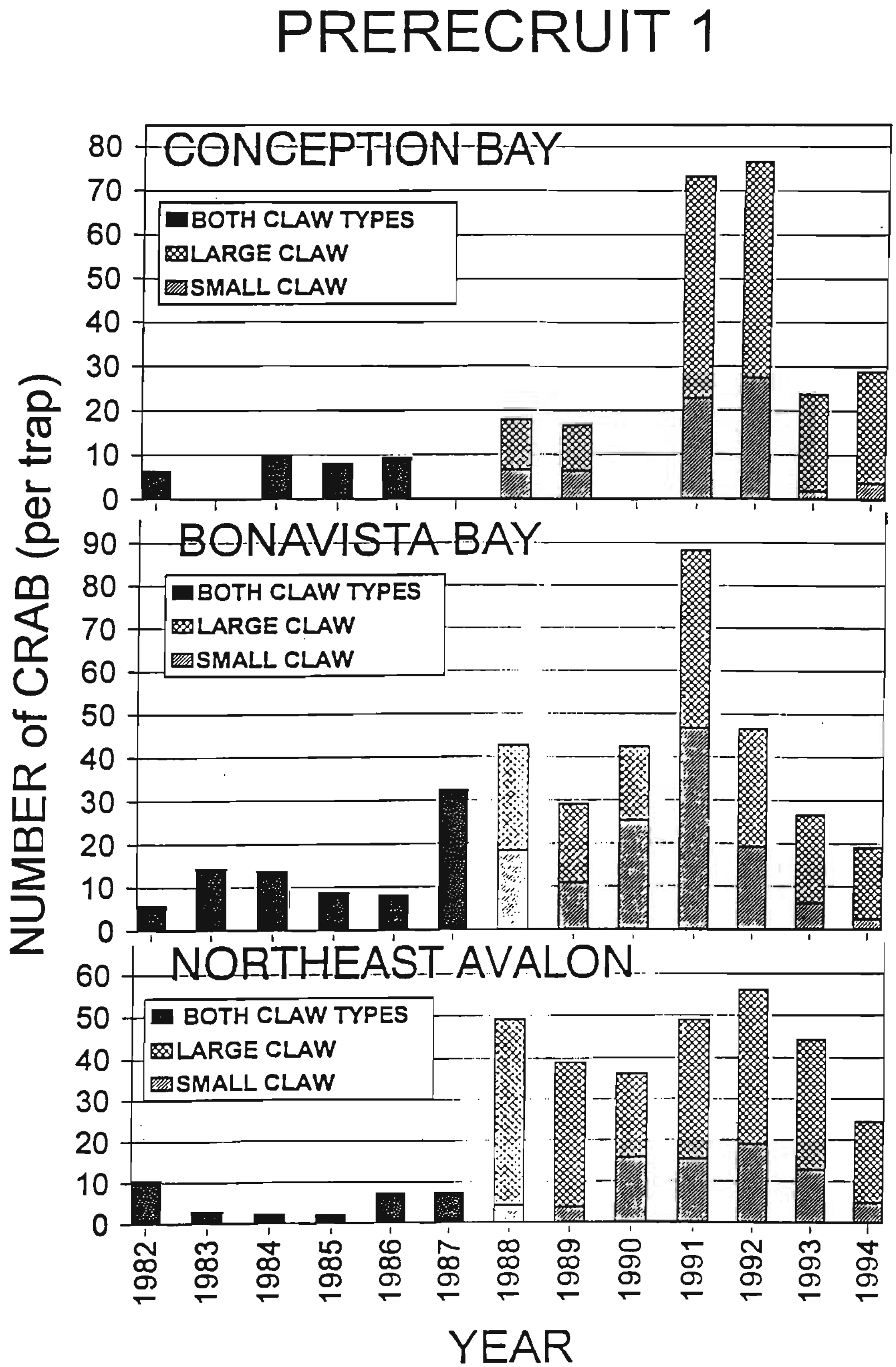


Fig. 11. Yearly trends in survey catch rate of prerecruit 1 crabs (76-94 mm carapace width) from small-meshed traps, by survey area. (Winters)

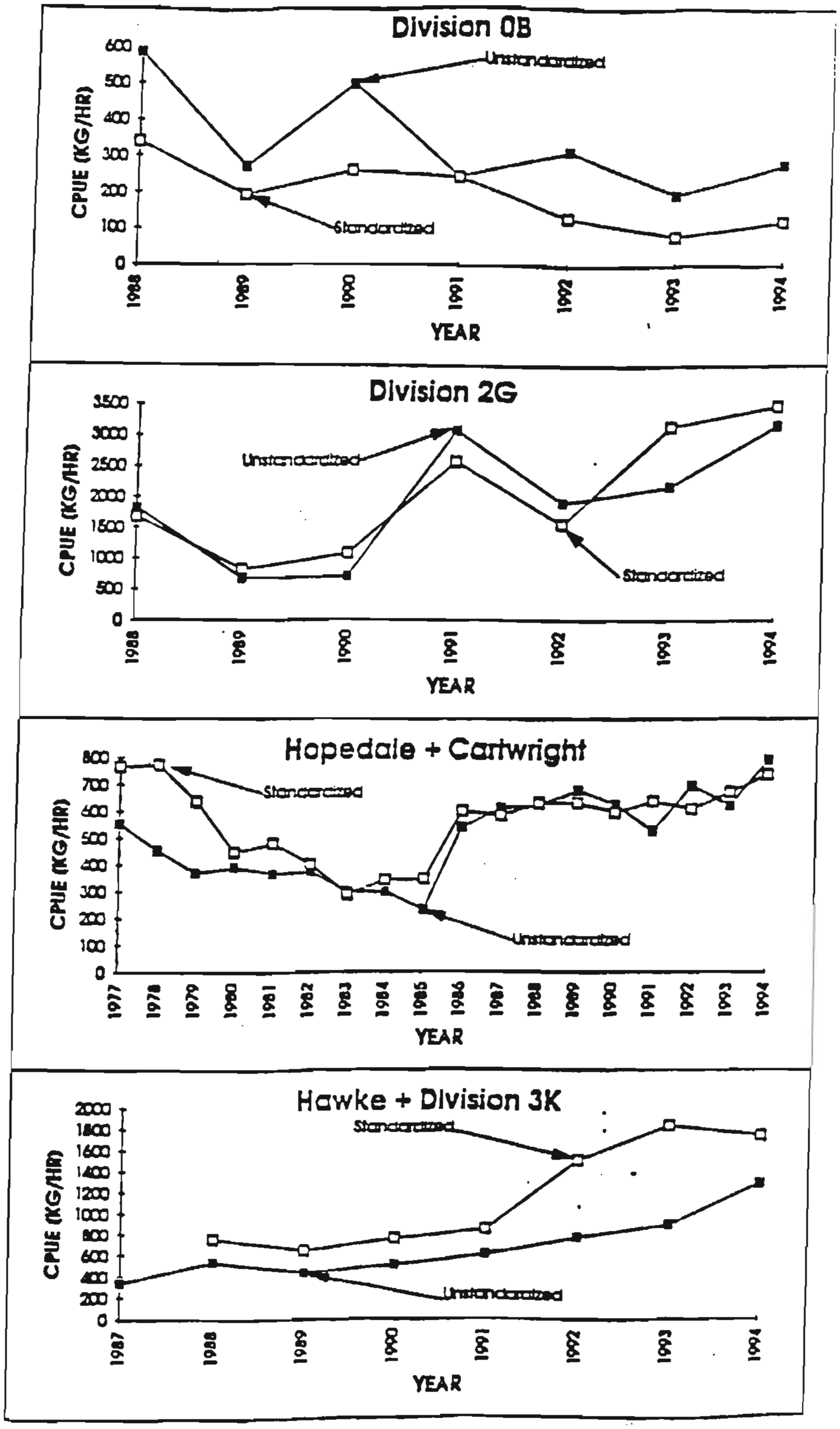


Fig. 12. Catch per unit effort in four northern shrimp management areas. (Winters)

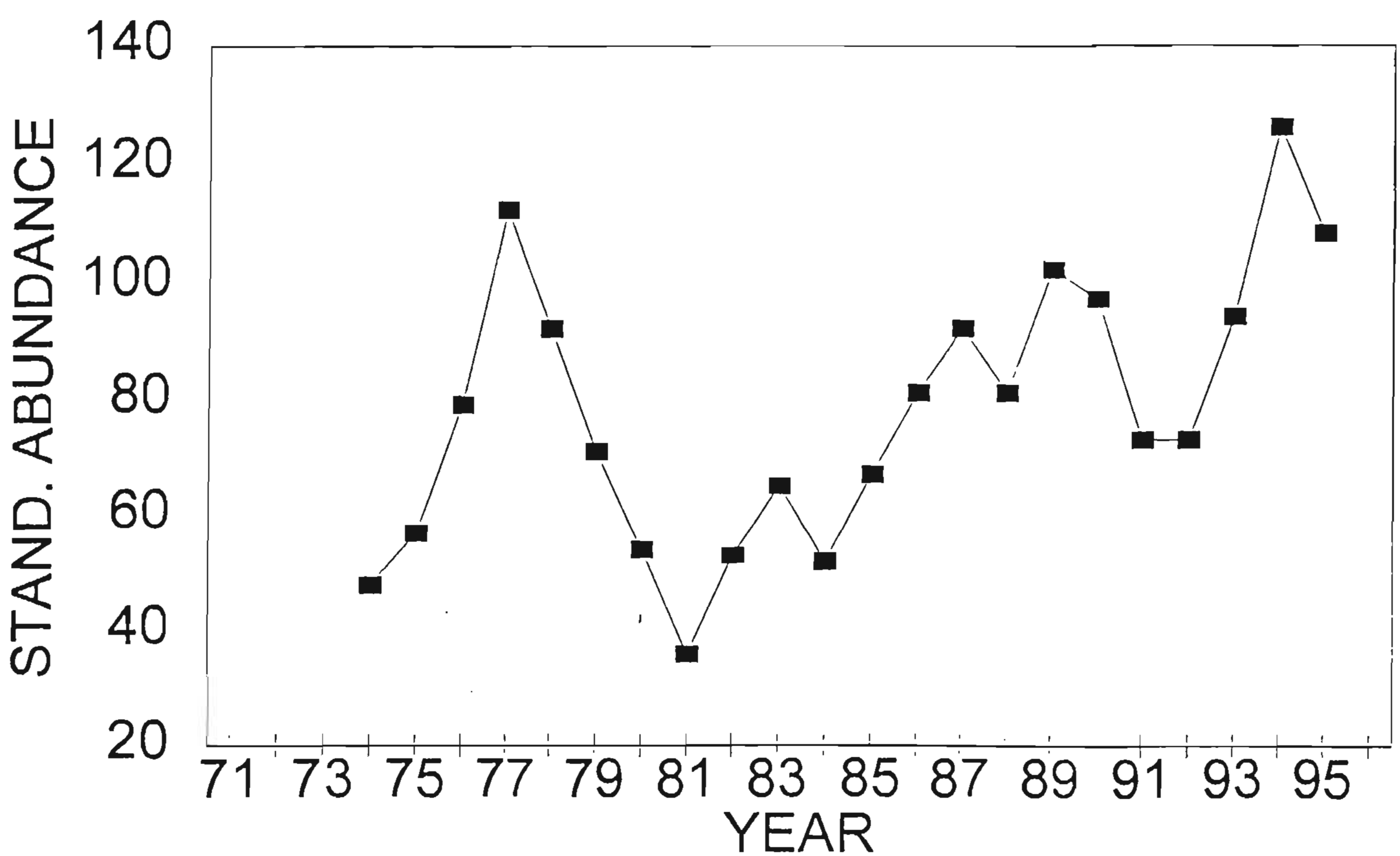


Fig. 13. Annual trends in capelin abundance for the period 1974-95. (Winters)

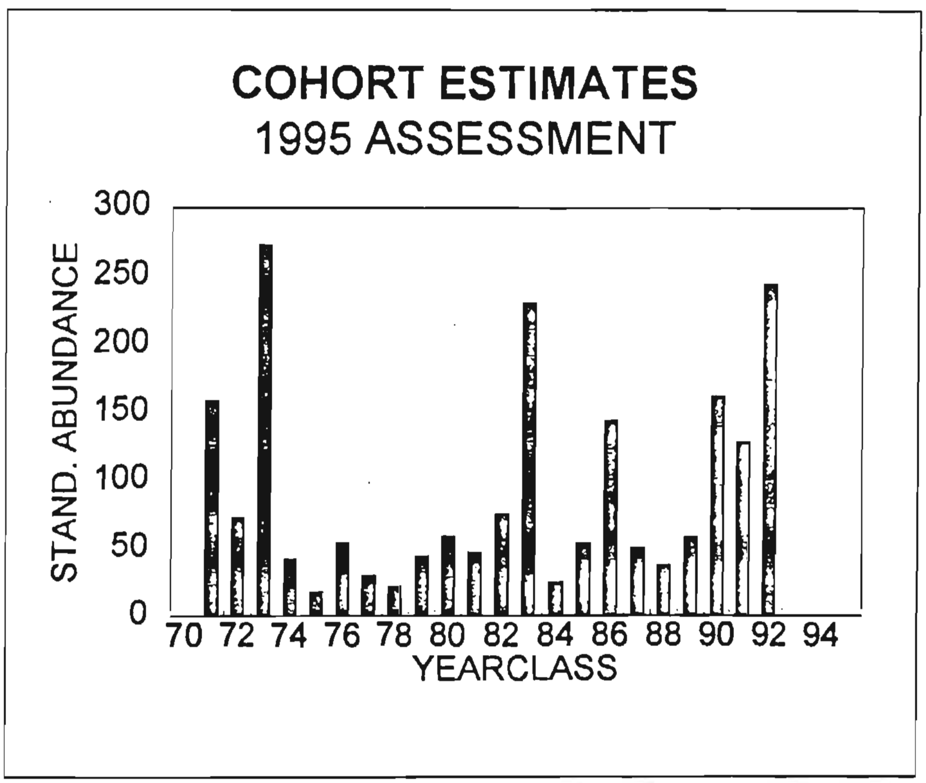


Fig. 14. Standardized estimates of year-class size of capelin. (Winters)

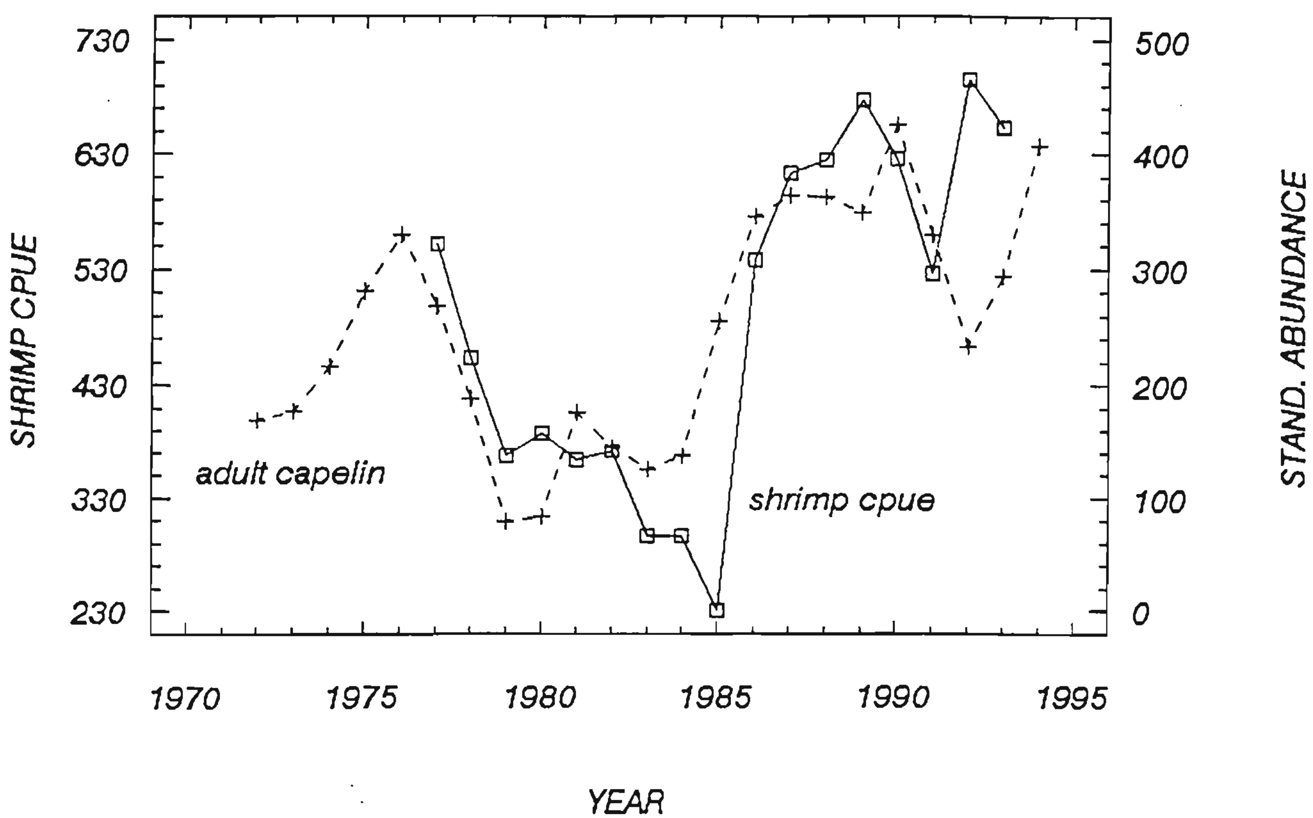
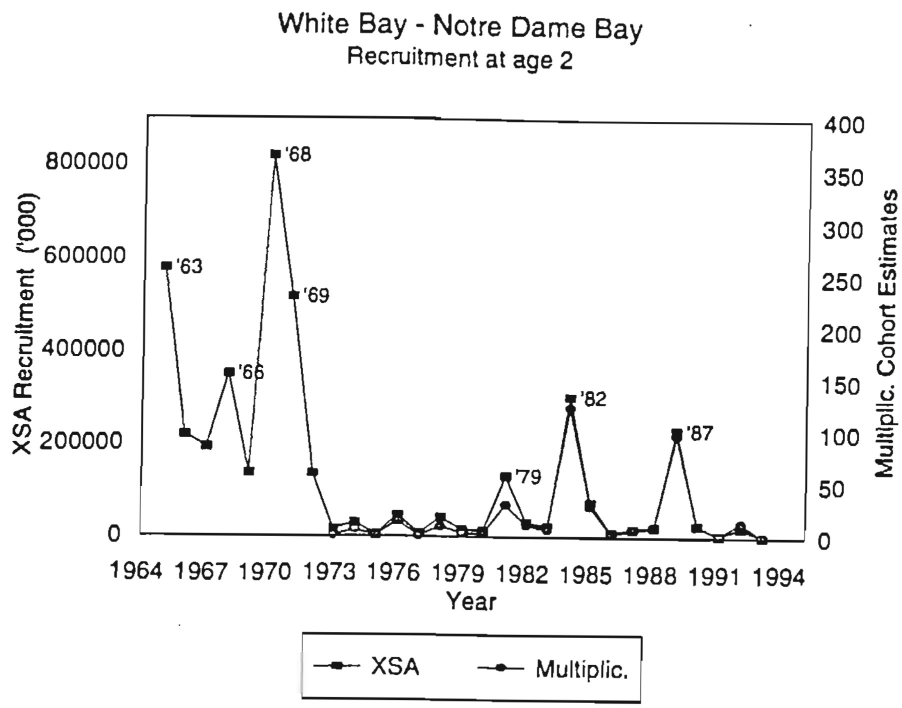


Fig. 15. Relationship between annual trends in capelin abundance and shrimp catch rates in Subarea 2-3. (Winters)



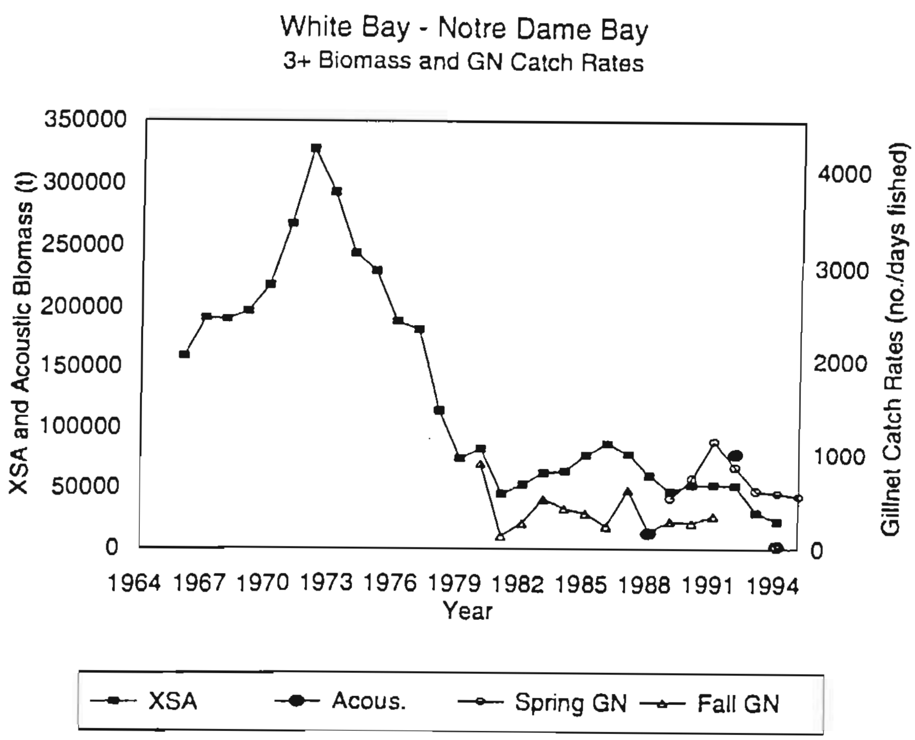


Fig. 16. Summary of abundance indices for White Bay-Notre Dame Bay:

A) Recruitment estimates from extended survivors analysis and multiplicative model;

B) Biomass estimates (ages 3+) from extended survivors analysis and acoustic surveys and research gillnet catch rates from spring and fall programs. (Winters)