Fisheries and Oceans Science
Pêches et Océans Sciences

**C S A S**
**Canadian Stock Assessment Secretariat**

**S C É S**
**Secrétariat canadien pour l'évaluation des stocks**

**Research Document 2000/143**
**Document de recherche 2000/143**

Not to be cited without permission of the authors [1]

Ne pas citer sans autorisation des auteurs [1]

# The Status of Monkfish in 4VWX5Zc

Diane Beanlands, Bob Branton and Bob Mohn

Department of Fisheries and Oceans
Bedford Institute Oceanography
1 Challenger Drive, Dartmouth, NS
B2Y 4A2

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at:
Ce document est disponible sur l'Internet à:
http://www.dfo-mpo.gc.ca/csas/

ISSN 1480-4883
Ottawa, 2000

## Abstract

Increasing catches of monkfish in the early 1990's prompted management to initiate a joint 5 year science/industry project in 1995, that provided for a 200 tonne directed fishery and a yearly industry survey. This, along with data from research vessel surveys, would help provide the basis for appropriate harvesting levels for monkfish on the Scotian Shelf and Georges Bank. Research vessel survey results indicated high abundance levels in the 1990's but low biomass. There are good indications of recruitment particularly in 4X. Length frequencies, however, indicate a loss of large fish > 60 cm during the 1990's. Estimates of total mortality have been increasing since the late 1970's. Industry survey results for mean number and weight per tow were variable although mean number per tow reached a series high in 1999. Effort levels for both the directed fishery and bycatch fishery declined over the 5 years while CPUE remained stable or increased. Over-exploitation is a concern for the few restricted areas where fishing is directed. Increased catches by the inshore scallop fleet need to be verified and size composition documented.



## Résumé

Le nombre croissant de prises de baudroie au début des années 1990 a incité les organismes de gestion à mettre sur pied un projet conjoint science/industrie de 5 ans qui assurerait une pêche sélective de 200 tonnes ainsi qu'un relevé annuel de l'industrie et qui, tout comme les données des relevés scientifiques, aiderait à déterminer les niveaux appropriés d'exploitation pour les baudroies du plateau néo-écossais et du banc Georges. Les résultats des relevés scientifiques démontrent que, contrairement à la biomasse, l'abondance était élevée dans les années 1990. Les signes de recrutement sont bons, particulièrement dans 4X. Cependant, les fréquences de longueur témoignent d'une perte de grands poissons (> 60 cm) au cours de cette décennie. Les estimations de mortalité totale sont en hausse depuis la fin des années 1970. Bien que le nombre moyen par trait ait atteint un nouveau sommet dans la série en 1999, les résultats du relevé de l'industrie quant au nombre et au poids moyens par trait variaient. Les niveaux d'effort pour les pêches sélective et accessoire étaient tous deux à la baisse pendant les cinq années du projet, tandis que les CPUE étaient inchangées ou à la hausse. La surexploitation est une source de préoccupation dans les quelques zones limitées de pêche sélective. L'augmentation des prises par la flottille de pêche côtière du pétoncle doit faire l'objet d'une vérification, et la composition de ces prises selon la taille reste à être documentée.

# Introduction

Monkfish (*Lophius americanus*) also known as goosefish and angler, is a benthic fish occurring in the Northwest Atlantic from the northern Gulf of Saint Lawrence, southward to Cape Hatteras, North Carolina (Bigelow and Schroeder 1953, Scott and Scott 1988). The stock structure of monkfish as well as the degree of mixing in both USA and Canadian waters are unknown, although large scale migrations have not been reported in either literature or by industry observation. Spawning appears to take place in Canadian waters during the summer and fall, further suggesting some degree of independence between the various components. However, the lack of any concrete evidence for stock structure is reflected in this review by recognizing 4VWX5Zc as the appropriate management unit.

Monkfish was first assessed in 1996 as a result of increasing fishing pressure by the mobile gear fleet < 65 ft in 4X. Management had responded to this increase in 1995 by restricting this fleet to a 20% bycatch of monkfish and initiated a 5 year co-operative science/ industry study that would provide science the data necessary to assess the resource and provide advise to management on appropriate harvest levels. As part of this study, a yearly survey by industry was begun, and in 1999, the final survey in the series was completed. This represents the first assessment since the completion of the 5 year exploratory fishery.

## The Fishery

Total landings of Scotian Shelf and northeastern Georges Bank monkfish increased from 96 tonnes in 1964 to a reported high of 18,000 tonnes in 1975 with the USSR the major exploiter of the resource (Table 1, Fig. 1). However, USSR landings by species during that period are not considered to be reliable. Landings dropped to the 300 tonne range in 1978 likely due to the extension of jurisdiction to the Canadian 200 mile limit. Since then, monkfish have been almost exclusively a bycatch fishery of groundfish and scalloping ventures on the Scotian Shelf and Georges Bank. Between 1978 and 1985 the monkfish resource was not exploited in any significant way and in terms of reported landings, some uncertainty exists as to what may actually have been caught and discarded or used for meal. The highest landings were subsequently reported by the scallop fleet fishing in 4VW (Western Bank) during 1986 and 1987 and Georges Bank (5Zc) between 1989 and 1991 (Table 2, Fig. 2). Although landings in both these areas have since declined, 4X showed an increasing trend during the early 1990s, mostly due to increased pressure by the mobile gear fleet < 65 ft. Prior to this time, monkfish in 4X were caught equally by this fleet as well as the fixed gear fleet. (Beanlands, Annand 1996) In 4VW, large catches (i.e. greater than 100 tonnes) have been sporadically taken by the offshore scallop fleet and the mobile gear fleet > 65 ft throughout the 1990s.

Since 1993 the < 65 ft mobile gear fleet have been directing for monkfish in 4X due to increased markets and higher prices. As a result of this additional effort, 4X landings increased from almost 350 tonnes in 1991, to over 1100 tonnes in 1994. In 1995, to control possible over-exploitation, this fleet was restricted to a 20% bycatch of monkfish during their regular groundfishing trips on 4X and 10% while fishing on Georges Bank. However, through provisions in their Conservation Harvesting Plan (CHP), they were permitted to direct for this bycatch. Five vessels were also given 200 tonnes of quota as part of the co-operative science/industry study and are reflected in the landings in Table 2. As a result of these management measures, monkfish landings in 4X dropped to 930 tonnes in 1995 but were variable over the next 5 years reflecting market and price fluctuations. Management restrictions however, have not been extended to the scallop fleet, where landings have risen to a high of 322 tonnes in 1997. These landings have traditionally resulted as bycatch of the offshore scallop fleet on Georges Bank, Brown's and German Bank areas (Fig. 3a), but has now shifted to the inshore scallop fleet operating in 4X, principally in the Bay of Fundy. (Fig. 3b) Landings by gear and area for 1990 to first quarter of 2000 are presented in Table 3, and Figure 4.

Market categories have expanded to utilize more of the fish and currently include round fish, tails, livers, cheeks and belly flaps. In general the <65 ft mobile gear fleet utilizes all of these market categories while the scallop fleet generally makes use of only the tail portion. In recent years, monkfish landings appear to be very dependent on market conditions. For the 5 vessels in the exploratory fishery, market value played an important part in whether the 200 tonne allocation was taken. In fact, it was never reached until the final year of the fishery when price and availability of fish were both high. Landings of the directed fishery also indicate that fall/winter markets are usually higher while for the fleet as a whole, monkfish landings are spread throughout the year with some concentration in the spring and fall months.

## Resource Status

Estimates of abundance and biomass from the Scotian Shelf summer research vessel (RV) survey (1970-2000) indicate a declining trend from the mid 1970s to the late 1980s. (Fig. 5a) However, abundance has been increasing since 1989 with a series high in 1995. Biomass has shown some increase but to a lesser degree than abundance and remains at a low level at approximately 3000 tonnes. Indices of abundance and biomass by area and survey type follow similar trends in both 4VW and 4X although the 1998 peak in abundance in 4VW was not seen to the same extent in the 4X series. (Fig. 6) The 4VW Spring RV survey estimates are lower overall but also show a declining trend from 1980 to 1991 with a subsequent increase to 1994 for both indices.

The Scotian Shelf summer RV survey (1970-1996) stratified mean numbers per tow in 4X and 4VW (Table 4, Fig. 7) show similar trends. Although variable from year to year, they indicate a period of relatively high abundance through the mid 1970s, followed by a declining trend through the 1980s and then increasing from 1989 to a series high in 1995. Numbers have been variable since but at a high level with the 2000 value the second highest in the 4X series. Mean weight per tow exhibited a similar but less pronounced trend, and without a series high in 1995. This limited increase in biomass may be an indication of improved recruitment (Fig. 8).

A length at 50 % maturity of 46 cm (Almeida et al, 1995) was used to separate the survey numbers from 4VWX into mature and immature sizes. The results closely follow the abundance trend and provide further evidence of good recruitment, particularly in 4X. (Fig. 9)

A summer RV survey series is not available for Georges Bank (5Zc), however, February RV survey results from 1986 to 2000 for this area were examined. Abundance and biomass estimates are variable but reveal a steep decline from 1986 to 1993 with a subsequent increasing trend to 1999. (Fig.5b) Stratified mean number per tow reached a series low in 1993, and although variable since, show an overall increasing trend. (Fig. 6) Mean weight per tow declined to a series low in 1993 and 1994 and then increased to 1999 before dropping again in 2000. (Fig.8)

Distribution data from the RV summer survey series show monkfish distributed across the Scotian Shelf particularly along the edges of the banks. Historically (1970-1989), they appear more abundant on the central Scotian Shelf than on either the western or eastern portions, although some monkfish are caught along the edge of the Laurentian Channel and in the Bay of Fundy and it’s approaches. (Fig. 10) Recent years (1992-2000) show no significant changes in distribution (Fig. 11), although fewer monkfish appear to be present along the edge of the Laurentian Channel. The February RV survey of Georges Bank catches very few monkfish, but when present, appear to be distributed primarily along the edge. (Fig. 12)

The proportion of annual RV survey sets where a species occurs in a non-zero set is a measure of area occupied. While variable to 1986, the index dropped from 1986 to 1990 in both 4VW and 4X. Since then, monkfish has been increasingly occurring in survey sets and is currently higher in 4X than pre 1986 levels. (Fig. 13a) The increase is much less pronounced in 4VW. The density (or resource concentration) of a species in an area, can be determined by taking the mean of the logged numbers of the non-zero sets. Although both areas show similar patterns in density, 4VW increased to a series high in 1998 while the 4X peak in 1998 was closer to mid 1970 levels. (Fig. 13b) This appears consistent with the large numbers of small fish appearing in recent years.

While survey results show monkfish distribution across the shelf, our lack of understanding of the stock structure of this species raises some concerns. Currently, the fishing industry is targeting monkfish in the 4X area and in only a couple of “holes”. It would be very easy to over exploit this stock if indeed, it was concentrated in several small areas. As well, the possibility exists that the high exploitation of monkfish on the USA side of Georges Bank may impact the sustainability of the Canadian resource. Though there is no evidence to suggest a north to south migration pattern, the National Marine Fisheries Service (NMFS) spring and autumn RV survey indices for monkfish in the Gulf of Maine are similar to those on the Scotian Shelf. (NEFC, 2000) Biomass estimates decreased from the early to mid 1970s and remain at a low level while abundance estimates show an increase since the early 1990s with series highs in 1994 in the autumn and 1995 in the spring.

**Survey Length Frequencies**

The long-term summer RV length frequency distribution of monkfish in both 4X and 4VW shows a wide range of sizes (7-120 cm) with modes at 60 to 80 cm during the 1970s and

1980s. ( Fig.14) However, recent trends (1990-2000) indicate a distinct shift to small fish. Fish larger than 60 cm that were so prominent in the 1970s, particularly in 4VW, have virtually disappeared, while there has been a notable increase in the number of monkfish <40 cm particularly in the mid-20 cm range. The declining trend in size range was not observed in the Georges Bank survey but a recent influx of small fish can be seen.

Recent length frequencies from 1995 to 2000 are shown for 4X and 4VW (Fig. 15). Large numbers of small monkfish are evident in both areas in the 1995 survey. The 4VW peak in that year does not appear to be sustained while the continued appearance of these fish in 4X through to 1998 would support incoming recruitment. A pulse of small fish was again seen in 4X in 1999. These small monkfish have been consistently found in adjacent inshore stratum (Fig. 16) specifically strata 60 in 4VW and strata 70 in 4X. (Figs. 17, 18) Length frequencies from the Georges Bank survey over the same time period show small fish in 1996 and 1999 but they do not appear to be sustained. (Fig. 19)

**Joint Industry /DFO Survey**

Distribution

A joint science/industry survey of 4X was conducted each October as part of the five year exploratory fishery. Five trawlers <65 ft conducted a fixed station survey, designed to cover all of 4X, including inshore areas that are unable to be surveyed by larger science vessels. The area was divided into boxes and one set in each box, chosen by the captains in the first year, was redone in each of the 5 years from 1995 to 1999. (Fig. 20) Each set was to complete a 1 nautical mile tow with 130 mm square mesh flounder gear. Due to weather problems, gear conflicts and untrawlable bottom, all sets could not be done in all years. Sampling during the survey was conducted by observers, with length frequencies and catch estimates recorded for all species.

Results on the Scotian Shelf, showed a similar distribution pattern to the RV surveys, with monkfish found across the shelf, generally along the edges of the banks. Concentrations of small fish (10 to 30 cm) were found in the same inshore area of 4X as the RV survey i.e. inshore of LaHave Basin. (Fig. 21) In 1996, a separate fixed station survey of Georges Bank was initiated, and carried out for the next 4 years in October, immediately following the 4X survey. Monkfish here, were found distributed across the bank with concentrations along the northern edge. (Fig. 20)

Abundance

Mean number and weight per tow from all observed sets were used as a relative index of abundance. (Fig. 22a, b) Results show that both mean number and mean weight in 4X increased from the 1995 value and subsequently dropped to 1998. The Georges Bank survey showed the same decreasing trend in mean numbers but mean weight seems to have stabilized from 1997 onward. In 1999, both surveys showed an increase in mean number per tow. In comparison, the RV survey numbers for the same time period show a drop from 1995 to 1997 and have been variable but increasing since. Where industry survey sets were missing in a year, a generalized linear model using fixed effects was used to predict the value. This was compared with an index of only stations which were completed every year and with the index of all observed stations (as seen in 22a,b). (Fig. 22c) The trend was similar in all cases. The Georges survey saw nearly all sets completed in all years so a predicted value was not calculated.

Length Frequencies

Size composition from the industry survey in 4X shows a mode of 35 to 40 cm in 1995. This mode shifts to 52 cm until 1998 when a second mode at 26 cm was evident. In 1999, only one mode at 26 cm was observed. (Fig. 23a) When the length frequency for the industry survey is compared with that of the bycatch fishery which uses the same 130 mm square mesh, the industry survey consistently catches a larger proportion of fish less than 40 cm. This is likely due to the fact that the abundance of small fish in the industry survey appears to be coming from an area inshore of LaHave Basin (Fig. 21) while commercial fishery samples are generally from the 4Xp, and 4Xq areas. This may also be influenced by the fact that small fish are often cut at sea for tails and, therefore, are not available for land based sampling. It is clear however that the 130 mm mesh has the potential for taking large numbers of small monkfish.

The Georges Bank survey length frequencies are more variable due to the limited numbers of fish caught. The modes were similar to those in 4X at roughly 52 cm, however, fewer fish less than 40 cm were seen from 1995 to 1998. (Fig. 23b)

## Commercial Fishery

Catch Rates

A catch per unit of effort (CPUE) series was estimated for both the directed (exploratory) and commercial (bycatch) fisheries. A requirement of the exploratory fishery was that all the survey trips and one third of the directed trips must be observed by the International Observer Program (IOP), while the captains were required to fill out the same observer datasheets for the remaining directed trips. The directed CPUE was then estimated from the IOP database where all information from the exploratory fishery is being stored.

It is important to note that the 4X quota of 200 tonnes was primarily directed at an area in Crowell Basin known as the "monkfish hole". (Fig. 24) Some directed trips were made along the northern edge of Georges Bank as well as outside of Brown's Bank from 1996 to 1998. However, it is the "monkfish hole" that was the main target of the directed fishery and catch rates reflect this. (Fig. 26a) A decline in prices beginning in 1996 kept the directed fishery from taking the whole quota until 1999 when prices increased. (Fig. 25) This is reflected in the effort series which shows a decline to 1998 and a subsequent increase to 1999. (Fig. 26b) In contrast, the catch rate (CPUE) continued to increase gradually over the 5 years of the experimental fishery with a sharp increase in 1999. This increase is likely due to incoming recruitment from the early 1990s. The allocation for Georges Bank was never taken due to low prices and large bycatches of flatfish.

The commercial catch rate, based on mobile gear, tonnage class 1-3, was estimated from zonal interchange file format (ZIFF) data. (Fig. 26c) Catch and effort from the directed fishery were subtracted from the ZIFF estimates to ensure only bycatch trips were being accounted for. Management measures introduced in 1995 resulted in a decline in effort from the 1994 value. Market and price limitations resulted in a further reduction to 1998. The CPUE remained relatively stable during the same time period. However, this catch rate is confounded by a management plan that allows this fleet to direct for their bycatch. For a more accurate estimate, further research to extract the information on a set by set basis is required. It is also important to note that the majority of monkfish are caught as bycatch of vessels fishing other groundfish and scallops and have no associated effort.

Distribution

Commercial (bycatch) catch distributions for the mobile gear fleet < 65 ft from 1995 to 2000 indicate that monkfish were generally caught west of LaHave Bank to the mouth of the Bay of Fundy with high concentrations in the Crowell Basin area. Small amounts were also caught on Georges Bank. (Fig. 27) As previously discussed, catches by the offshore scallop fleet concentrating in the Georges Bank area have diminished substantially since 1995 while catches from the inshore scallop fleet in the Bay of Fundy area have been increasing to a high in 1997 of 309 tonnes. Catches have dropped slightly since. These fleets are not observed and landings may not be representative of the actual catch.

Bycatch

Bycatch in the directed commercial fishery was examined and found to be generally well below 10%. Cod was the most abundant bycatch species in both the observed and unobserved trips (Table 5). This would indicate that the 203 mm square mesh is successful in allowing a directed monkfish fishery with little concern about excessive bycatch in this area. However, as the directed fleet fished almost entirely in the Crowell Basin area, it is difficult to determine if the less than 10% bycatch levels could be sustained in other areas.

Commercial Length Frequencies

Requirements for observer coverage on the survey and directed fishing trips made it possible to compare the size compositions from directed fisheries using the IOP database with the commercial (bycatch) fishery using the National Sampling Program (NSP).

Length frequencies from the commercial bycatch fishery and the directed monkfish fishery were quite comparable despite the difference in mesh size (130 mm square Vs 203 mm square). A slight decrease in modal length from 58 cm to 52 cm was detected for both fisheries between 1995 and 1996 but subsequently remained stable with a slight increase in 1999. (Fig. 28)

The bycatch fishery length composition is more variable than the directed fishery which tends to be unimodal. The higher variability of the bycatch sample may be due to the vessels fishing in different unit areas (4Xq, 4Xo and 4Xp) while the directed fishery was prosecuted almost entirely within a small area in 4Xp. Also, the directed fishery samples (IOP) were taken generally during the fall and winter months while the bycatch samples (NSP) were distributed throughout the year.

Because the scallop fleet lands mostly tails, and a conversion rate for tail length to total length is yet to be established, length information is minimal from this fleet. Irregular cutting techniques at sea has made the development of a conversion rate difficult and further work is needed. Observer deployment to this fleet to measure the bycatch would provide the most accurate information.

**Other Surveys**

A number of industry and sentinel fisheries are currently being carried out on the Scotian Shelf and the incidental bycatch of monkfish were explored for a majority of them. Catch rates from the 4VW Sentinel Survey, 4X ITQ Survey, and the 4VW Skate survey are presented in Fig. 29. No particular trend is apparent although mean weight in the sentinel fishery appears to have increased from 1996 to 1999. The most recent year for that survey is not available. An examination of the IOP database, found monkfish to be a common bycatch of the silver hake fishery. When these catch rates were calculated and compared to the RV summer survey mean weight per tow, a similar decreasing trend was apparent, particularly in the 4VW area from the early 1980s to 1993. (Fig. 30) Information from 1994 onward is not considered comparable as an escapement grate for all silver hake trawling gear was introduced in that year.

**Biological Studies**

As part of the monkfish project, industry was required to hire a technician to assist with biological sampling on monkfish, with the goal to describe basic biological parameters i.e. age, growth and reproduction for this developing fishery on the Scotian Shelf.

To date, nearly 2000 monkfish have been collected and sampled in detail for total length, total weight, and tail length and weight in order to determine size relationships of whole goosefish to landed tails. Field studies must be conducted however, to establish whether landmarks used for measurement in the lab, can be seen often enough in the field to be useful for developing appropriate conversion rates. To determine spawning seasonality and proportion mature at length, sex and maturity stages were determined by macroscopic examination of the gonads according to criteria established by Armstrong (1987). As well, approximately 200 gonads were prepared for histological examination.

Preliminary results indicate that monkfish spawn in the late summer and fall. Observations have been made of numerous veils seen in November by the 4VSW sentinel fishery. Females appear to mature between 30 and 40 cm which is younger than most literature suggests but until the histological examination can be completed, this estimation cannot be confirmed. Length frequencies by sex indicate that females grow larger than males. Preliminary estimates from a von Bertalanffy growth model indicate $L_{inf}$ for males at 78.5cm and 102.8cm for females.

Ageing structures (vertebrae, otoliths) were collected. Vertebrae were chosen as the best method to age monkfish based on an extensive literature search and a preliminary examination revealing that each centrum contained concentric rings which appeared to be annuli. To date, 1500 vertebrae have been prepared and of these approximately 700 have been read, based on the methodology described by Armstrong *et al* (1992), and Hartley (1995). Preliminary results indicate that the ages in the fishery range between 1 and 10 for females and 1 and 8 for males, however this initial attempt at age interpretation for monkfish remains to be validated. Several hundred otoliths have also been aged and comparisons with vertebrae indicate that otoliths consistently give younger ages. A preliminary growth curve was developed using vertebral ages but when compared to those developed by Armstrong et al (1992) and Hartley (1995), over ageing on the younger fish and under ageing of the older fish was apparent. Further work must be conducted before a reliable growth model can be established.

Condition factor (the relative weight of a fish at a given length) for immature (30cm) and mature (60 cm ) monkfish was examined using predicted values from the summer RV surveys. Although a decreasing trend is seen in both sizes, it was not found to be significant. (Fig. 31) Current values for mature fish are below the long term mean in both 4X and 4VW. An anomalous point for 1980, present in the Stock Status Report (SSR) was not used in Fig. 31. Recent examination of this value showed that it was not based on any observations for the length range.

Mean weight of a fish from the summer RV exhibited a downward trend from the mid 1970s to 1994 before stabilizing. It is likely this trend is being influenced by the large numbers of small fish coming into the fishery. (Fig. 32)

Growth and Mortality

A von Bertalanffy growth model was fit to vertebral ages from the RV survey indices. (Fig. 33) The von B parameters were then used to convert RV length frequencies into approximate ages. Z's were estimated by regressing these ages in a catch curve analysis. (Fig. 34a) Results indicate a sharp increase in total mortality from 1988 to 1994 and decreasing to 1997 and subsequently increasing. A von B growth model was also fit to industry survey data from 1995 to 2000. (Fig. 34b) This approach also showed a similar pattern of Z's. Because the mortality appears to be greatest on older fish, a further estimate was derived using the length frequency data for mature fish only (52cm to 82 cm). (Fig. 35) The pattern was again similar but the increase in Z's began in 1978 and has been variable but increasing since. Finally, due to possible ageing biases, Z's were also calculated using a von B growth model fit to length frequency data from Hartley, 1995. The trend was the same in all cases.

It would appear that survivorship for this species decreased dramatically during the 1990s which is consistent with the loss of large fish seen in the survey. However, because the patterns of Z from the catch curve analysis are based on the assumption of a stable age distribution, the recent strong abundance of young fish makes this assumption suspect. These estimates may be confounding changes in mortality with changes in recruitment and growth and so interpretation is difficult. Nevertheless, it seems reasonable to view these estimates as an indication that these young fish are not persisting at older ages as would have been expected in the past.

Conser's surplus production model (Conser, 1992) was used as a further approach to assessing the monkfish resource. Catch (converted to numbers) and summer RV abundance indices for mature and immature monkfish (based on a length at 50 % maturity of 46 cm) provided the input data. Results indicated that F's for the adults have been increasing since the late 1980s which is consistent with Z calculations and with the lack of large fish seen in the RV survey. (Fig. 36)

The relative fishing mortality (F) was derived for 4X by dividing the catch by the RV biomass index. (Fig. 37) Because of concerns about the accuracy of catches in earlier years, only the period from 1986 to 2000 was used. The results are highly variable with no apparent trend, although values appear somewhat higher after 1989.

## Traffic Light Approach

A Traffic Light approach (Anon. MS2000) was used to summarize the indicators of stock status and to give an overall summary. The table shows the annual values of each indicator as one of three lights depending on whether they are among the highest values observed for that indicator, among the lowest, or in between. (To minimize confusion from non-colour copying, a plus "+" sign was added to the green light indicator and a minus "-"sign to the red light indictor.) For indicators such as stock biomass and recruitment, high values are good and have a green light ⊕ and low values are bad and have a red light ⊖. However, for indicators such as mortality, high values are bad and are assigned a red light whereas low values are good and receive a green light. Intermediate values are yellow ●. The method allows the division between red/yellow and yellow/green to be arbitrarily set by the investigator. This can be based on different mathematical methods depending on the type of data but for monkfish, simple averages or percentiles were used. The boundary values chosen for indices using simple averaging were the average value for yellow/green and 0.6 of the average for the red/yellow boundary. For indicators using percentiles (Condition factor), 66.6 percentile (yellow/green) and 33.3 percentile (red/yellow) were used. For indicators with an inverse relationship with the traffic lights, like mortality, simple averaging was used with the mean value for the yellow/green boundary but 1.4 times the mean was used to define the red/yellow boundary. Weights can also be assigned to each indicator. A weight of 1.0 was used for all indices that spanned most of the 30 years of data. Shorter time series were given a weight of 0.1.

The results for the indicators combined are shown in the summary line above the array of individual indicators and characteristics. If most indicators in a particular year are red, then the summary light for that year will be red. If most are green the summary light will be green, and so on. The actual summary scores from the range of indicators in the table are shown in the bar chart above the table. The height of the bar determines the colour for the corresponding year and the horizontal lines on the bar chart indicate the boundaries between the colours (red-yellow and yellow-green).

Stock Indicators

The **Traffic Light** table (Fig. 38) summarizes some of the indicators of stock status discussed above. The current stock area includes all of 4VWX and 5Zc but in the last 5 years the exploratory fishery has been conducted almost entirely in 4X and most of the balance of the landings also come from that area. The relationship between 4X and the remaining stock area is unknown. Because of the current fishery distribution, 4X was the specific focus of the traffic light approach in this document. The following 8 indicators were selected for inclusion in the table:

- Area occupied (proportion of sets in which monkfish were caught) from the 4X RV summer survey
- RV mature and immature abundance (kg/tow) from the 4X RV summer surveys
- Condition factor (predicted weight at 60 cm) from 4X RV summer survey
- Total mortality (Z) from catch curve analysis from 4X RV summer survey
- Industry survey biomass from 1995 to 1999
- Catch per unit of effort (CPUE) from the directed fishery
- Relative fishing mortality (F) (commercial landings/RV survey biomass) from 4X RV summer survey

Although many indicators may be used, the above were chosen as the most appropriate as well as the most independent indices. Survey abundance and biomass indicators that are variants of those used were omitted to avoid use of multiple indicators of the same population attribute, giving it undue weight in summaries. Area occupied was chosen over the resource concentration index as both gave the same signal and the former is easier to understand. Mean length and weight of RV survey catches were not used because these reflect the aggregate effects of factors such as growth, recruitment, mortality and condition, making them difficult to interpret. (Note: the 1980 value for condition although not used in the analysis, was left in this table for consistency with the SSR. The results are the same when the value is left out.)

Indicators of abundance (Area occupied, Mature Abundance, Industry Survey Biomass, Directed fishery cpue) of the adult part of the monkfish population in 4X have improved from low levels in the early 1990s and is now near the long-term average. However, the proportion of large fish (> 60 cm) has declined and biomass remains low.

Indicators of productivity of the adult population have been poor in the 1990s. Condition factor (Condition factor) is in the low part of the historical range and the average size of fish in the adult population is low. The latter could result from reduced growth, improved recruitment or increased mortality. Estimates of total mortality (RV Total Mortality) show an increasing trend since 1978. Alternatively, there is evidence of much improved recruitment (Immature Abundance) since 1992.

The evidence with regard to the absolute level of fishing mortality (Relative F) is weak, however relative changes should be indicative. It appears that fishing mortality was higher after 1989 but there is no basis to provide a more reliable estimate of recent fishing mortality.

The summary of the indices used is shown in the bar chart at the top of the table and in the array labelled Summary, immediately below. Stock status has fluctuated between green and yellow through the 1970s to yellow and red through the 1980s and back to green and yellow in the 1990s. The last 2 years are yellow.

**Summary**

From a long-term perspective, the survey abundance over the whole area in the 1990s has been increasing and is at a high point in the range with the best signs of recruitment in 4X. The result of this recruitment is now being seen in the rise in catch rates in the directed fishery. If this trend continues, commercial catch rates should remain at a high level.

Biomass estimates however, remain low at 3000 tonnes for 4VWX with the recent increases likely due to high abundance levels of small fish. There is a concern over the distinct decline in the abundance of fish over 60 cm and whether it is related to unreported bycatch taken or discarded by fleets selecting for cod, haddock, pollock, and scallops has not been determined. While calculations of total mortality indicate low survivorship from the late 1980s onward, relative F shows no real trend.

Although catch rates for the directed fishery and commercial (bycatch) fishery in 4X continued to climb over the 5 years of the exploratory fishery, effort trends declined significantly likely due to changes in the market. Catches with associated effort for the bycatch fishery however, are low and efforts should be made to capture more complete information.

The five year exploratory fishery was completed in 1999 and fishing reverted to bycatch status only. The 200t allocation to the 5 vessels as well as the survey conducted by these same vessels was not extended to 2000-2001 fishing year. The potential for catches of small monkfish by commercial mesh size (130 mm) gear is a concern, particularly when fishing occurs inshore of LaHave Basin. A large mesh size restriction for any planned directed effort on this species could minimize exploitation of pre-recruits as well as limit incidental bycatch of other species and should be considered.

The increasing catches of monkfish by the inshore scallop fleet in the Bay of Fundy need to be documented in terms of size composition and verification of catches. Currently there is no sampling from this fleet and as fish are generally landed as tails only, it is necessary for the conversion factor, developed in the lab, to be tested in the field to obtain appropriate estimates of length distribution.

If harvesting levels are to be set for monkfish, appropriate actions should be taken to ensure the very restricted area being targeted by the directed fishery be monitored closely for signs of overfishing. The potential exists for large increases in effort as a reflection of market fluctuations.

The summary indicator for monkfish in 4X has fluctuated between green and yellow zones in recent years and is yellow in 2000 indicating a continued cautious approach. The population appears to have gone through a period of low productivity and abundance in the late 1980s to early 1990s and the factors causing this may still be affecting the present population. There are, however, signs of improved recruitment that is beginning to have a positive influence on the adult stock size.

Available indicators for monkfish in 4VW show very similar trends to those for 4X, although fishery removals have been much lower. This suggests that a cautious approach to exploitation should continue in the 4VW area. It also suggests that many of the changes observed in both areas may have been driven by changes in environmental conditions.

## Acknowledgements

The authors would like to acknowledge and thank the members of the Assessment Working Group of the Marine Fish Division, BIO, for their contributions, support and patience in the production of this document. We would also like to thank Tom McLane for all his dedicated efforts to sample monkfish at sea and in the lab and to Ken Frank for his time and energy to review this document. Lastly, we offer our sincere thanks to the captains and crews of the vessels involved in this co-operative project and particularly to Allister d'Entremont who co-ordinated their efforts. Their willingness and dedication to the project was invaluable.

## References

Anonymous. MS2000. Use of the Traffic Light method for application of the Precautionary Approach to fishery management planning. A methods workbook. First draft, July 2000 DFO, unpublished.

Armstrong, M.P. 1987. Life history of the goosefish *Lophius americanus*. M.A. Thesis. School of Marine Sciences, College of William and Mary, Virginia. 80 p.

Armstrong, M.P., J.A. Musick and J.A. Colvocoresses. 1992. Age, growth and reproduction of the goosefish *Lophius americanus* (Pisces: Lophiiformes). U.S. Fish. Bull. 90: 217-230.

Beanlands, D., and C. Annand. 1996. Status of monkfish in 4VWX5Zc. DFO Atl. Fish. Res. Doc. 96/104.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish. Wild. Serv. Fish. Bull. 53(74): 532-541.

Canada. Dept. of Fisheries and Oceans, Scotia-Fundy Region. 1995. 4VW monkfish. In: Scotia-Fundy Spring 1995 Groundfish Stock Status Report. DFO Atlantic Fisheries Stock Status Report 95/6. p 137-139.

Conser, R.J., and J.S. Idoine. 1992. A modified DeLury model for estimating mortality rates and stock sizes of American lobster populations. Res. Doc. SAW14/7. Appendix to CRD-92-07. Northeast Regional Stock Assessment Workshop Report. Woods Hole, MA. 28p.

Hartley, D.R. 1995. The population biology of the goosefish, *Lophius americanus,* in the Gulf of Maine. M.S.Thesis. School of University of Massachusetts Amherst Dept. of Forestry and Wildlife Management, Massachusetts. 142 p.

Markle, D.F. and J.A. Musick. 1974. Benthic slope fishes found at 900 m depth along a transect in the western North Atlantic Ocean. Mar. Biol. (Berl.) 26: 225-233.

NEFC (Northeast Fisheries Science Center). 2000. Report of the $31^{st}$ Northeast Regional Stock Assessment Workshop ($31^{st}$ SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. NEFSC Ref. Doc. 00- 15; 400p.

O'Boyle, R.N., C. Annand, R. Branton, P. Hurley, R. Mohn, K. Zwanenburg, D. Clark, J. Neilson and E. Trippel. 1994. Survey update for selected Scotia-Fundy groundfish stocks. DFO Atl. Fish. Res. Doc. 94/76 69 p.

Scott, W.G. and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci 219: 713 p.

Simon, J.E. and PE. Comeau. 1994. Summer distribution and abundance trends of species caught on the Scotian Shelf from 1970 - 1992, by the research vessel groundfish survey. Can. Tech. Rep. Fish. Aquat. Sci. No. 1953. 145 p.

Sparre, P. 1985. Introduction to tropical fish stock assessment. FAO / DANICA Project, Training in Fish Stock Assessment, GCP / INT / 392 / DEN, Manual 1: 187-191.

Table 1. Total monkfish landings (t) by country for divisions 4VWX and 5Zc.

| Year | Canada | Russia[2] | Other | Total |
|---|---|---|---|---|
| 1964 | 96 | - | - | 96 |
| 1965 | - | - | - | - |
| 1966 | 56 | 640 | - | 696 |
| 1967 | 8 | - | - | 8 |
| 1968 | 8 | 2418 | 2 | 2428 |
| 1969 | - | 3295 | - | 3295 |
| 1970 | 1 | 2123 | - | 2124 |
| 1971 | - | 13506 | - | 13506 |
| 1972 | 7 | 2872 | - | 2879 |
| 1973 | 50 | 10241 | - | 10291 |
| 1974 | 14 | 11758 | - | 11772 |
| 1975 | 15 | 18250 | - | 18265 |
| 1976 | 29 | 3394 | 2 | 3425 |
| 1977 | 86 | 2840 | 2 | 2928 |
| 1978 | 141 | 186 | 3 | 330 |
| 1979 | 143 | 31 | 2 | 176 |
| 1980 | 120 | 202 | 3 | 325 |
| 1981 | 176 | 30 | 6 | 212 |
| 1982 | 182 | 10 | 16 | 208 |
| 1983 | 297 | 87 | 27 | 411 |
| 1984 | 480 | 39 | 32 | 551 |
| 1985 | 492 | 139 | 29 | 660 |
| 1986 | 2755 | 161 | 59 | 2975 |
| 1987 | 2597 | 336 | 41 | 2974 |
| 1988 | 1434 | 46 | 14 | 1494 |
| 1989 | 1740 | 46 | 9 | 1795 |
| 1990 | 2269 | 93 | 37 | 2399 |
| 1991 | 1634 | 139 | 45 | 1818 |
| 1992 | 1300 | - | 47 | 1347 |
| 1993 | 991 | - | 53 | 1044 |
| 1994[1] | 1744 | - | - | 1744 |
| 1995[1] | 1421 | - | - | 1421 |
| 1996[1] | 1356 | - | - | 1356 |
| 1997[1] | 1582 | - | - | 1582 |
| 1998[1] | 1006 | - | - | 1006 |
| 1999[1] | 1076 | - | - | 1076 |
| 2000[3] | 922 | | | 922 |

1 Foreign catch not available.

2 Reported landings prior to 1978 cannot be verified so should not be used as any indication of exploitable biomass.

3 Year to date

Table 2. Total monkfish landings (t) for divisions 4VWX and 5Zc.

| Year | 4VW | 4X/5Y | 5Zc[2] | Total |
|---|---|---|---|---|
| 1964 | - | 96 | | 96 |
| 1965 | - | - | | - |
| 1966 | 641 | 55 | | 696 |
| 1967 | 4 | 4 | | 8 |
| 1968 | 2420 | 8 | | 2428 |
| 1969 | 3291 | 4 | | 3295 |
| 1970 | 2124 | - | | 2124 |
| 1971 | 13372 | 134 | | 13506 |
| 1972 | 2858 | 21 | | 2879 |
| 1973 | 8991 | 1300 | | 10291 |
| 1974 | 10422 | 1350 | | 11772 |
| 1975 | 16161 | 2104 | | 18265 |
| 1976 | 3408 | 17 | | 3425 |
| 1977 | 2407 | 521 | | 2928 |
| 1978 | 205 | 125 | | 330 |
| 1979 | 98 | 78 | | 176 |
| 1980 | 228 | 97 | | 325 |
| 1981 | 77 | 135 | | 212 |
| 1982 | 39 | 169 | | 208 |
| 1983 | 123 | 288 | | 411 |
| 1984 | 199 | 352 | | 551 |
| 1985 | 291 | 369 | | 660 |
| 1986 | 2096 | 540 | 339 | 2975 |
| 1987 | 1830 | 396 | 748 | 2974 |
| 1988 | 295 | 290 | 909 | 1494 |
| 1989 | 388 | 231 | 1176 | 1795 |
| 1990 | 438 | 407 | 1554 | 2399 |
| 1991 | 461 | 342 | 1015 | 1818 |
| 1992 | 415 | 463 | 469 | 1347 |
| 1993 | 120 | 570 | 354 | 1044 |
| 1994[1] | 44 | 1159 | 541 | 1744 |
| 1995[1] | 68 | 935 | 418 | 1421 |
| 1996[1] | 105 | 1067 | 184 | 1356 |
| 1997[1] | 144 | 1249 | 189 | 1582 |
| 1998[1] | 68 | 748 | 190 | 1006 |
| 1999[1] | 118 | 807 | 151 | 1076 |
| 2000[3] | 35 | 786 | 101 | 922 |

1 Foreign catch not available.
2 Catches prior to 1986 are for 5Ze so are not included here.
3 Year to date

Table 3. Canadian monthly landings (t) by quarter of monkfish by gear and tonnage class 1990-2000.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OTB TC1-3 (includes unknown TC) | | | | | | | | | | | | | | | |
| | 4VW | | | | | 4X&5Y | | | | | 5Zc | | | | |
| | 1st Quart. | 2nd Quart. | 3rd Quart. | 4th Quart. | Total | 1st Quart. | 2nd Quart. | 3rd Quart. | 4th Quart. | Total | 1st Quart. | 2nd Quart. | 3rd Quart. | 4th Quart. | Total |
| 1990 | 0 | 1 | 0 | 0 | 1 | 46 | 34 | 26 | 14 | 120 | 0 | 2 | 13 | 0 | 15 |
| 1991 | 0 | 0 | 3 | 0 | 3 | 24 | 19 | 27 | 20 | 90 | 0 | 1 | 4 | 0 | 5 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 23 | 21 | 57 | 43 | 144 | 0 | 1 | 1 | 0 | 2 |
| 1993 | 0 | 2 | 4 | 0 | 6 | 62 | 48 | 100 | 87 | 297 | 0 | 3 | 25 | 15 | 43 |
| 1994 | 0 | 1 | 7 | 1 | 9 | 161 | 311 | 158 | 158 | 788 | 0 | 28 | 137 | 4 | 169 |
| 1995 | 0 | 0 | 11 | 0 | 11 | 138 | 99 | 149 | 161 | 547 | 0 | 0 | 22 | 2 | 24 |
| 1996 | 0 | 1 | 2 | 5 | 8 | 220 | 156 | 204 | 216 | 796 | 0 | 1 | 44 | 42 | 87 |
| 1997 | 0 | 5 | 2 | 1 | 8 | 127 | 312 | 170 | 129 | 738 | 0 | 12 | 43 | 11 | 66 |
| 1998 | 1 | 2 | 1 | 6 | 10 | 170 | 175 | 54 | 45 | 444 | 0 | 5 | 20 | 8 | 33 |
| 1999 | 0 | 5 | 1 | 1 | 7 | 236 | 159 | 64 | 64 | 523 | 0 | 6 | 67 | 14 | 87 |
| 2000 | 0 | 1 | 1 | | 2 | 317 | 136 | 59 | | 512 | 0 | 4 | 60 | | 64 |
| OTB TC4+ | | | | | | | | | | | | | | | |
| | 4VW | | | | | 4X&5Y | | | | | 5Zc | | | | |
| | 1st Quart. | 2nd Quart. | 3rd Quart. | 4th Quart. | Total | 1st Quart. | 2nd Quart. | 3rd Quart. | 4th Quart. | Total | 1st Quart. | 2nd Quart. | 3rd Quart. | 4th Quart. | Total |
| 1990 | 3 | 10 | 6 | 3 | 22 | 1 | 3 | 1 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| 1991 | 11 | 4 | 142 | 23 | 180 | 1 | 5 | 9 | 1 | 16 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 5 | 98 | 9 | 7 | 119 | 0 | 17 | 0 | 0 | 17 | 0 | 1 | 0 | 0 | 1 |
| 1993 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 1 | 4 | 2 | 1 | 8 | 0 | 17 | 0 | 2 | 19 | 0 | 0 | 1 | 0 | 1 |
| 1995 | 3 | 1 | 9 | 1 | 14 | 5 | 6 | 2 | 1 | 14 | - | 0 | 0 | 1 | 1 |
| 1996 | 1 | 1 | 65 | 0 | 67 | 4 | 1 | 2 | 1 | 8 | 0 | 0 | 1 | 0 | 1 |
| 1997 | 1 | 0 | 30 | 0 | 31 | 1 | 3 | 2 | 3 | 9 | 0 | 0 | 1 | 0 | 1 |
| 1998 | 0 | 1 | 0 | 1 | 2 | 2 | 3 | 0 | 1 | 6 | 0 | 0 | 0 | 1 | 1 |
| 1999 | 1 | 8 | 5 | 0 | 14 | 1 | 3 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 0 | 3 | 0 | | 3 | 0 | 21 | 0 | | 21 | 0 | 2 | 10 | | 12 |

Table 3 (con't). Scallop Dredge - All Tonnage Classes Combined.

| 4VW | | | | | |
|---|---|---|---|---|---|
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 0 | 97 | 143 | - | 240 |
| 1991 | 0 | 38 | 42 | 0 | 80 |
| 1992 | 0 | 40 | 148 | 9 | 197 |
| 1993 | 0 | 17 | 26 | 0 | 43 |
| 1994 | 0 | 13 | 8 | 1 | 22 |
| 1995 | 0 | 18 | 17 | 0 | 35 |
| 1996 | 0 | 16 | 0 | 2 | 18 |
| 1997 | 0 | 54 | 42 | 0 | 96 |
| 1998 | 0 | 24 | 8 | 14 | 46 |
| 1999 | 0 | 5 | 61 | 21 | 87 |
| 2000 | 0 | 1 | 23 | | 24 |
| 4X | | | | | |
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 1 | 3 | 111 | 22 | 137 |
| 1991 | 0 | 8 | 59 | 33 | 100 |
| 1992 | 3 | 40 | 72 | 27 | 142 |
| 1993 | 0 | 38 | 97 | 23 | 158 |
| 1994 | 1 | 46 | 169 | 48 | 264 |
| 1995 | 0 | 22 | 178 | 68 | 269 |
| 1996 | 2 | 22 | 103 | 36 | 163 |
| 1997 | 0 | 52 | 227 | 43 | 322 |
| 1998 | 0 | 17 | 129 | 46 | 192 |
| 1999 | 0 | 41 | 65 | 26 | 132 |
| 2000 | 1 | 25 | 58 | | 84 |
| 5Zc | | | | | |
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 177 | 340 | 577 | 430 | 1524 |
| 1991 | 118 | 321 | 432 | 128 | 999 |
| 1992 | 33 | 52 | 227 | 135 | 447 |
| 1993 | 8 | 57 | 149 | 90 | 304 |
| 1994 | 16 | 103 | 181 | 64 | 364 |
| 1995 | 8 | 81 | 180 | 117 | 386 |
| 1996 | 2 | 11 | 48 | 27 | 88 |
| 1997 | 1 | 14 | 75 | 26 | 116 |
| 1998 | 0 | 52 | 45 | 57 | 154 |
| 1999 | 5 | 30 | 10 | 12 | 57 |
| 2000 | 0 | 4 | 17 | | 21 |

Table 3 (con’t). Fixed Gear - All Tonnage Classes Combined.

| 4VW | | | | | |
|---|---|---|---|---|---|
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 2 | 5 | 42 | 10 | 59 |
| 1991 | 2 | 6 | 25 | 7 | 38 |
| 1992 | 0 | 6 | 28 | 11 | 45 |
| 1993 | 0 | 11 | 7 | 0 | 18 |
| 1994 | 1 | 0 | 3 | 0 | 4 |
| 1995 | 0 | 2 | 3 | 1 | 6 |
| 1996 | 0 | 1 | 4 | 4 | 9 |
| 1997 | 0 | 2 | 4 | 0 | 6 |
| 1998 | 0 | 2 | 7 | 1 | 10 |
| 1999 | 1 | 4 | 4 | 0 | 9 |
| 2000 | 1 | 1 | 4 | | 6 |
| 4X&5Y | | | | | |
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 12 | 12 | 62 | 19 | 105 |
| 1991 | 13 | 9 | 50 | 24 | 96 |
| 1992 | 17 | 13 | 66 | 50 | 146 |
| 1993 | 9 | 11 | 33 | 6 | 94 |
| 1994 | 2 | 12 | 43 | 17 | 74 |
| 1995 | 4 | 28 | 50 | 17 | 99 |
| 1996 | 4 | 23 | 39 | 28 | 94 |
| 1997 | 9 | 21 | 83 | 38 | 151 |
| 1998 | 5 | 12 | 33 | 22 | 72 |
| 1999 | 4 | 20 | 69 | 25 | 118 |
| 2000 | 37 | 25 | 105 | | 167 |
| 5Zc | | | | | |
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 0 | 1 | 12 | 1 | 14 |
| 1991 | 0 | 3 | 5 | 3 | 11 |
| 1992 | 0 | 2 | 11 | 5 | 19 |
| 1993 | 0 | 2 | 5 | 0 | 7 |
| 1994 | 0 | 1 | 6 | 0 | 7 |
| 1995 | 0 | 2 | 4 | 1 | 7 |
| 1996 | 0 | 0 | 6 | 2 | 8 |
| 1997 | 0 | 1 | 4 | 1 | 6 |
| 1998 | 0 | 0 | 3 | 0 | 2 |
| 1999 | 0 | 1 | 4 | 1 | 6 |
| 2000 | 0 | 1 | 3 | | 4 |

Table 3 (con't). Other Gear - All Tonnage Classes Combined.

| 4VW | | | | | |
|---|---|---|---|---|---|
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 1 | 9 | 5 | 2 | 17 |
| 1991 | 0 | 3 | 0 | 1 | 4 |
| 1992 | 0 | 3 | 3 | 0 | 8 |
| 1993 | 0 | 6 | 5 | 0 | 11 |
| 1994 | 0 | 1 | 0 | 0 | 1 |
| 1995 | 0 | 0 | 1 | 1 | 2 |
| 1996 | 1 | 0 | 1 | 1 | 3 |
| 1997 | 0 | 1 | 2 | 0 | 3 |
| 1998 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 0 | 0 | 0 | 1 | 1 |
| 2000 | 0 | 0 | 0 | | 0 |
| 4X/5Y | | | | | |
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 7 | 0 | 2 | 0 | 9 |
| 1991 | 9 | 0 | 1 | 2 | 12 |
| 1992 | 8 | 1 | 1 | 3 | 13 |
| 1993 | 8 | 0 | 0 | 0 | 8 |
| 1994 | 9 | 2 | 0 | 3 | 14 |
| 1995 | 4 | 1 | 0 | 1 | 6 |
| 1996 | 3 | 1 | 0 | 2 | 6 |
| 1997 | 3 | 7 | 14 | 5 | 29 |
| 1998 | 7 | 9 | 14 | 4 | 34 |
| 1999 | 6 | 2 | 21 | 1 | 30 |
| 2000 | 2 | 0 | 0 | | 2 |
| 5Zc | | | | | |
| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Total |
| 1990 | 0 | 1 | 0 | 0 | 1 |
| 1991 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 0 | 0 | 0 | 0 | 0 |
| 1993 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 0 | 0 | 0 | 1 | 1 |
| 2000 | 0 | 0 | 0 | | 0 |

Table 4. Mean numbers/tow (standard errors) and mean weights/tow (standard errors) for 4VW and 4X monkfish for 1970-1999 (summer survey) and 5Zc Georges survey.

| | 4VW | | 4X | | 5Zc | |
|---|---|---|---|---|---|---|
| Year | Nos./Tow | Wts./Tow | Nos./Tow | Wts./Tow | Nos./Tow | Wts./Tow |
| 1970 | .44 (.17) | 2.28 (.98) | .52 (.15) | 4.92 (3.19) | | |
| 1971 | .27 (.09) | .95 (.34) | .3 (.10) | .99 (.48) | | |
| 1972 | .36 (.09) | 1.31 (.32) | .57 (.15) | 1.26 (.43) | | |
| 1973 | 1.19 (.52) | 5.04 (1.65) | .61 (.13) | 1.89 (.62) | | |
| 1974 | .81 (.21) | 4.01 (1.21) | .41 (.10) | 1.93 (.56) | | |
| 1975 | .54 (.12) | 2.82 (1.33) | 1.03 (.26) | 5.49 (1.52) | | |
| 1976 | .61 (.23) | 2.94 (1.09) | .66 (.24) | 3.61 (.96) | | |
| 1977 | .83 (.16) | 3.69 (.87) | 1.08 (.34) | 5.84 (2.37) | | |
| 1978 | .62 (.19) | 2.66 (1.21) | .33 (.10) | 1.67 (.55) | | |
| 1979 | .32 (.08) | .83 (.26) | .25 (.06) | 1.55 (.57) | | |
| 1980 | .52 (.11) | 1.47 (.33) | .28 (.11) | .94 (.39) | | |
| 1981 | .82 (.14) | 1.72 (.36) | .32 (.10) | 1.39 (.44) | | |
| 1982 | .55 (.15) | 1.89 (.73) | .59 (.15) | 1.64 (.54) | | |
| 1983 | .43 (.12) | .95 (.33) | .29 (.09) | 1.49 (.58) | | |
| 1984 | .65 (.12) | 1.47 (.31) | .62 (.13) | 2.13 (.65) | | |
| 1985 | .45 (.10) | 1.82 (.55) | .28 (.08) | .62 (.24) | | |
| 1986 | .60 (.12) | 1.92 (.52) | .41 (.13) | 1.71 (.63) | .43 (.10) | 1.51 (.51) |
| 1987 | .42 (.08) | .86 (.18) | .39 (.07) | 1.71 (.41) | .33 (.12) | 1.03 (.38) |
| 1988 | .53 (.17) | 1.53 (.42) | .36 (.13) | .96 (.43) | .35 (.08) | 1.31 (.43) |
| 1989 | .31 (.12) | .58 (.20) | .15 (.06) | .50 (.25) | .17 (.05) | .69 (.27) |
| 1990 | .15 (.05) | .37 (.15) | .35 (.21) | .29 (.15) | .24 (.06) | .84 (.29) |
| 1991 | .34 (.09) | .64 (.16) | .46 (.13) | 1.01 (.42) | .45 (.17) | .25 (.11) |
| 1992 | .33 (.13) | .23 (.08) | 41 (.18) | .48 (.18) | .42 (.17) | .20 (.08) |
| 1993 | .32 (.08) | .42 (.08) | .71 (.20) | 1.19 (.49) | .07 (.05) | .01 (.01) |
| 1994 | .52 (.11) | .36 (.12) | 1.19 (.34) | .79 (.21) | .16 (.10) | .02 (.02) |
| 1995 | .98 (.33) | .96 (.26) | 1.65 (.19) | 1.87 (.58) | .34 (.12) | .42 (.22) |
| 1996 | .34 (.07) | .63 (.16) | .72 (.15) | 1.29 (.29) | .44 (.13) | .50 (.20) |
| 1997 | .75 (.15) | .71 (.15) | .83 (.15) | .99 (.38) | .20 (.08) | .27 (.13) |
| 1998 | .96 (.18) | 1.28 (.29) | 1.03 (.19) | 1.80 (.46) | .35 (.20) | .85 (.53) |
| 1999 | .68 (.12) | .39 (.11) | .87 (.14) | .86 (.11) | .67 (.18) | .79 (.35) |
| 2000 | .58 (.14) | .59 (.19) | 1.24 (.26) | .84 (.21) | .49 (.16) | .20 (.06) |

Table 5 . Species Composition of the bycatch from the Directed (203mm) Fishery

| Species | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| | | | | | |
| Cod | 9.68 | 4.28 | 1.43 | 2.35 | 2.81 |
| Cusk | 0.03 | 0.05 | 0.03 | 0.01 | 0.09 |
| Dogfish | 0.20 | 0.26 | 0.39 | 0.22 | 0.20 |
| Haddock | 1.28 | 0.19 | 0.11 | 0.29 | 0.10 |
| Halibut | 0.01 | 0.05 | 0.09 | 0.15 | 0.07 |
| Monkfish | 83.17 | 92.14 | 95.36 | 92.07 | 94.10 |
| Pollock | 0.02 | 0.45 | 0.40 | 1.04 | 0.79 |
| Red Hake | 0.02 | 0.16 | 0.02 | 0.00 | 0.05 |
| Redfish | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 |
| Silver Hake | 0.14 | 0.20 | 0.05 | 0.01 | 0.15 |
| Smooth Skate | 0.13 | 0.45 | 0.41 | 0.14 | 0.21 |
| Thorny Skate | 0.80 | 0.40 | 0.37 | 1.20 | 0.24 |
| White Hake | 0.99 | 0.62 | 0.72 | 1.40 | 0.65 |
| Winter Skate | 0.47 | 0.02 | 0.14 | 0.00 | 0.00 |
| Winter flounder | 2.82 | 0.00 | 0.05 | 0.00 | 0.00 |
| Witch | 0.15 | 0.60 | 0.43 | 0.98 | 0.52 |
| Wolfish | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 |
| Yellowtail | 0.08 | 0.10 | 0.00 | 0.00 | 0.00 |

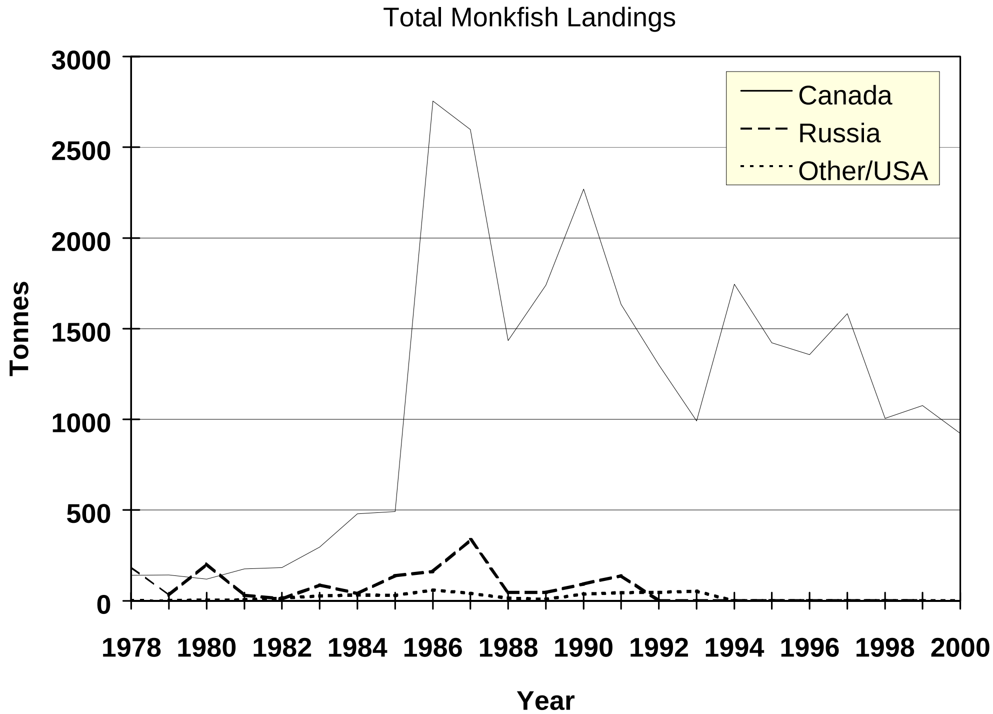



Fig. 1. Total monkfish landings by country.

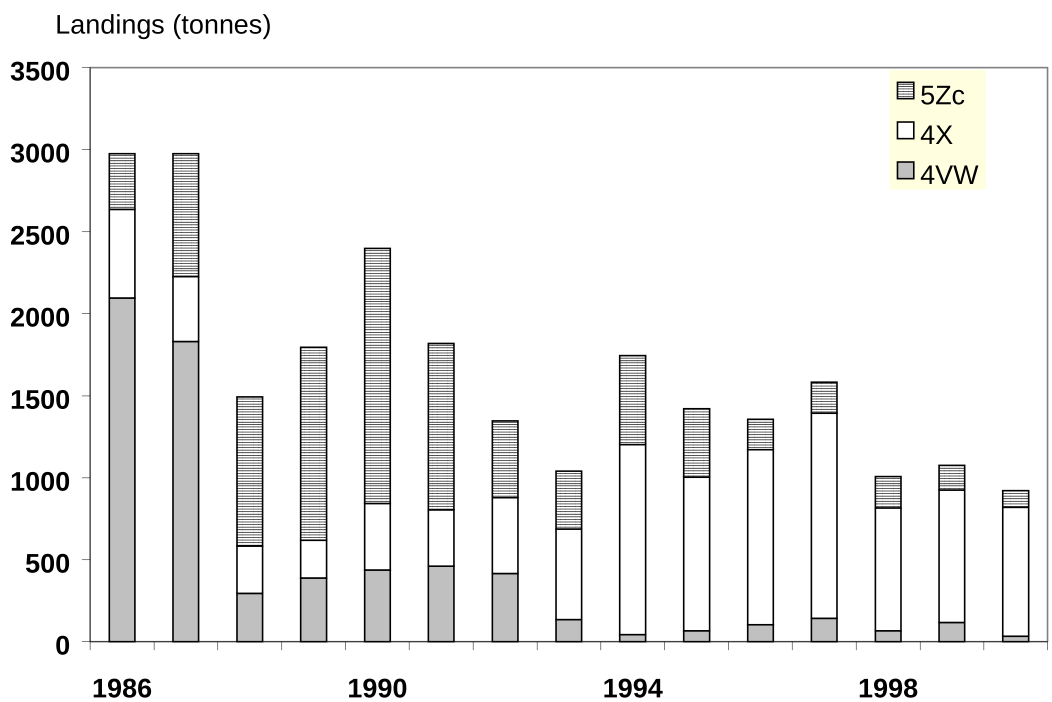



Fig. 2. Total monkfish landings by area.

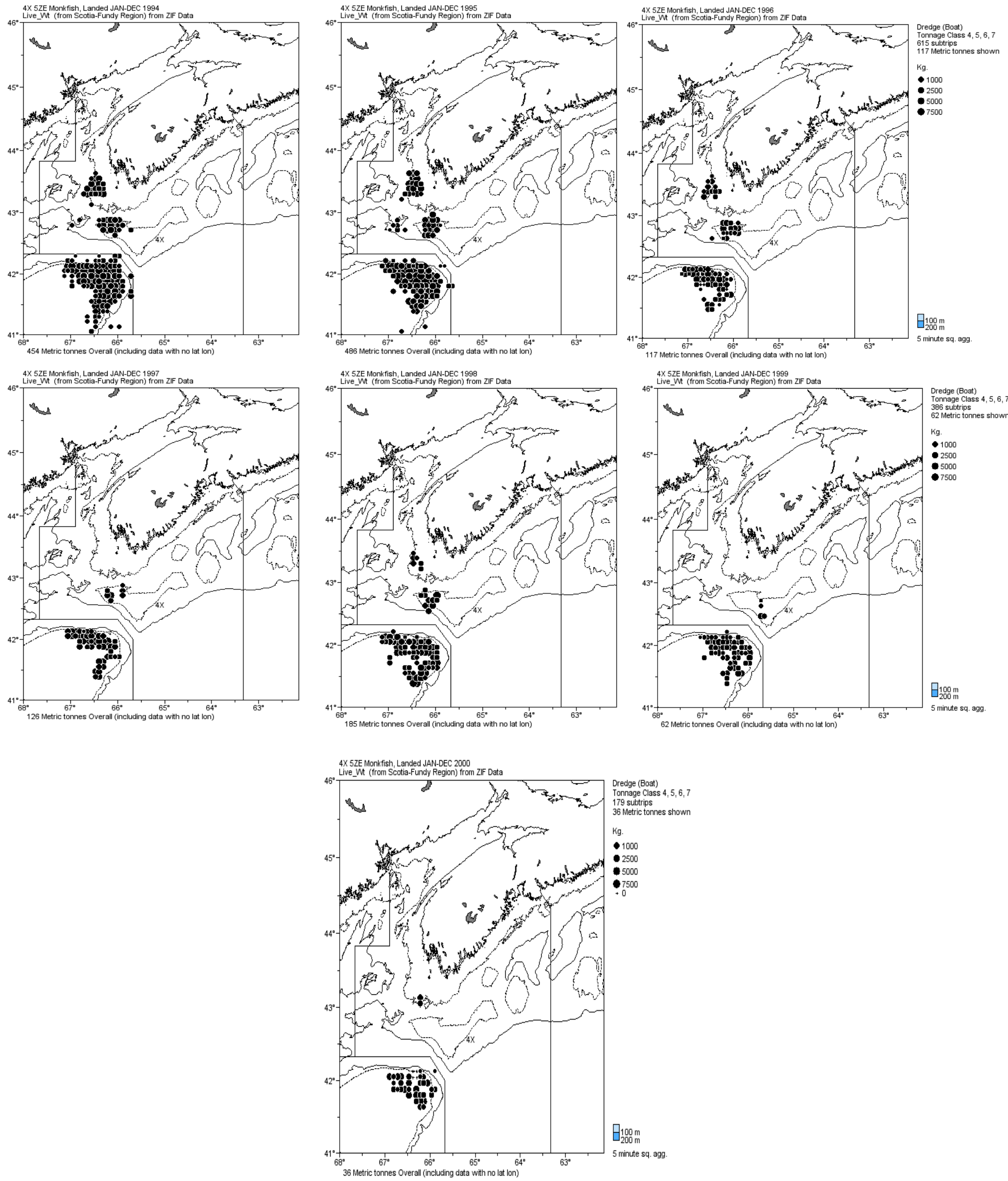



Fig. 3 a.  Scallop dredge (>tc 4) landings in 4X and 5Ze.

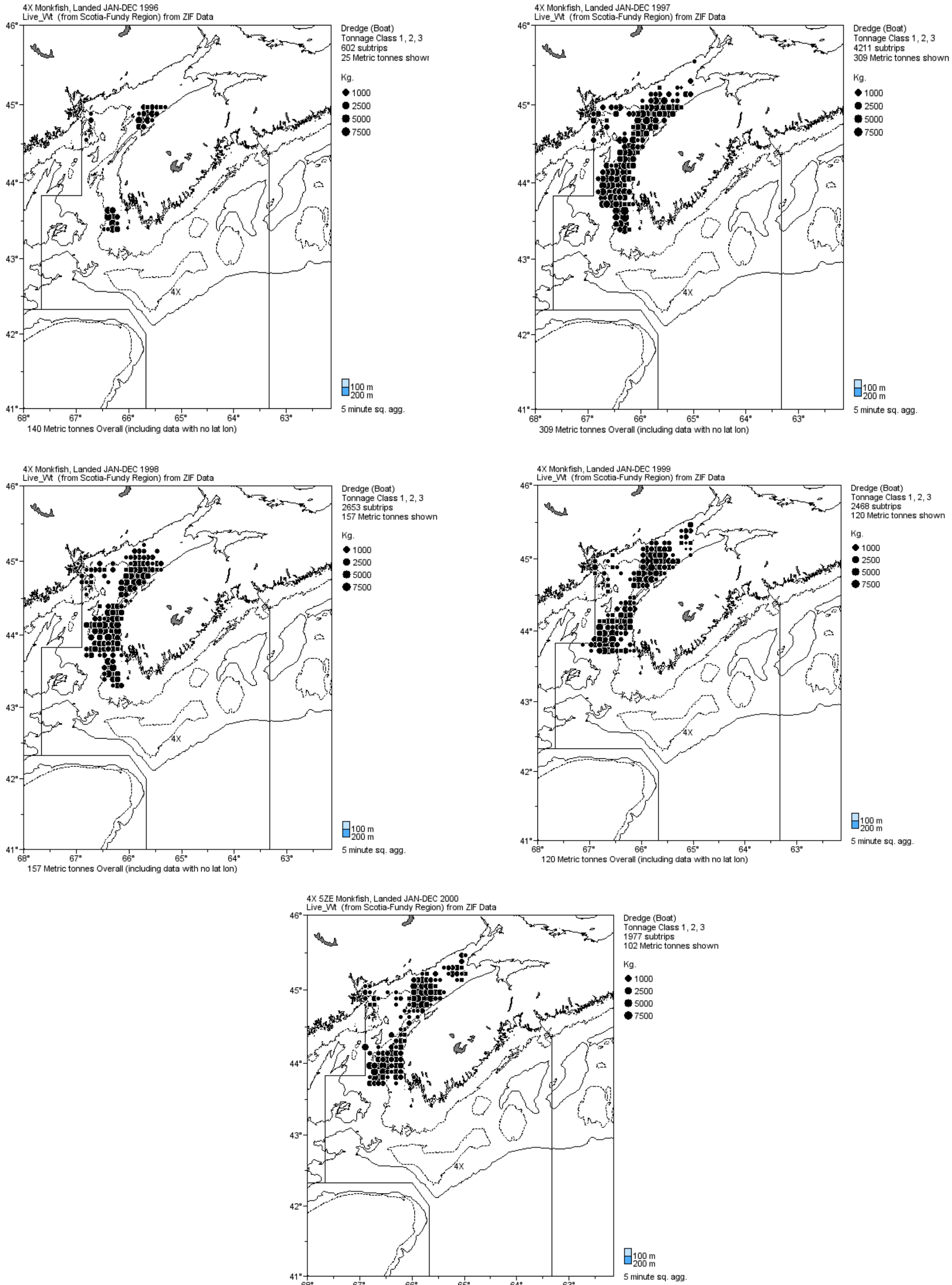



Fig. 3 b. Scallop dredge (tc 1 to 3) landings in 4X. (Note: There are no landings with associated positions prior to 1996.)

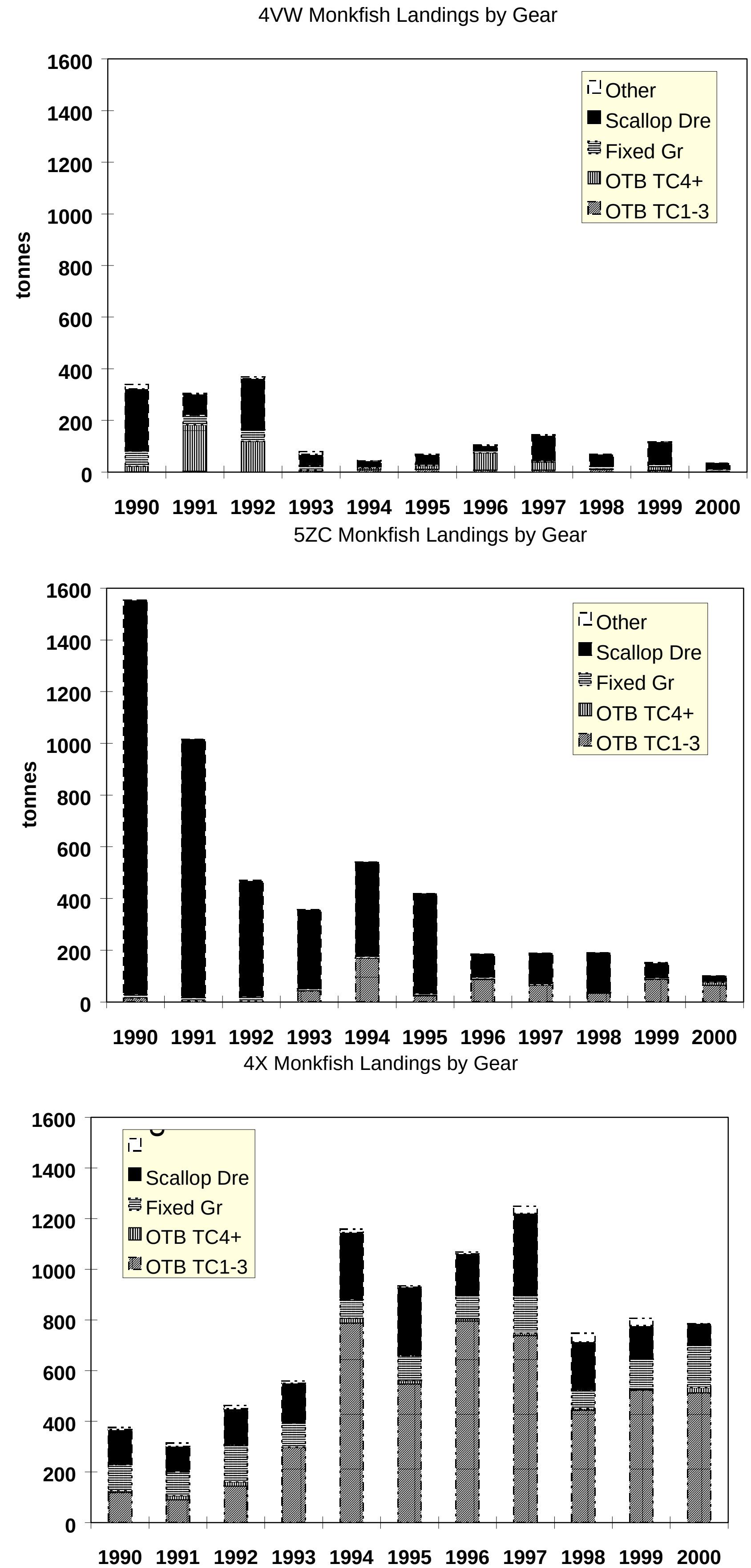
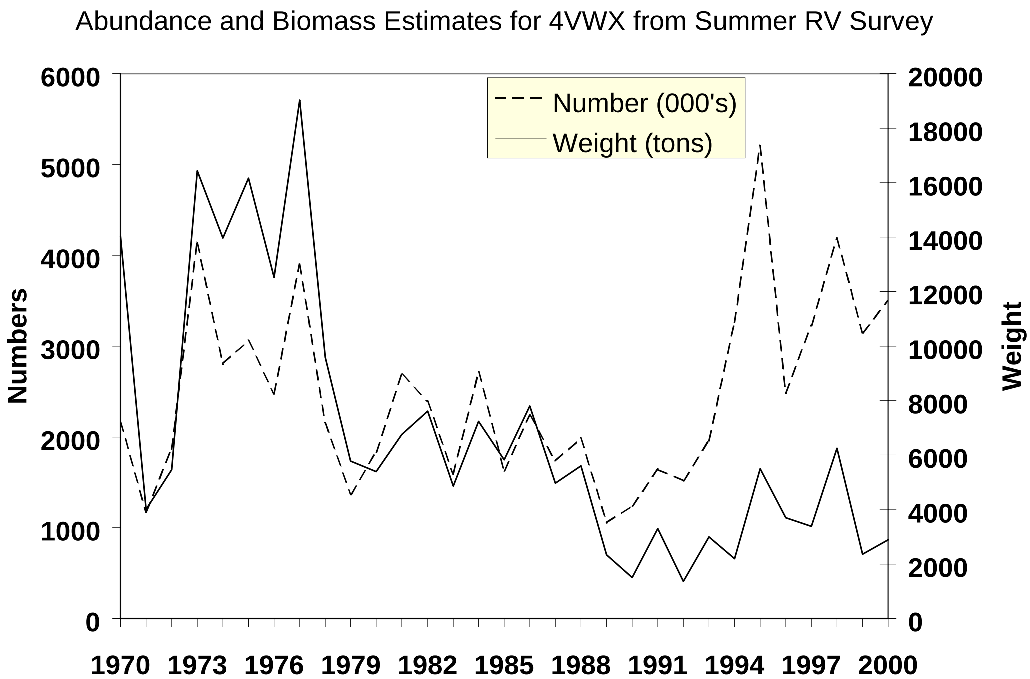
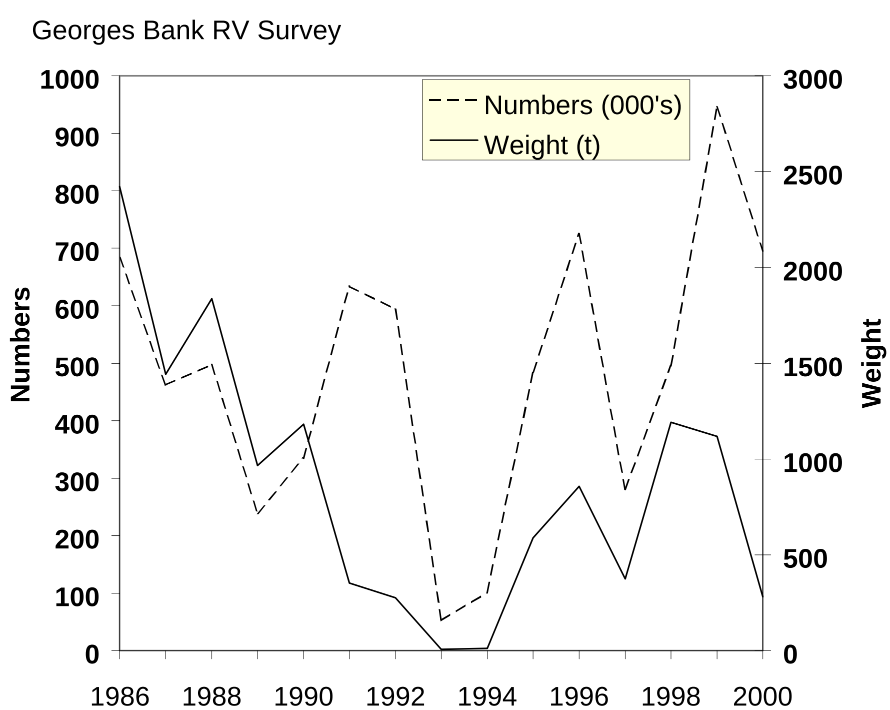



Fig. 4. Monkfish catches by gear and area




a.




b.

Fig. 5a,b. Abundance and biomass estimates for summer RV and Georges Bank surveys.

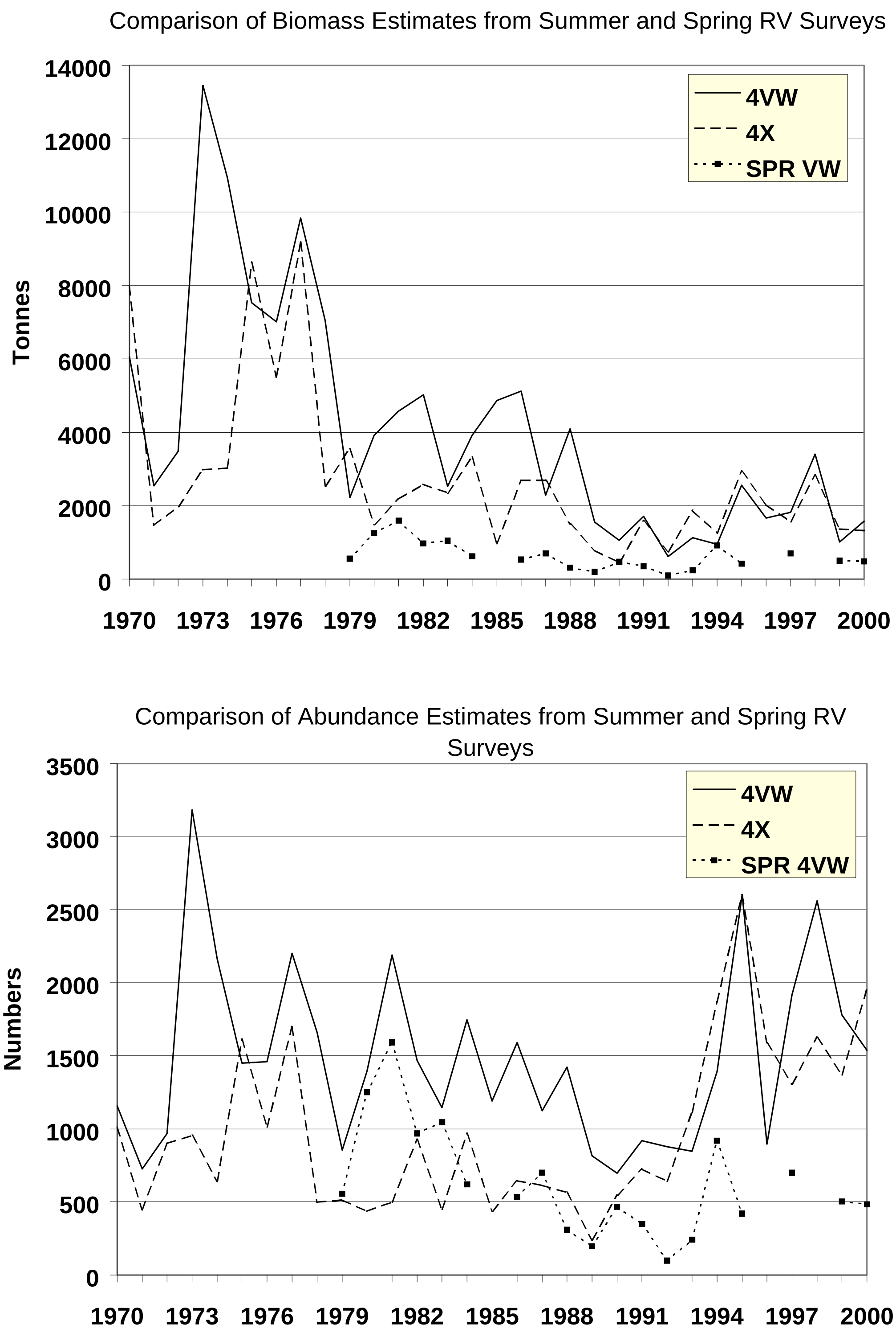
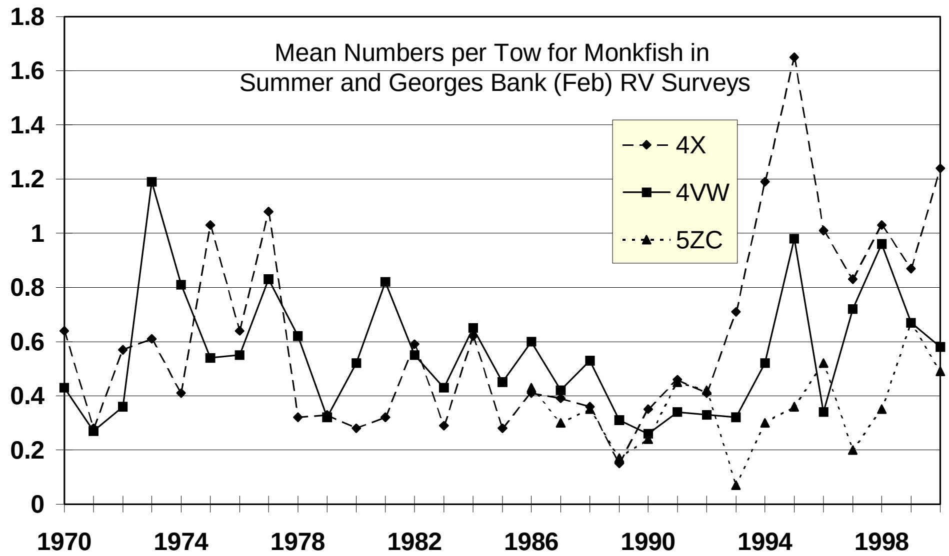



Fig. 6. Indices of biomass and abundance by area and RV survey.




Fig, 7. Mean number per tow from research vessel surveys.

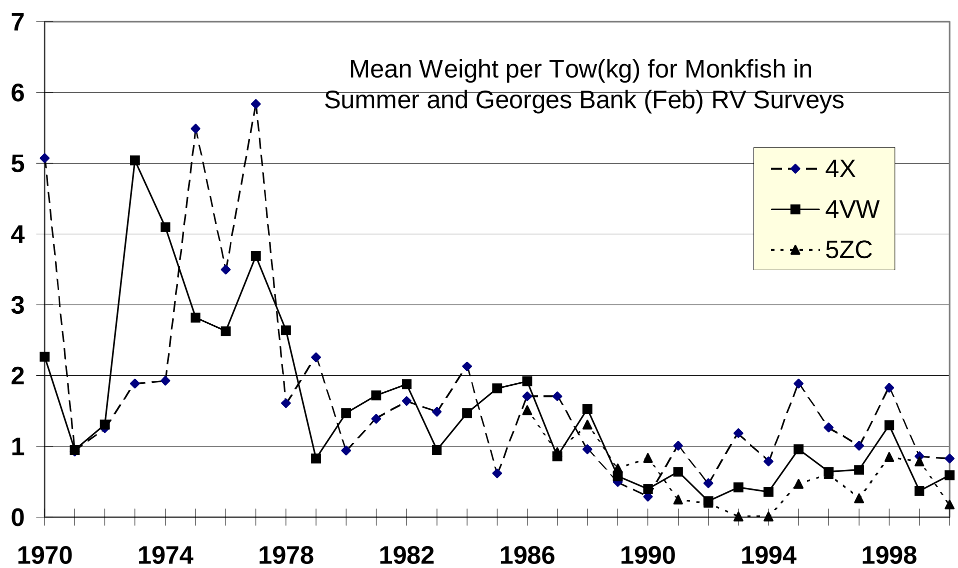



Fig. 8 Mean weight per tow from research vessel surveys.

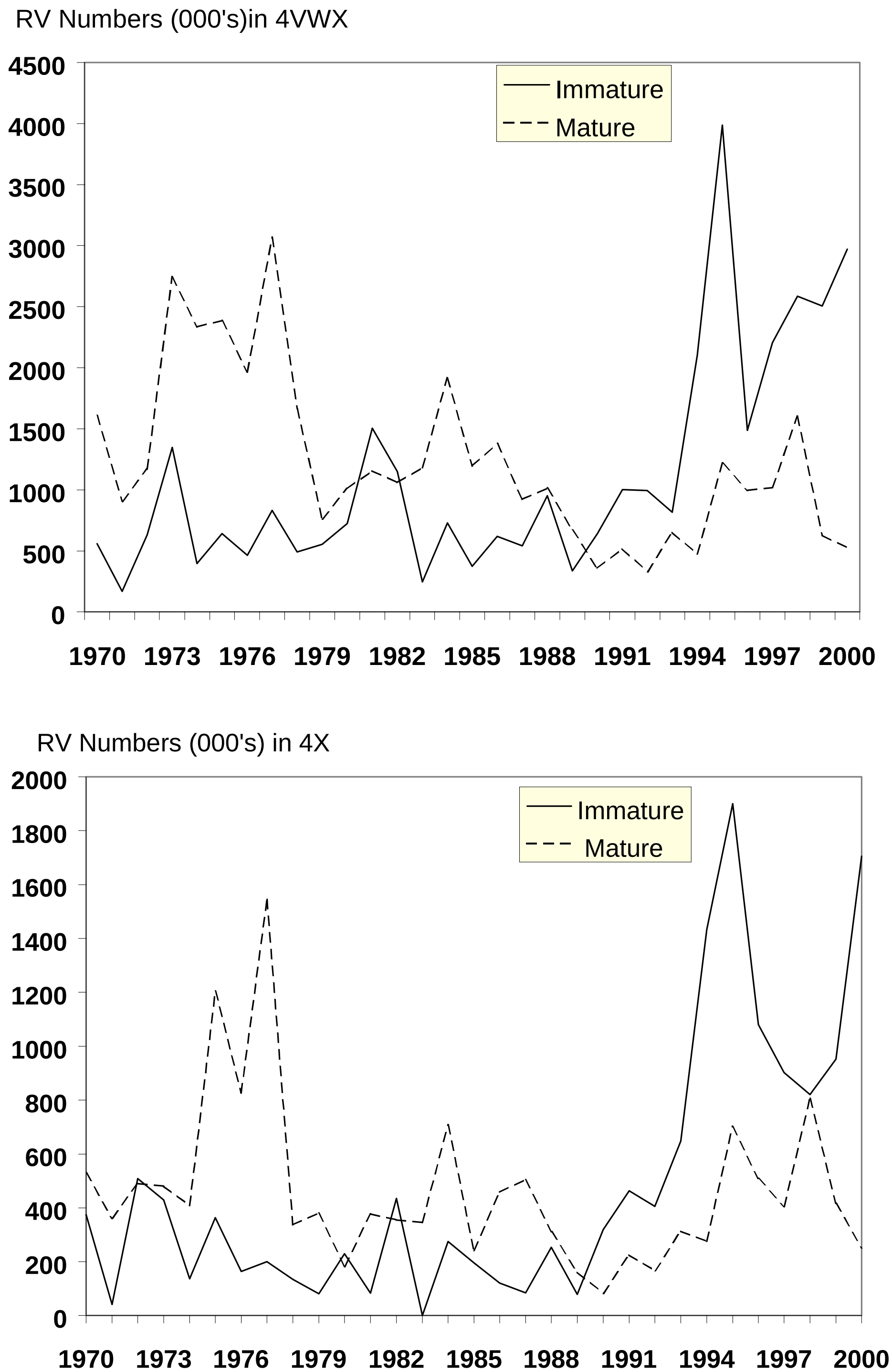



Fig. 9. Summer RV stratified numbers separated by length at 50% maturity.

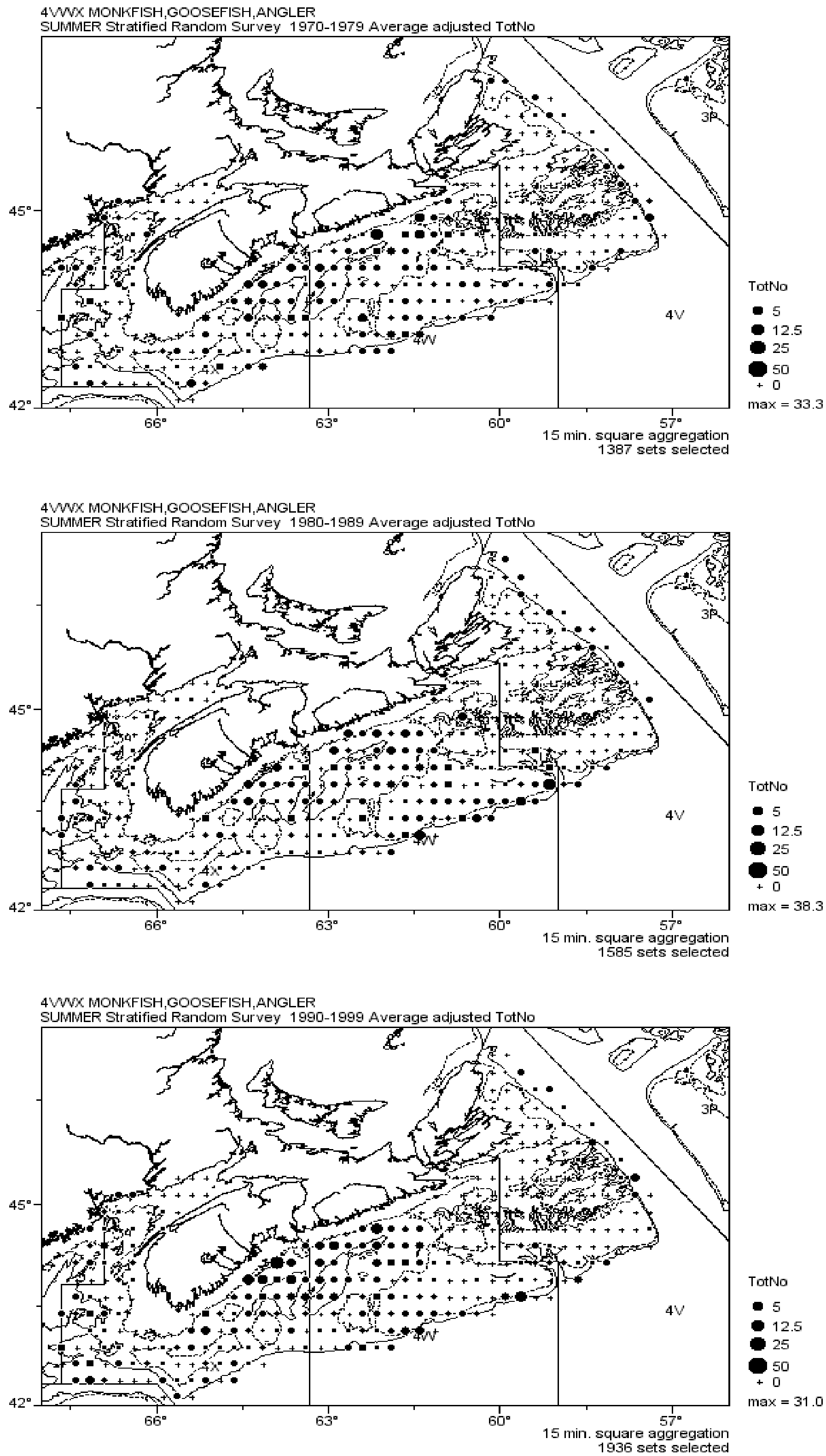



Fig. 10. Monkfish catch (numbers) in 10 year periods.

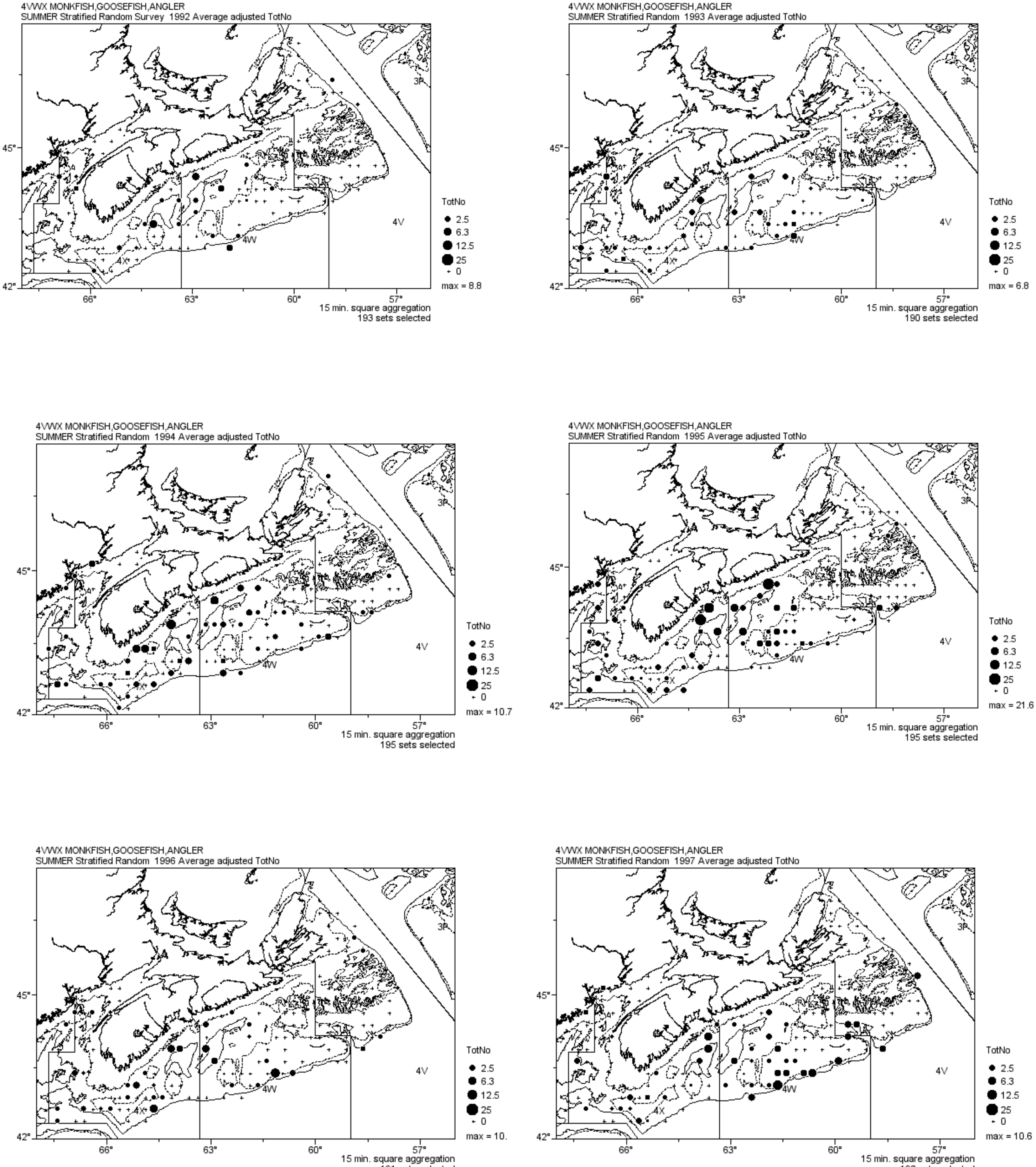
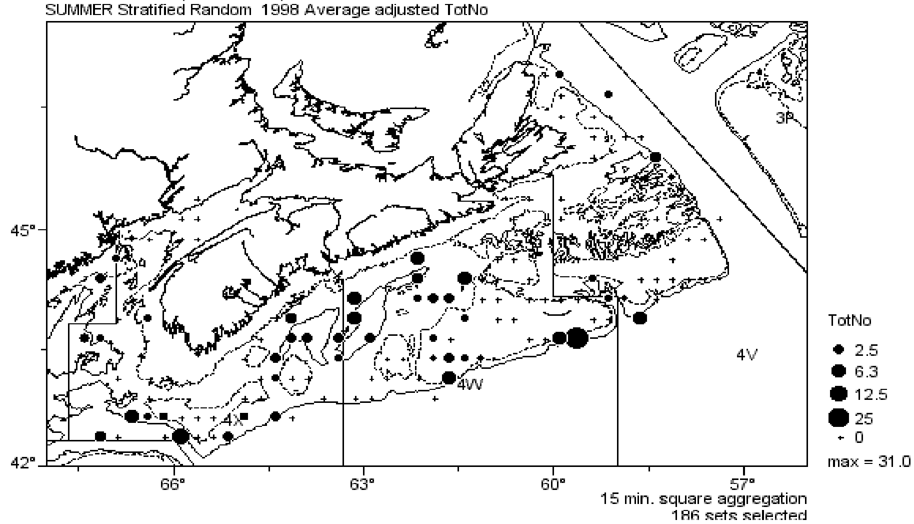
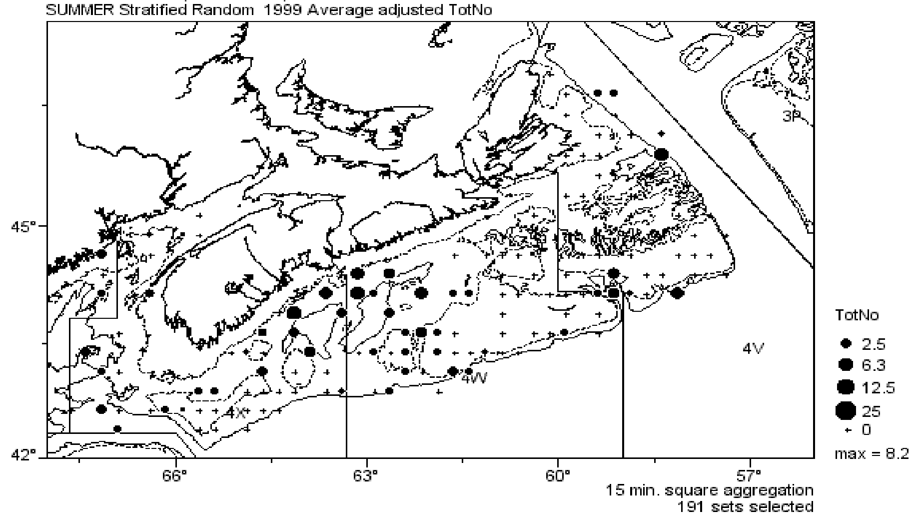



Fig. 11. Monkfish catch (numbers) from research vessel surveys.

4VWX MONKFISH,GOOSEFISH,ANGLER
SUMMER Stratified Random 1998 Average adjusted TotNo




4VWX MONKFISH,GOOSEFISH,ANGLER
SUMMER Stratified Random 1999 Average adjusted TotNo




4VWX MONKFISH,GOOSEFISH,ANGLER
SUMMER Stratified Random 2000 Average adjusted TotNo

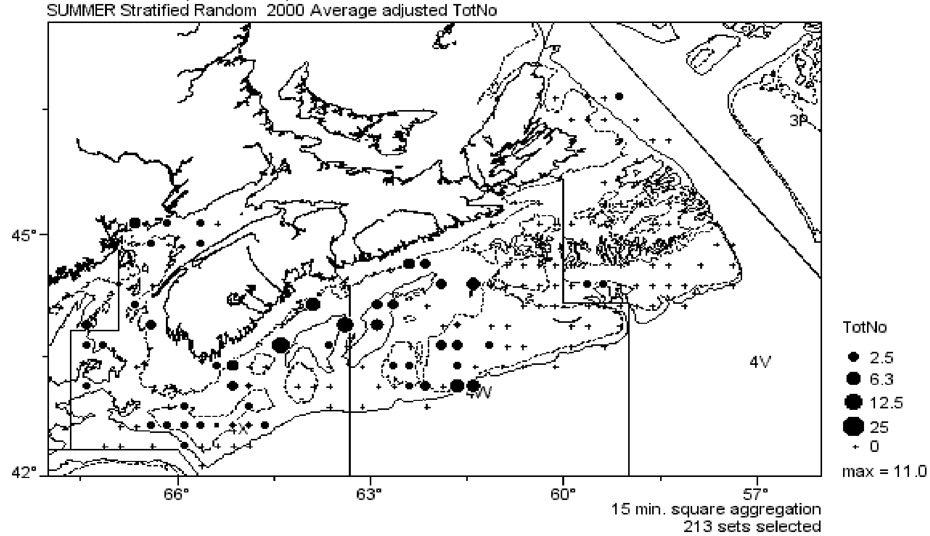



Fig. 11. (Continued)

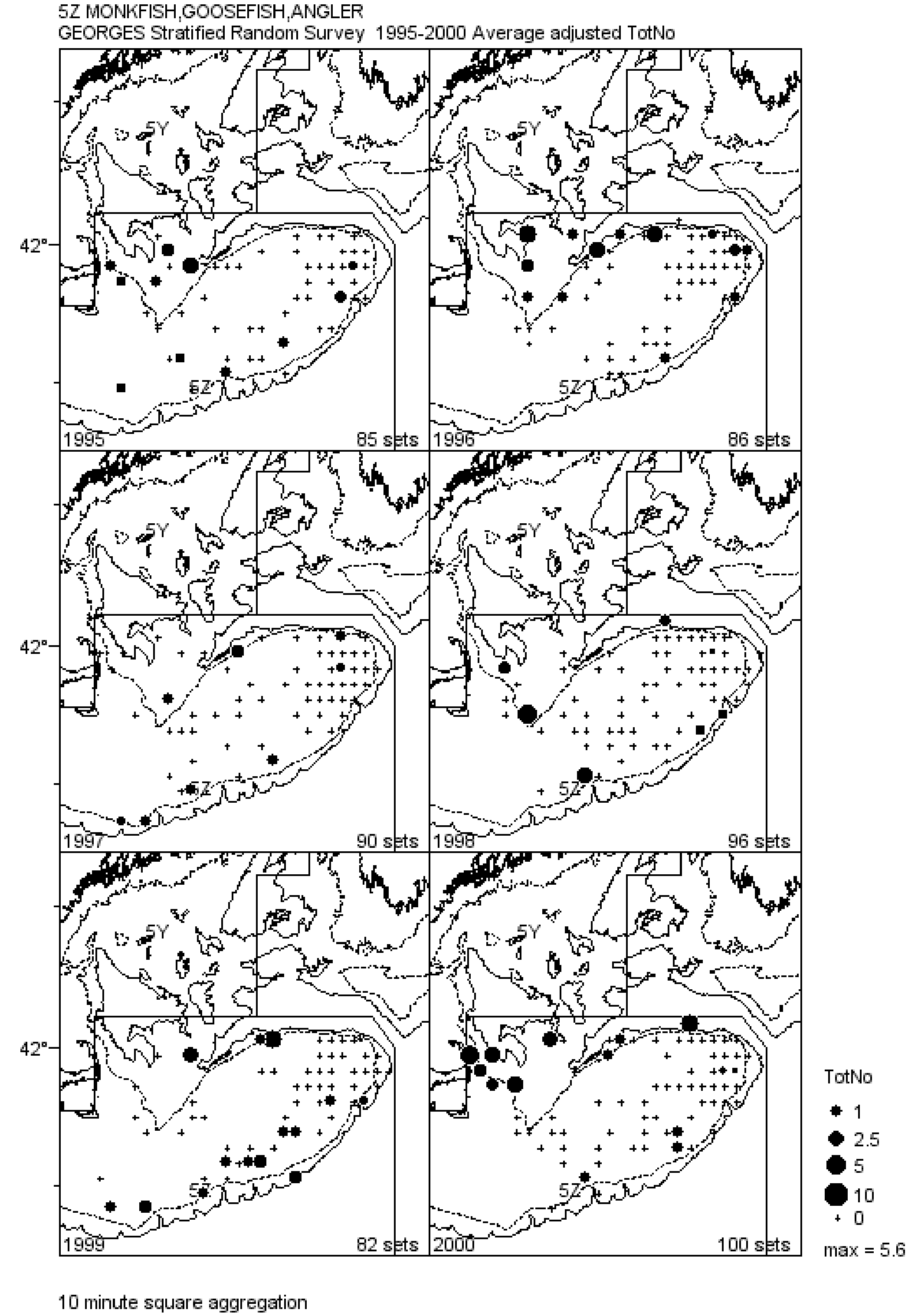
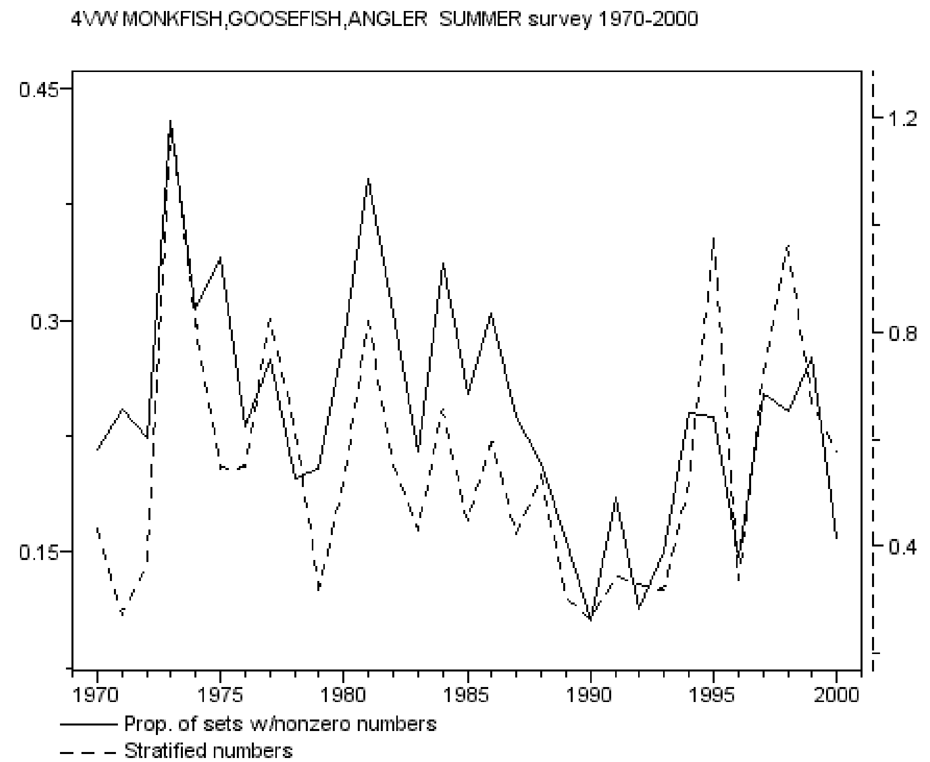



Fig. 12. Georges Bank February research vessel distribution



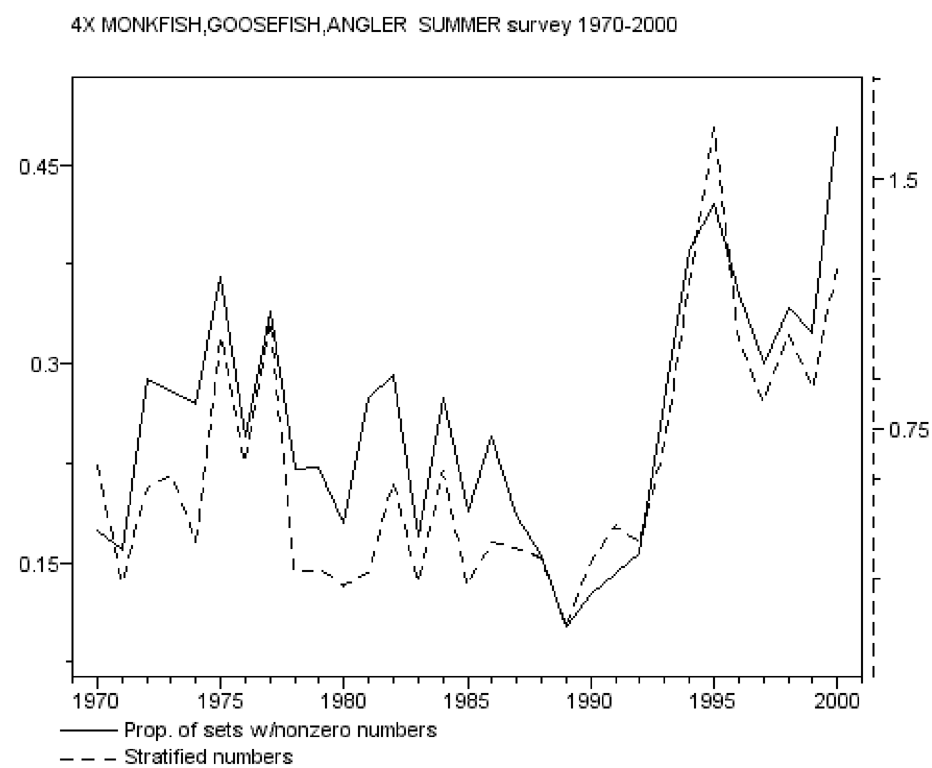
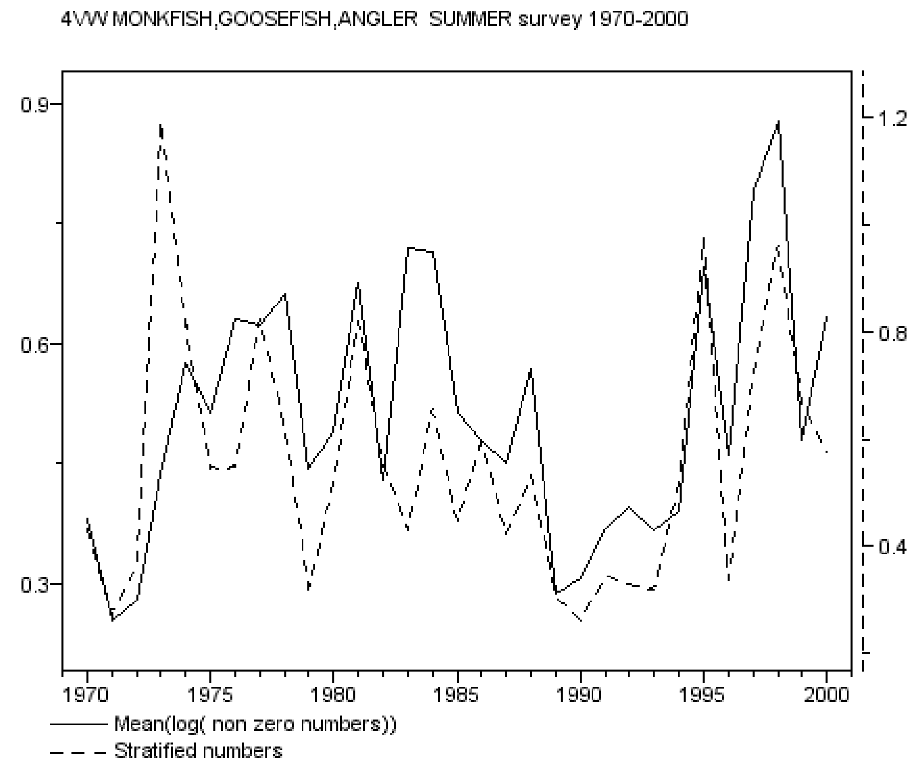




Fig. 13a. Area Occupied estimates from summer RV surveys for 4VW and 4X.



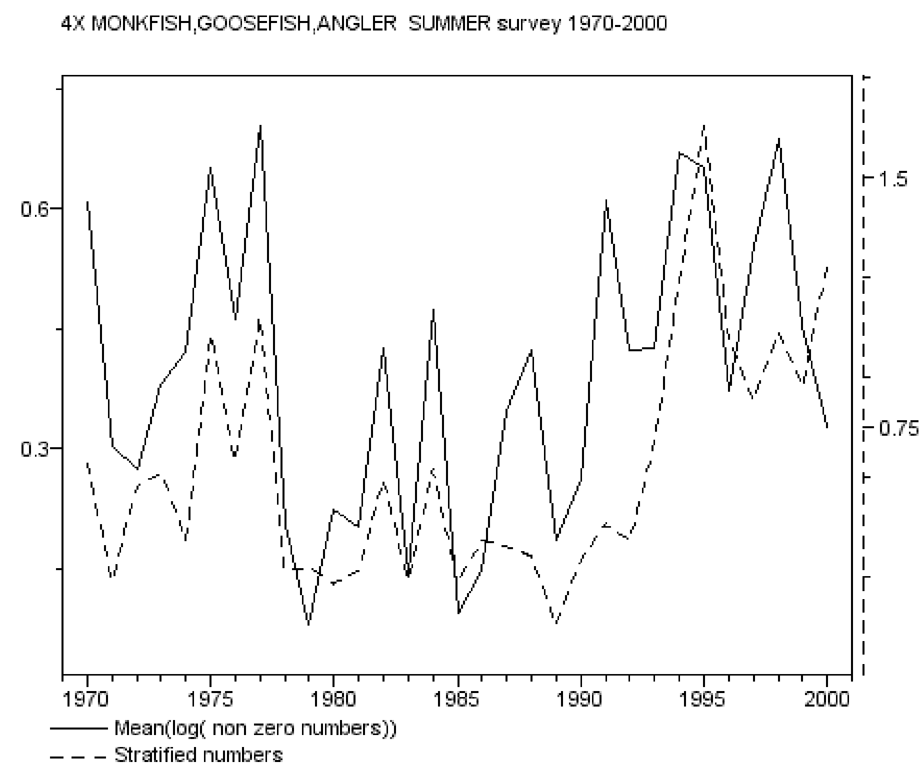




Fig. 13b. Resource concentration estimates from summer RV surveys in 4VW and 4X.

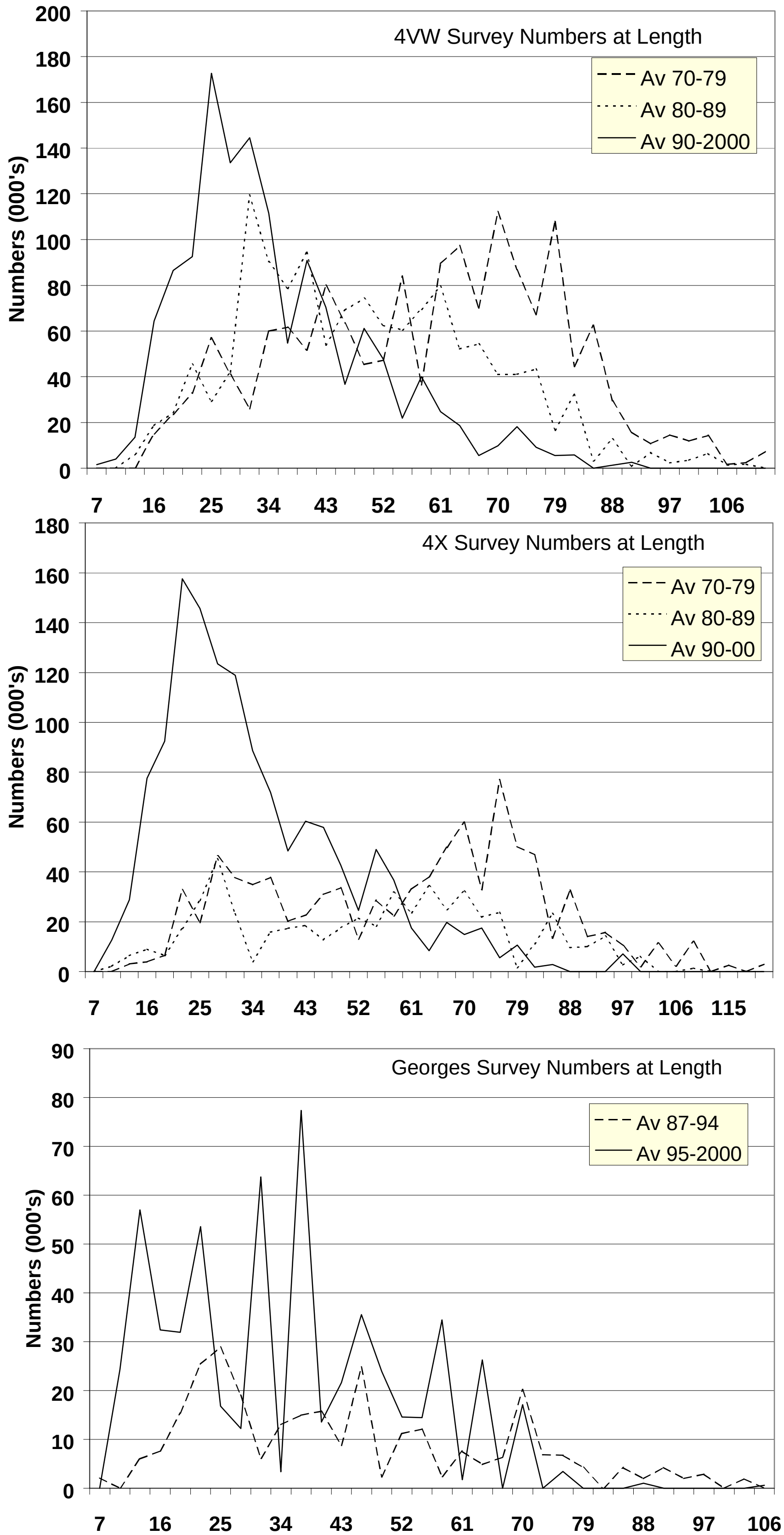
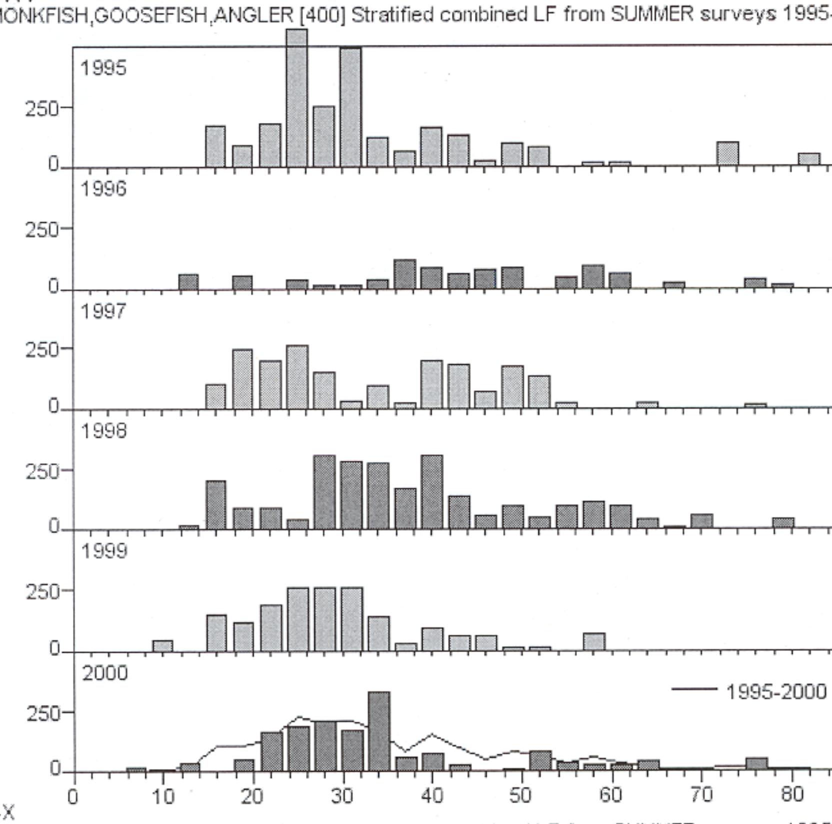



Fig. 14. Long-term numbers at length for summer and February (Georges) RV surveys.

4VW
MONKFISH,GOOSEFISH,ANGLER [400] Stratified combined LF from SUMMER surveys 1995-2000 (x




4X
MONKFISH,GOOSEFISH,ANGLER [400] Stratified combined LF from SUMMER surveys 1995-2000 (x

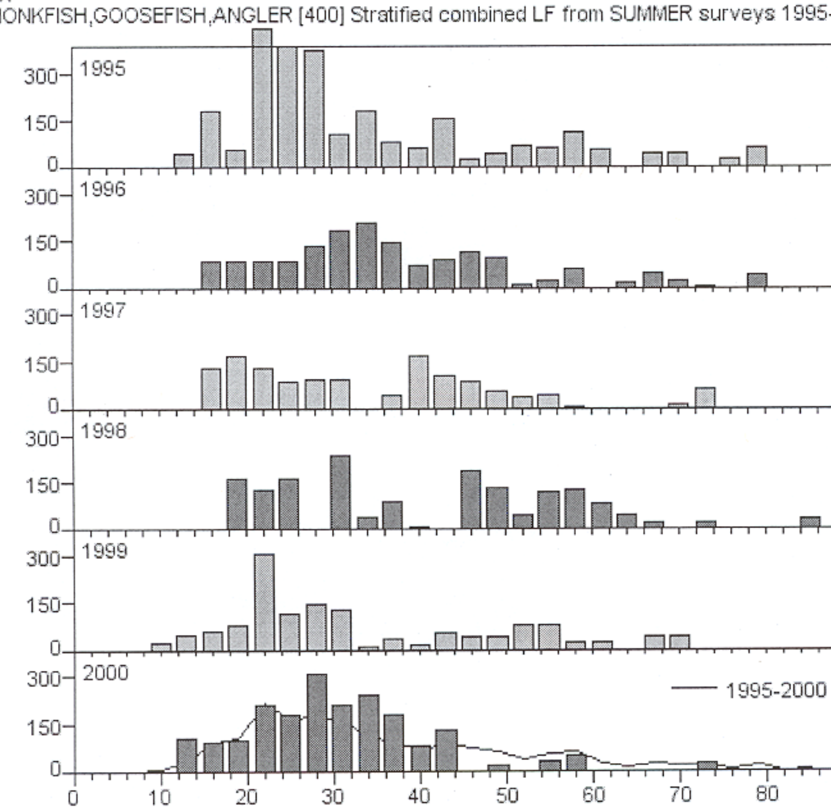



Fig. 15. Monkfish length frequencies from summer research vessel surveys.

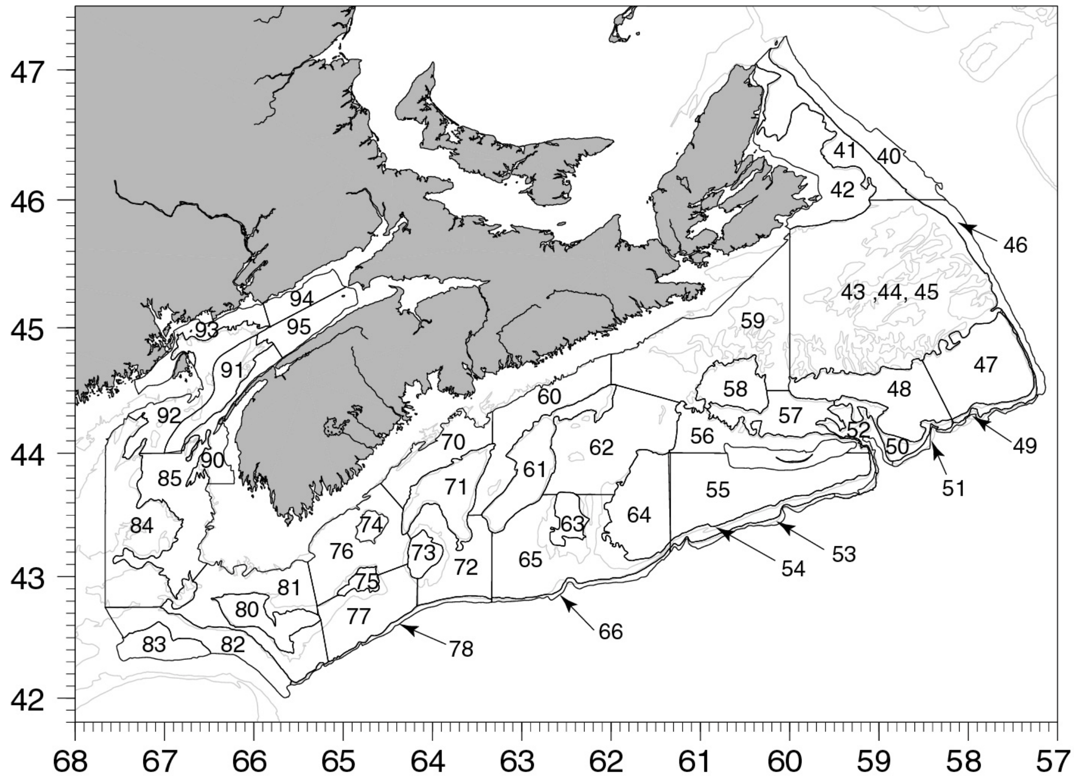



Fig. 16. Strata map for the Scotian Shelf summer research vessel survey.

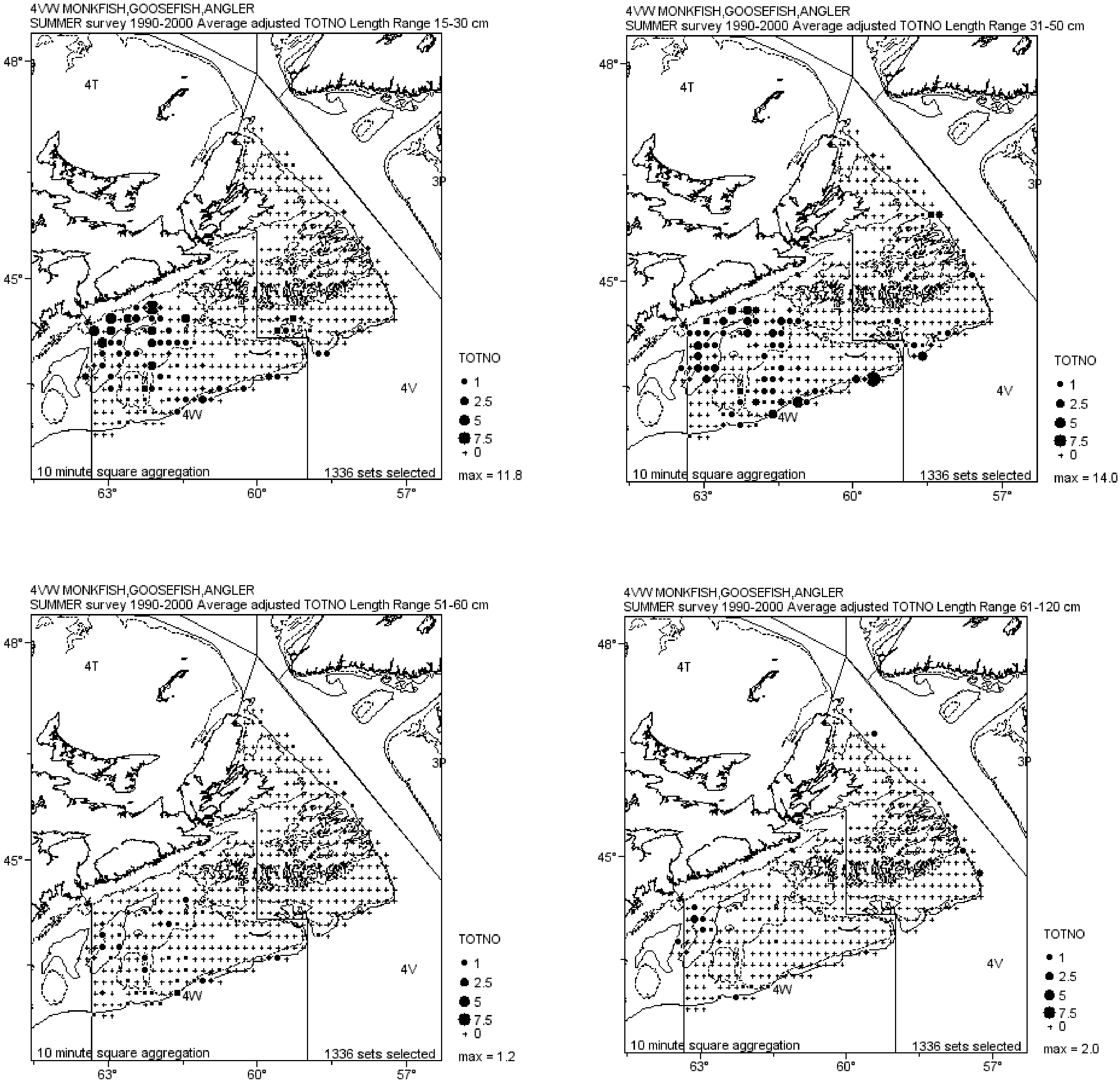



Fig. 17. Survey numbers from 4VW by length group.

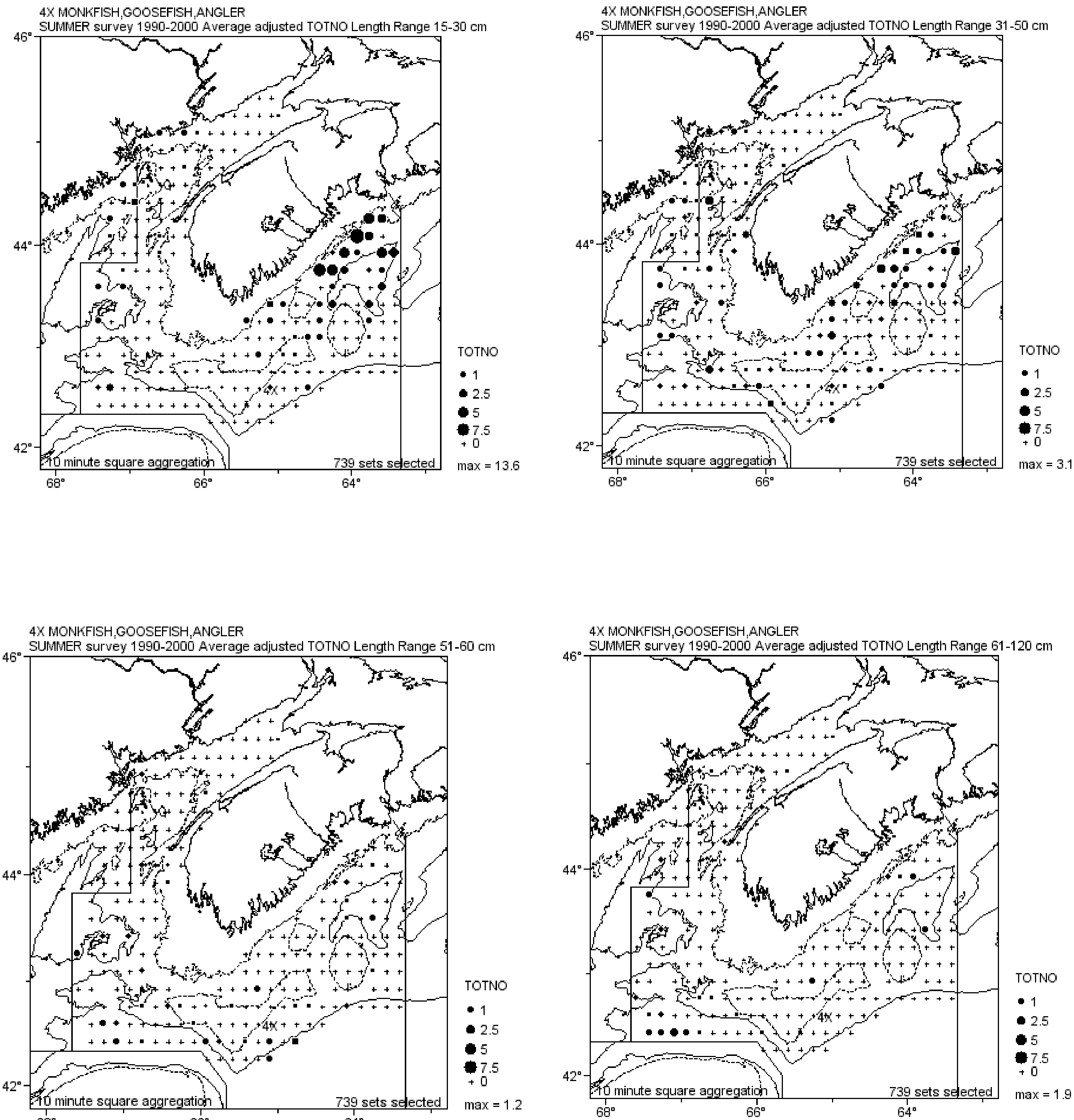



Fig. 18. Survey numbers from 4X by length group.

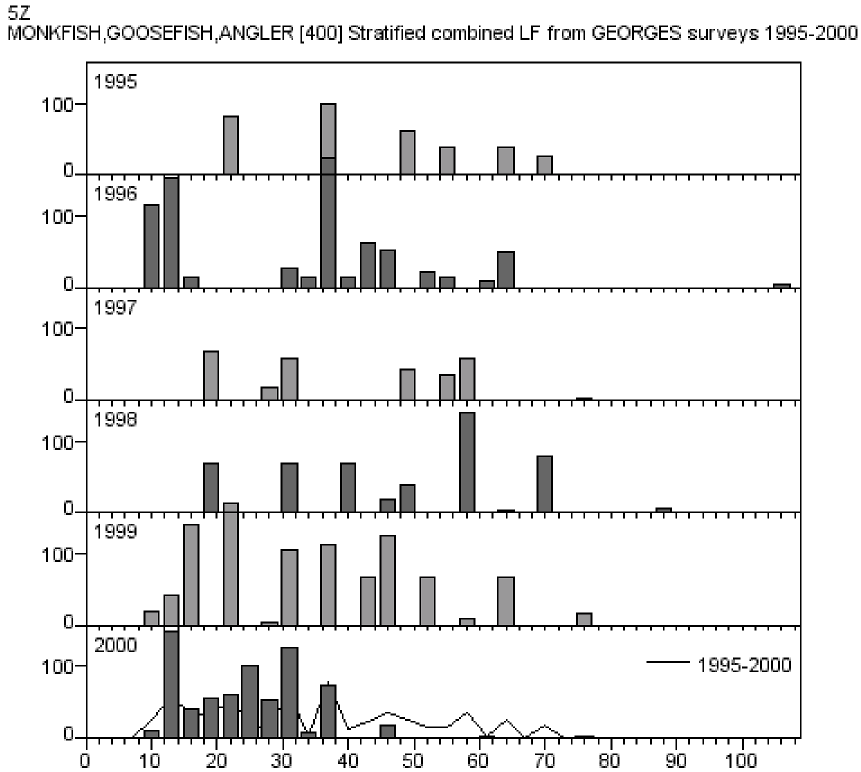



Fig. 19. Monkfish length frequencies from Georges Bank February research vessel surveys.

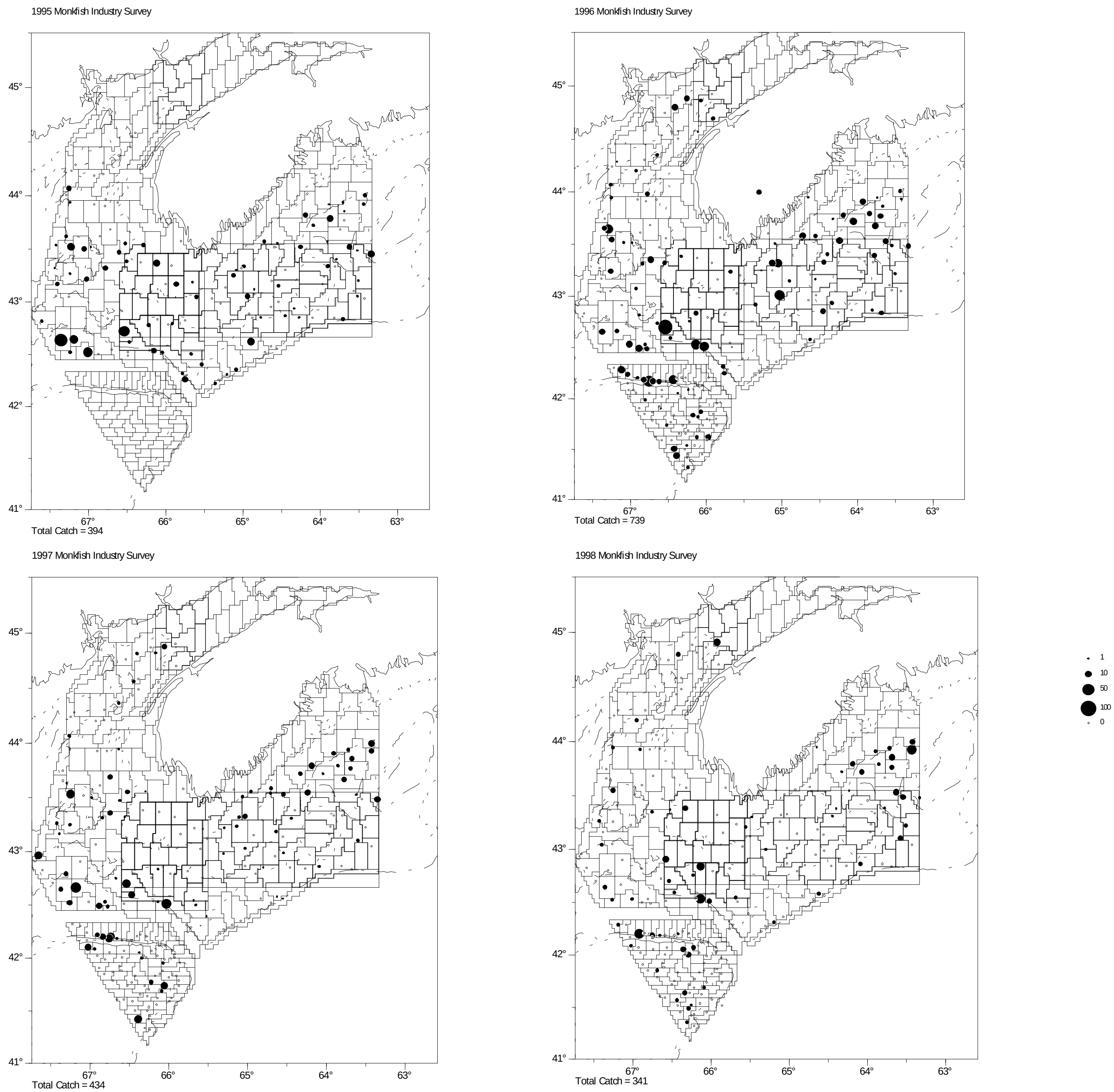



Fig. 20. Distribution of catches from industry surveys in 4x and 5Zc.

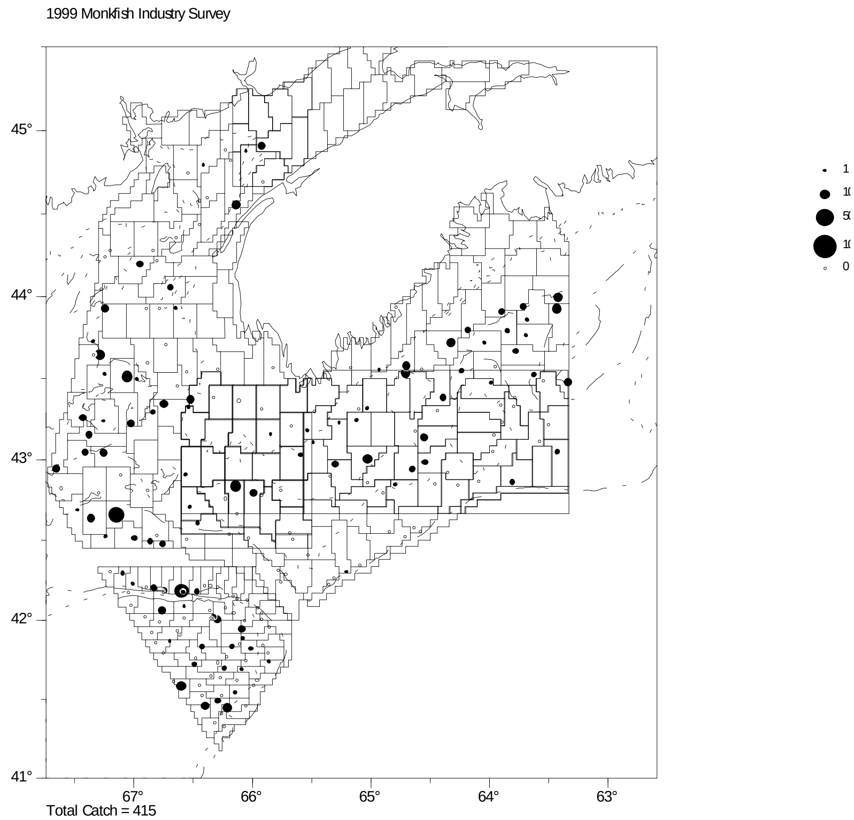



Fig. 20. (continued)

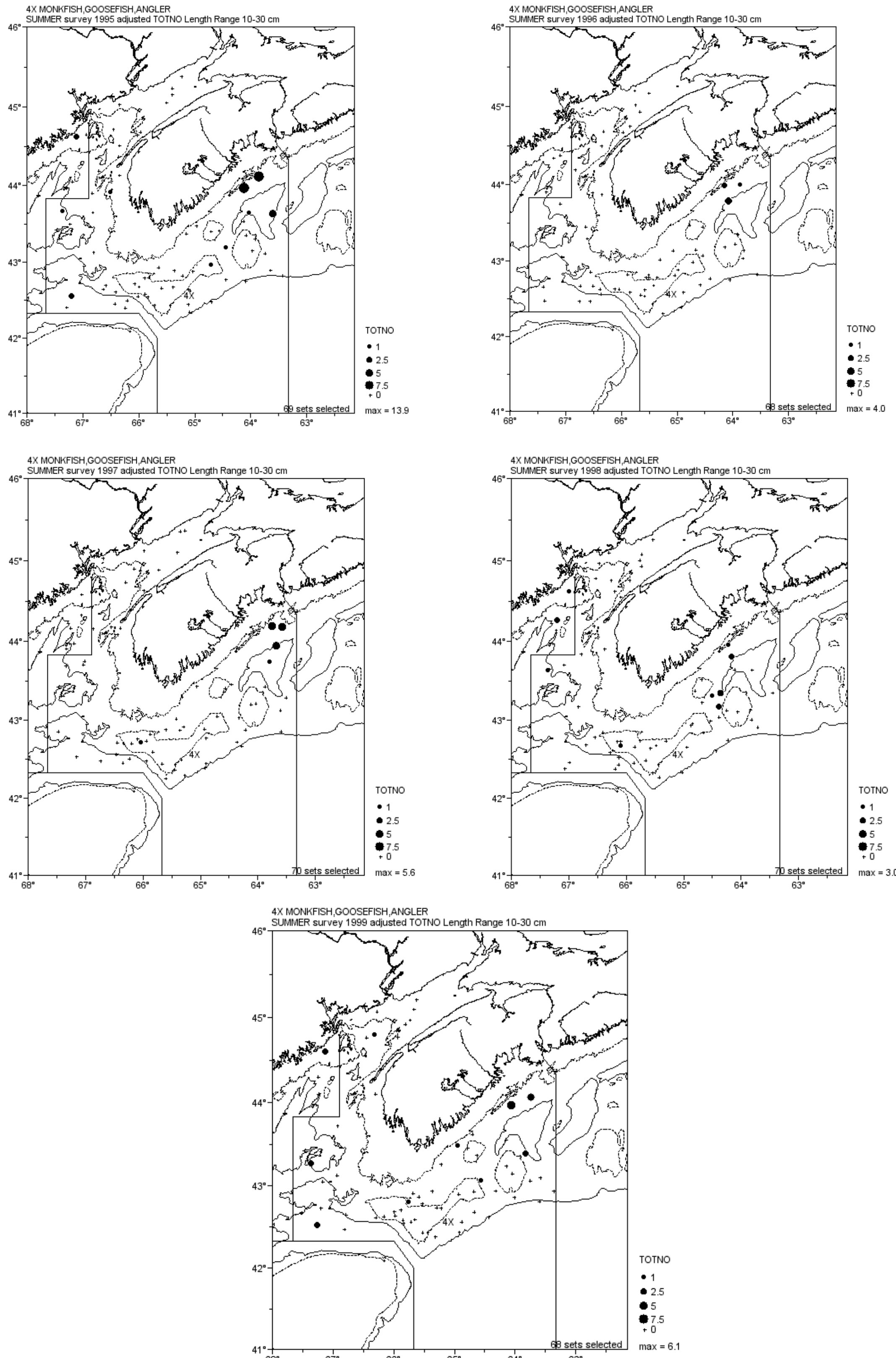
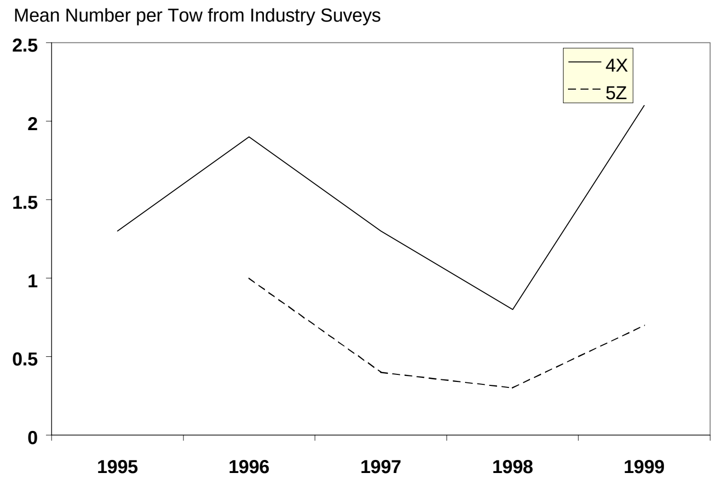
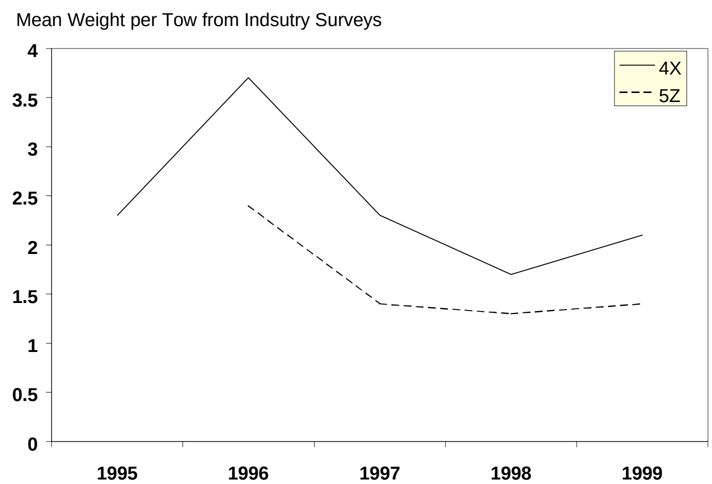


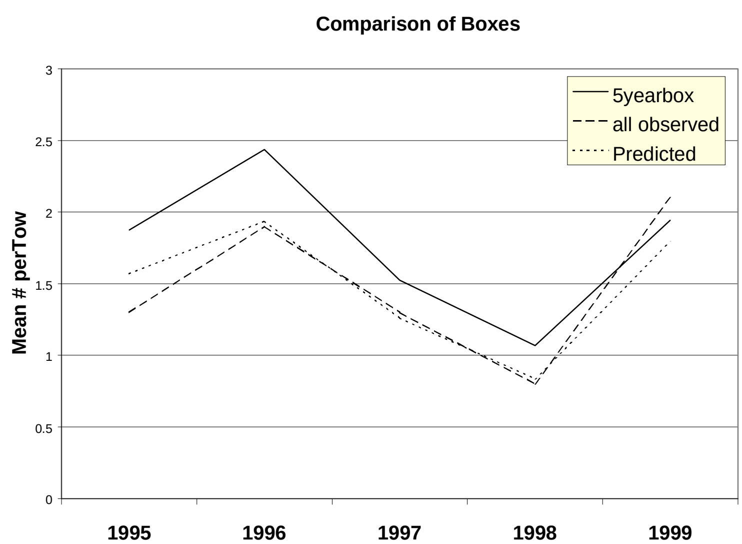

Fig. 21. Locations of 10 - 30 cm monkfish from the 4X industry survey.




a.

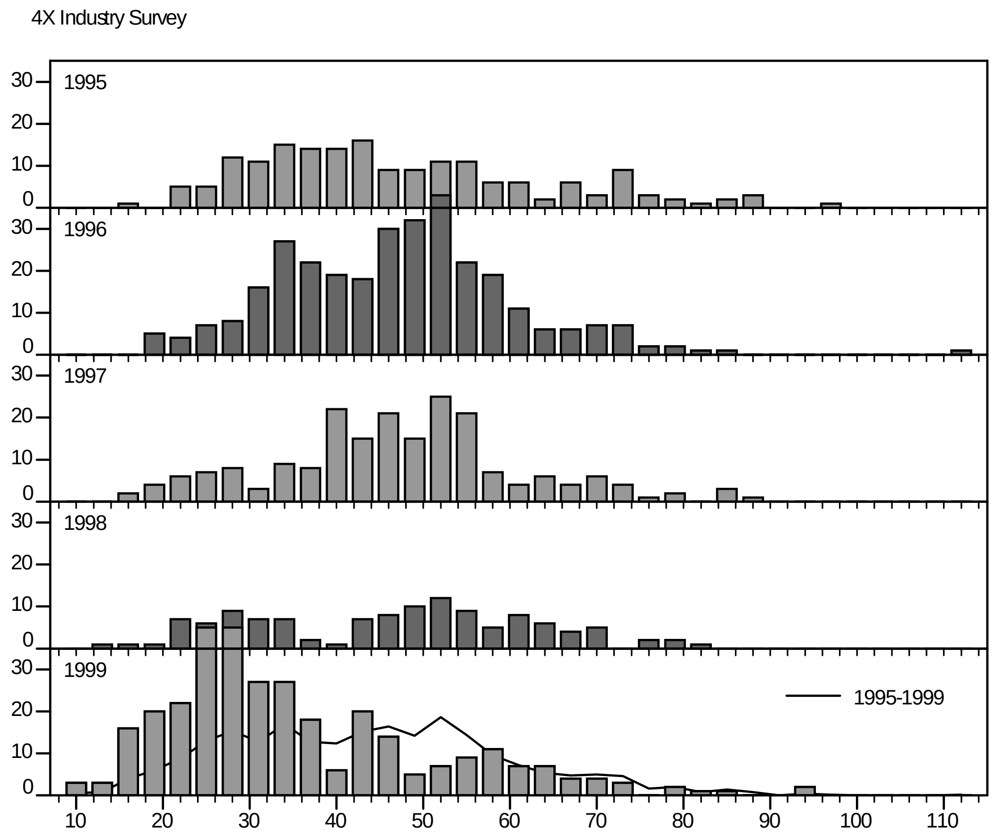



b.

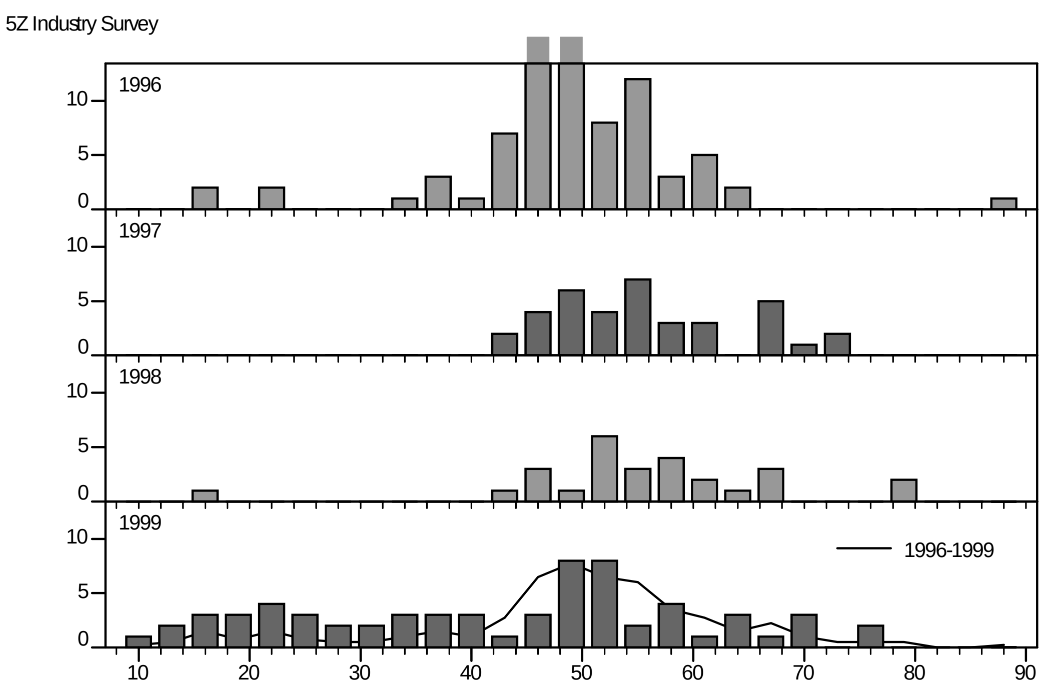



c.

Fig. 22a,b,c. Catch rates from monkfish industry survey.

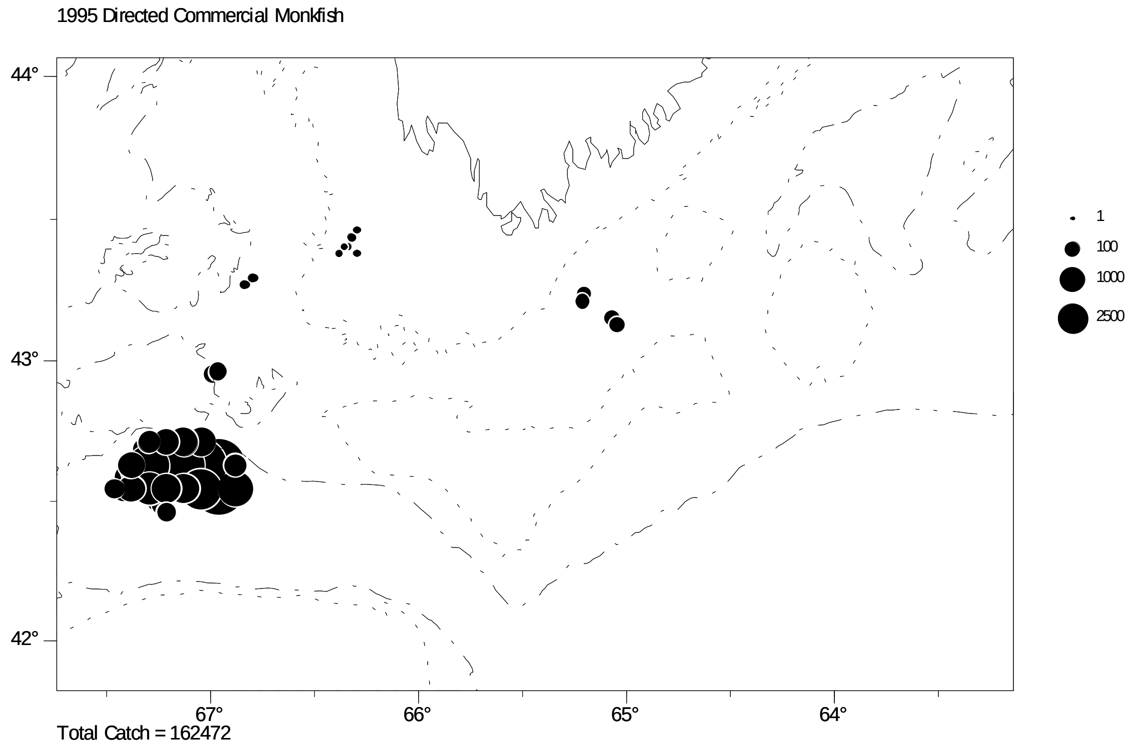



a.




b.

Fig. 23a,b. Industry survey length frequencies from 4X and Georges Bank.



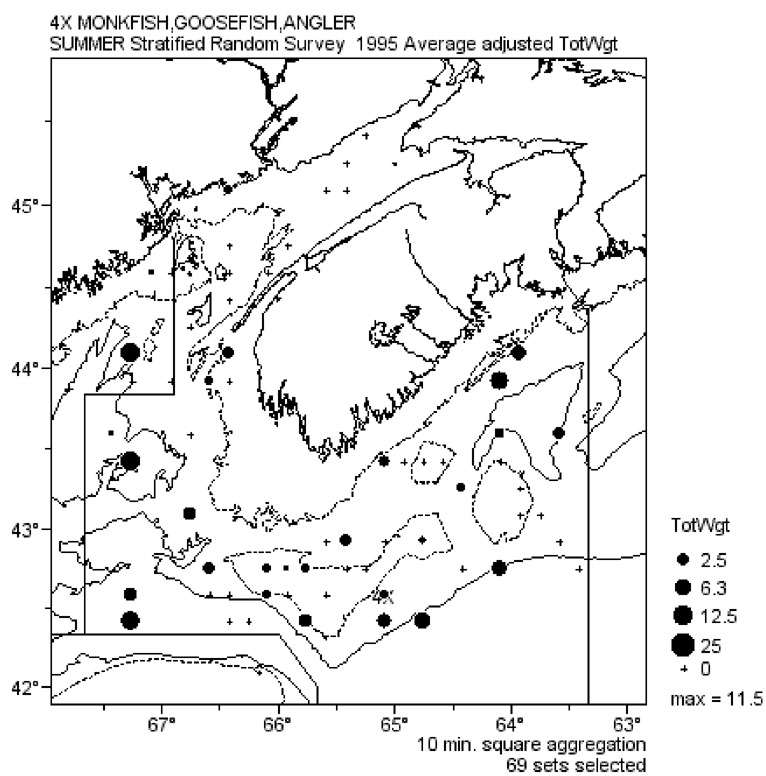
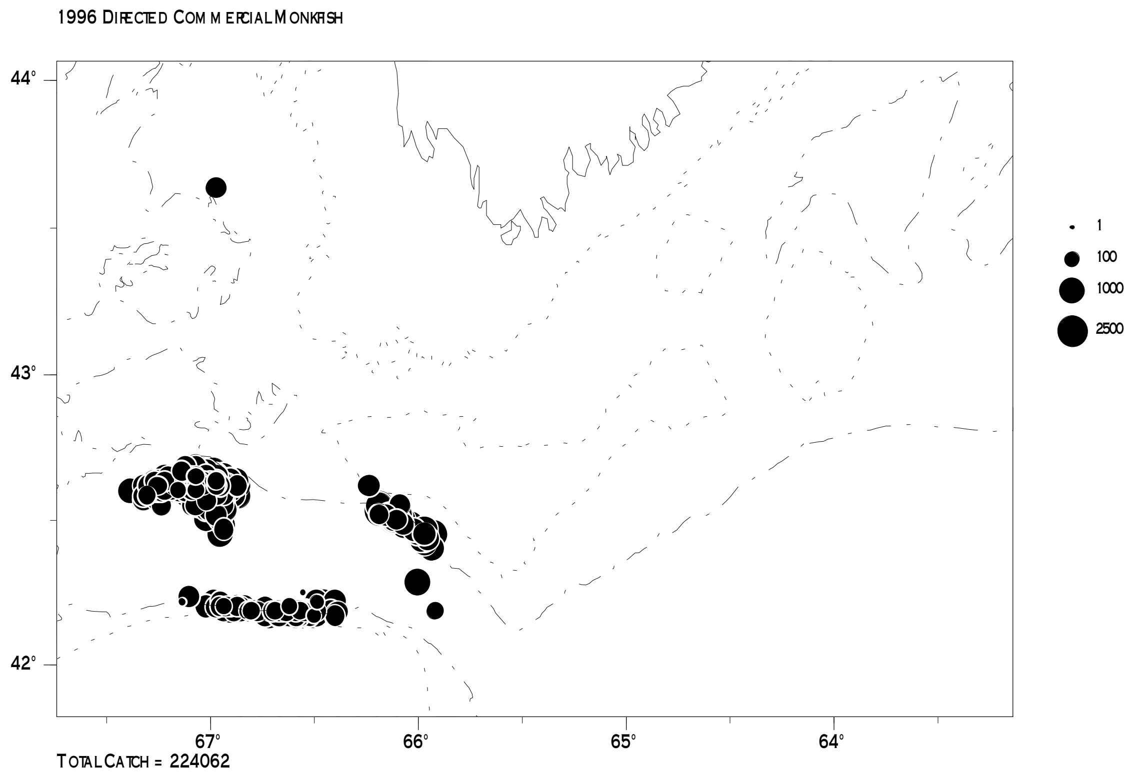




Fig. 24. Location of the directed fishery compared to RV survey (in kgs).


1996 DIRECTED COMMERCIAL MONKFISH
44°
43°
42°
67°
66°
65°
64°
1
100
1000
2500
TOTAL CATCH = 224062

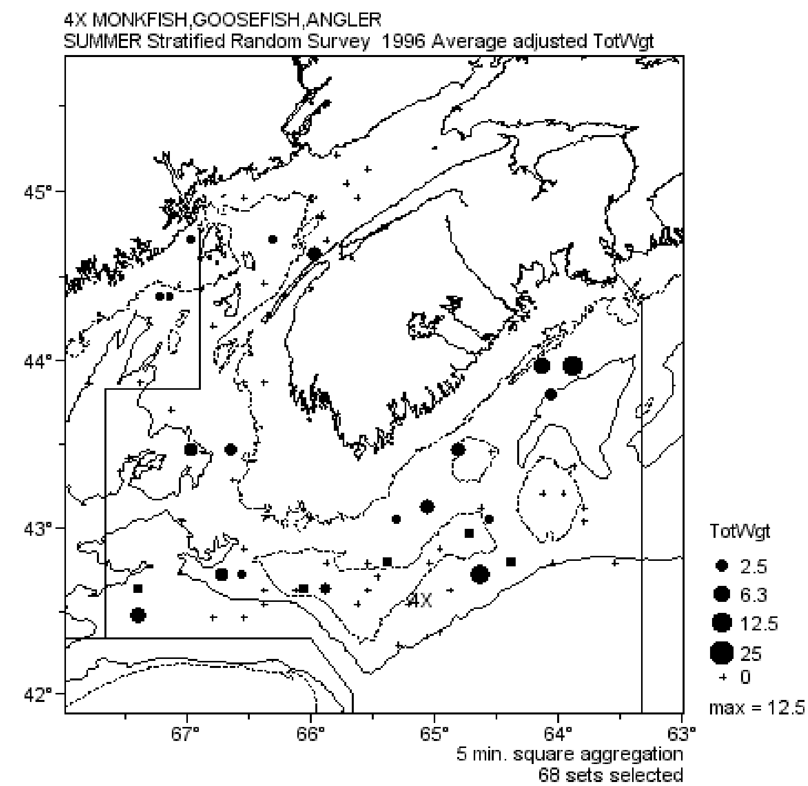
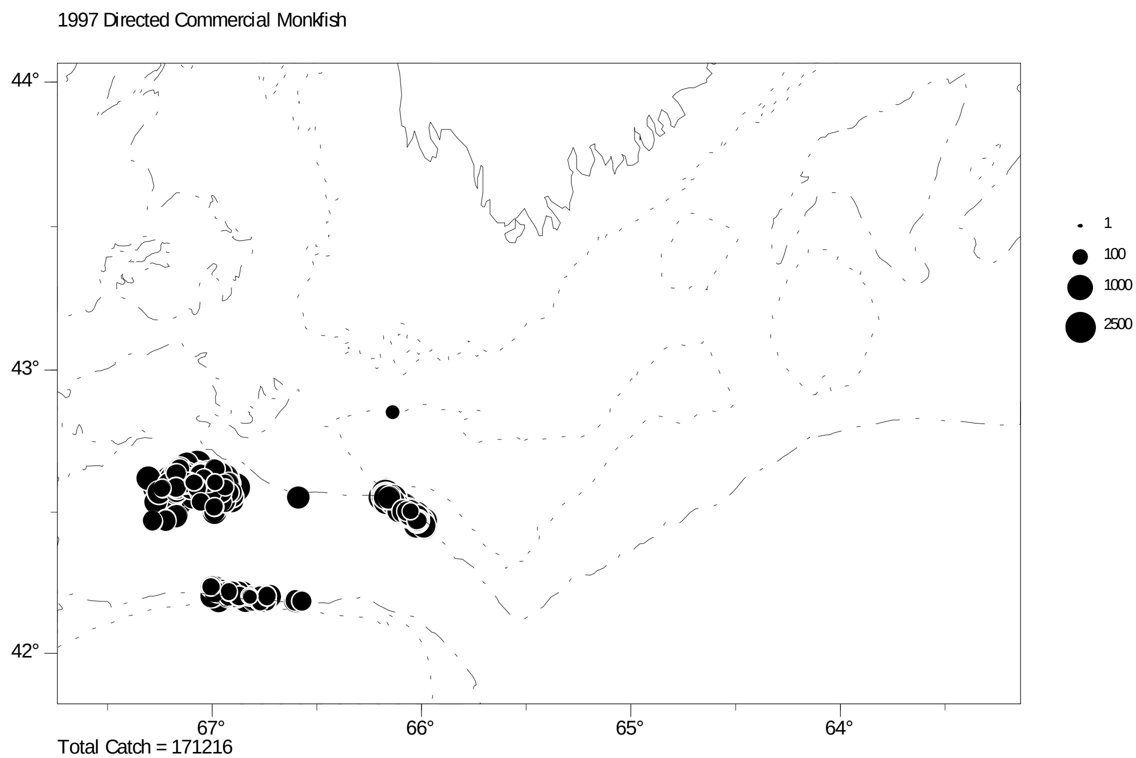

4X MONKFISH,GOOSEFISH,ANGLER
SUMMER Stratified Random Survey 1996 Average adjusted TotWgt
45°
44°
43°
42°
67°
66°
65°
64°
63°
4X
TotWgt
2.5
6.3
12.5
25
0
max = 12.5
5 min. square aggregation
68 sets selected

Fig. 24. (cont.)


1997 Directed Commercial Monkfish
44°
43°
42°
67°
66°
65°
64°
1
100
1000
2500
Total Catch = 171216

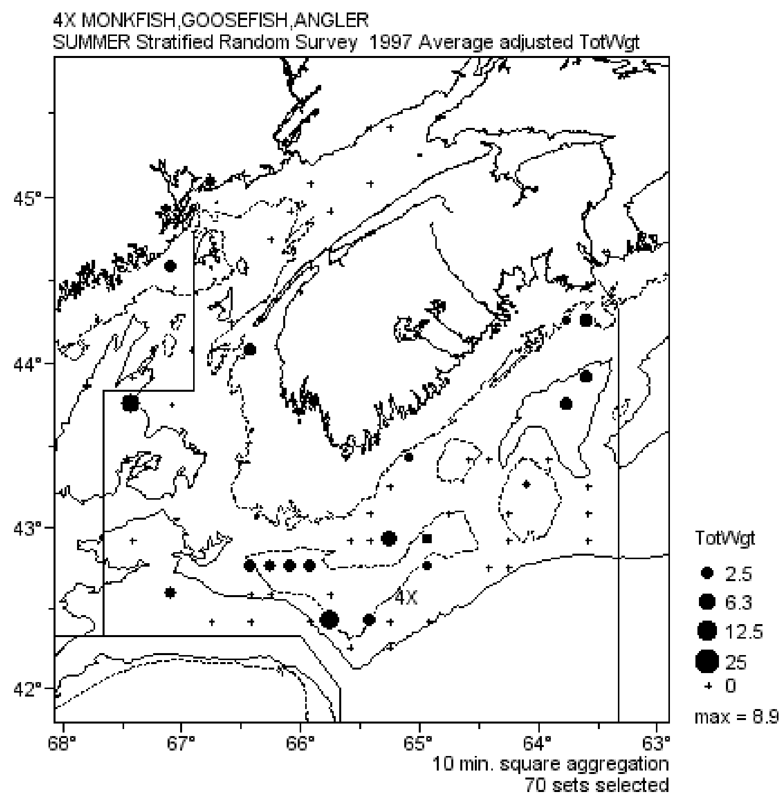
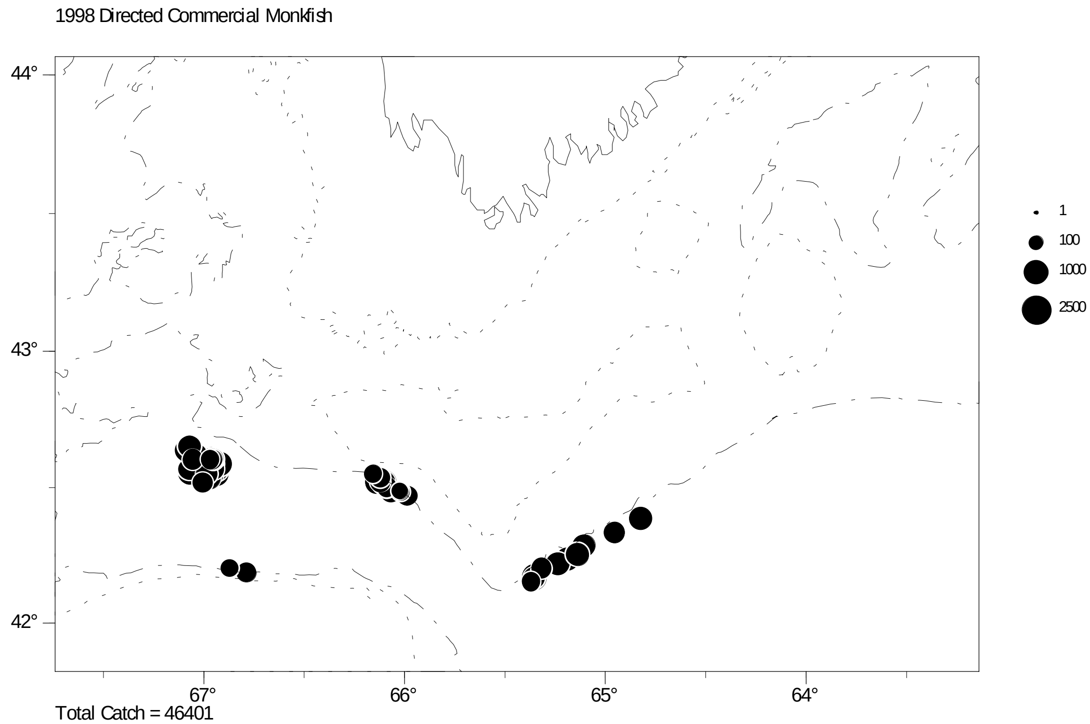

4X MONKFISH,GOOSEFISH,ANGLER
SUMMER Stratified Random Survey 1997 Average adjusted TotWgt
45°
44°
43°
42°
68°
67°
66°
65°
64°
63°
4X
TotWgt
2.5
6.3
12.5
25
0
max = 8.9
10 min. square aggregation
70 sets selected

Fig. 24. (cont.)


1998 Directed Commercial Monkfish
44°
43°
42°
67°
66°
65°
64°
Total Catch = 46401
1
100
1000
2500

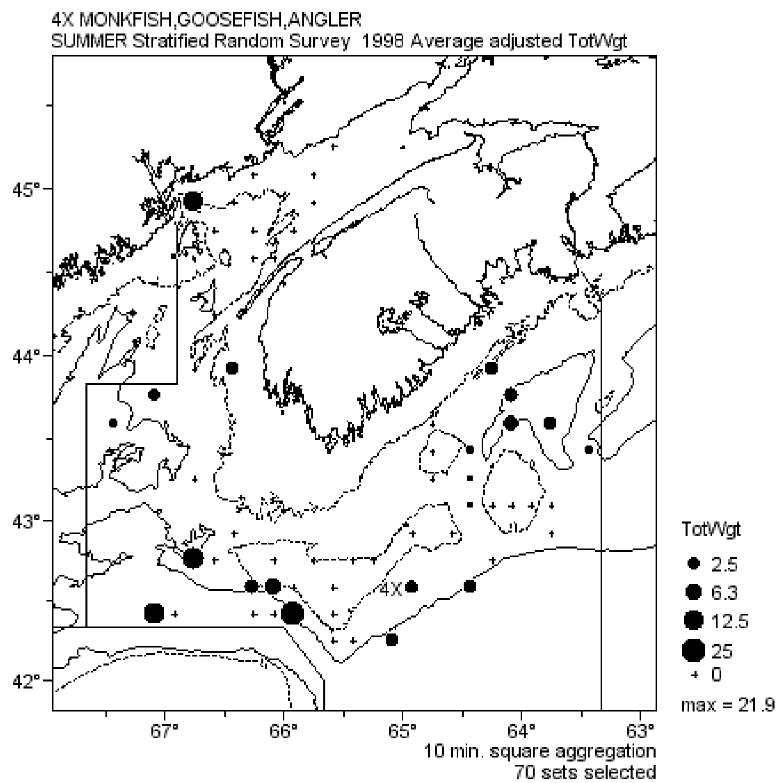
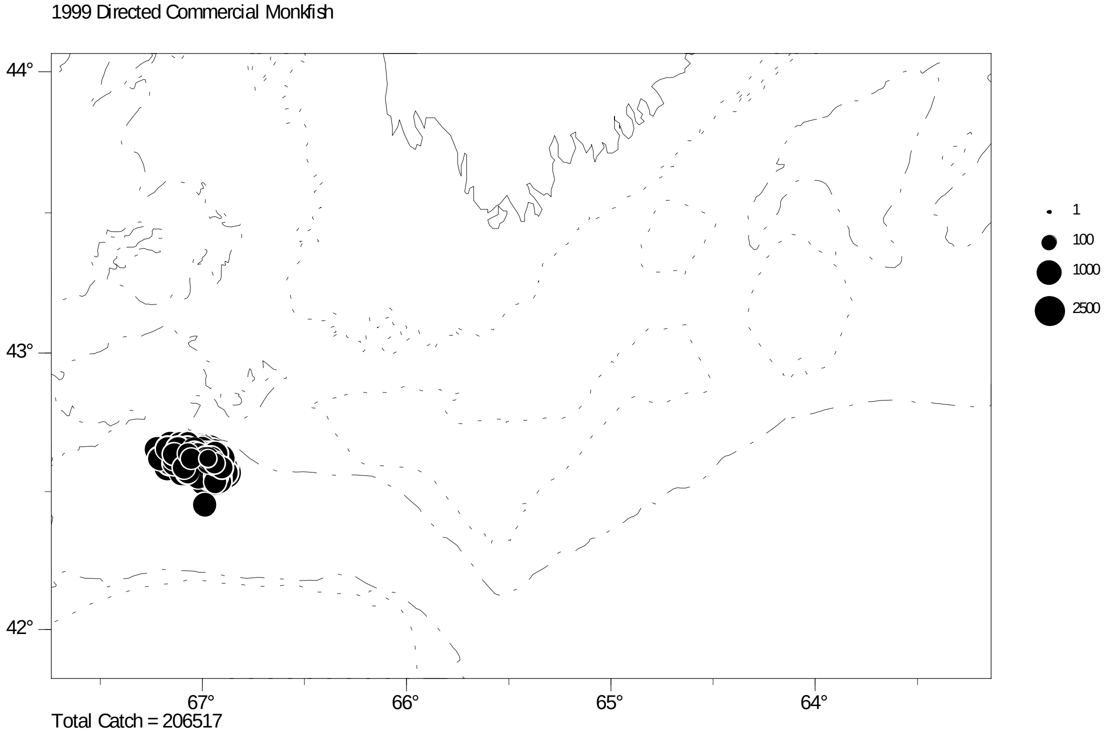

4X MONKFISH,GOOSEFISH,ANGLER
SUMMER Stratified Random Survey 1998 Average adjusted TotWgt
45°
44°
43°
42°
4X
67°
66°
65°
64°
63°
10 min. square aggregation
70 sets selected
TotWgt
2.5
6.3
12.5
25
0
max = 21.9

Fig. 24. (cont.)


1999 Directed Commercial Monkfish
44°
43°
42°
67°
66°
65°
64°
1
100
1000
2500
Total Catch = 206517

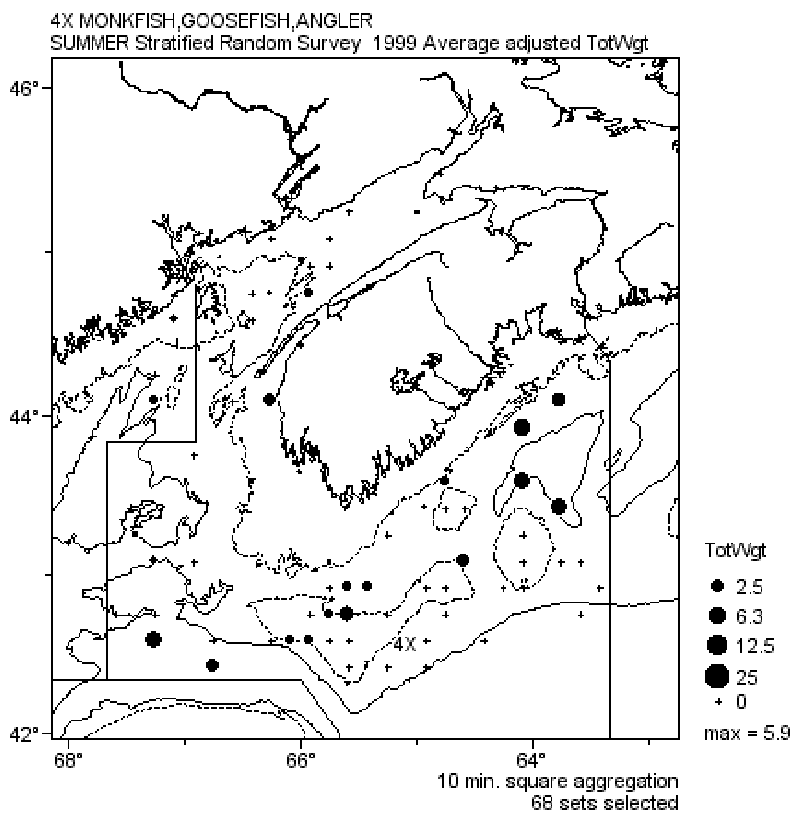
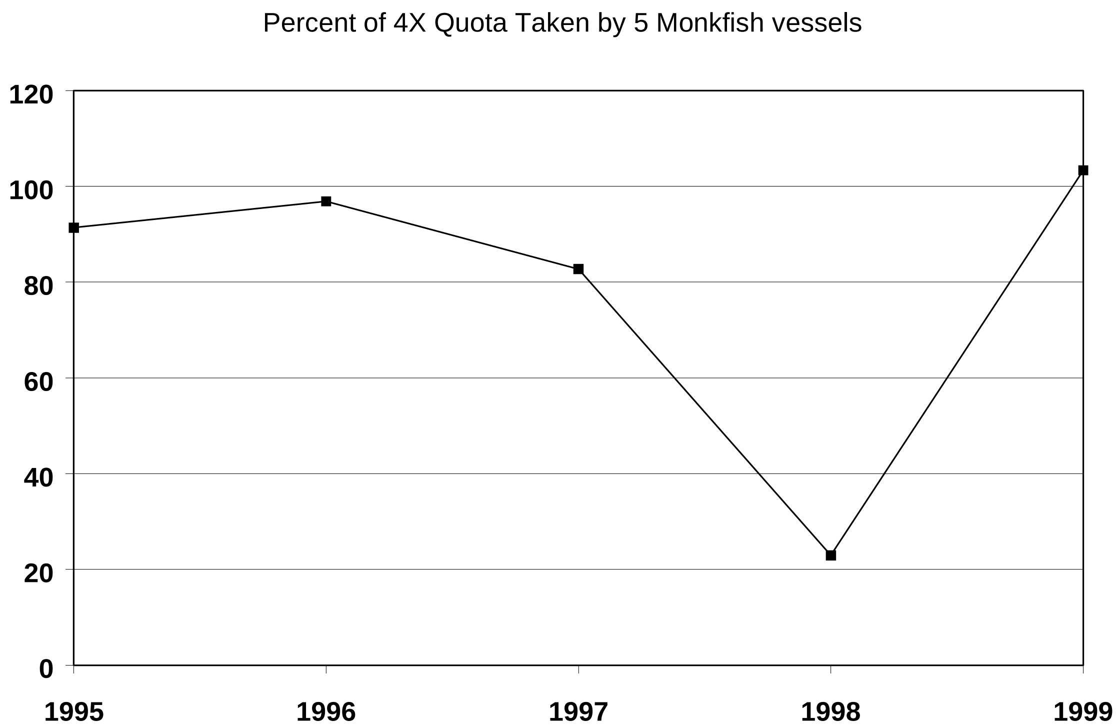

4X MONKFISH,GOOSEFISH,ANGLER
SUMMER Stratified Random Survey 1999 Average adjusted TotWgt
46°
44°
42°
68°
66°
64°
4X
TotWgt
2.5
6.3
12.5
25
0
max = 5.9
10 min. square aggregation
68 sets selected

Fig. 24. (cont.)



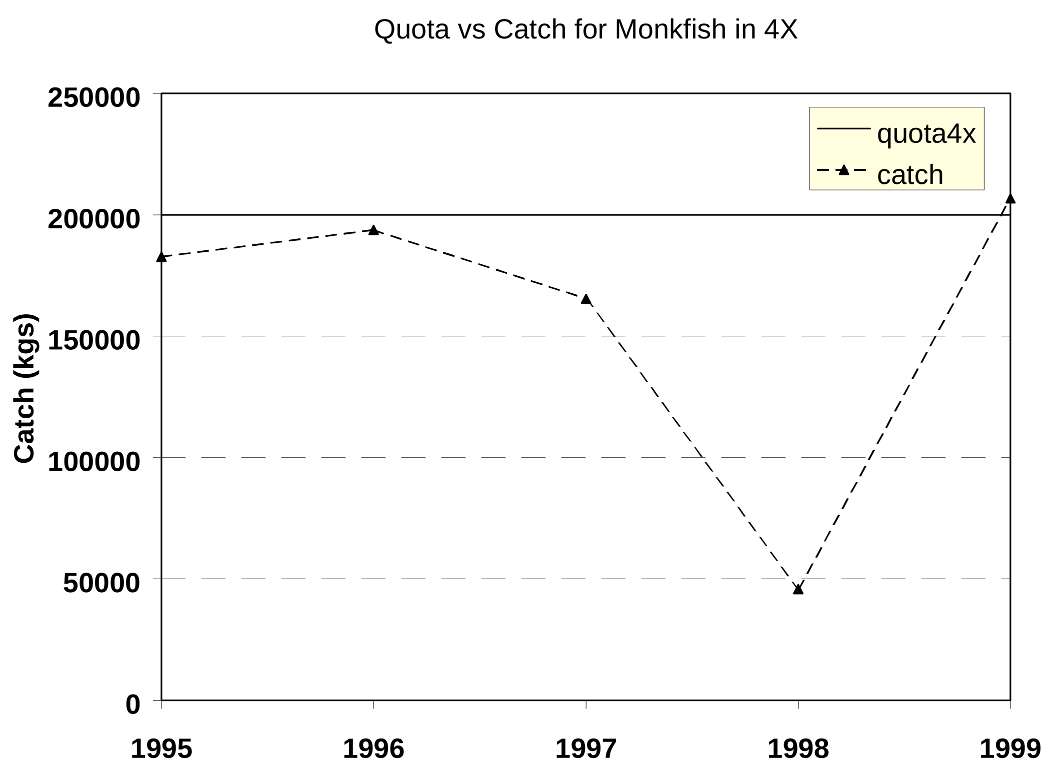
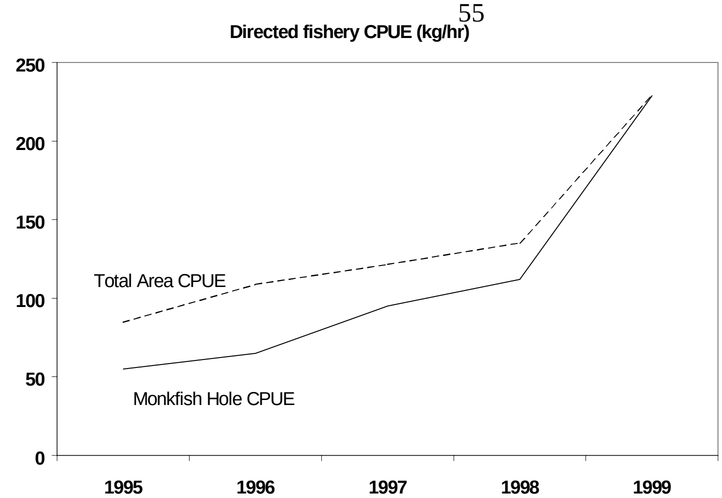
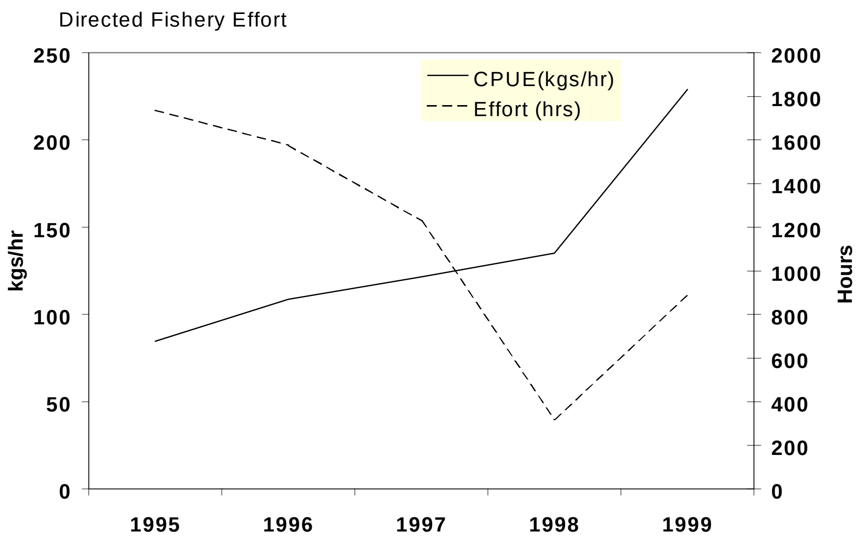



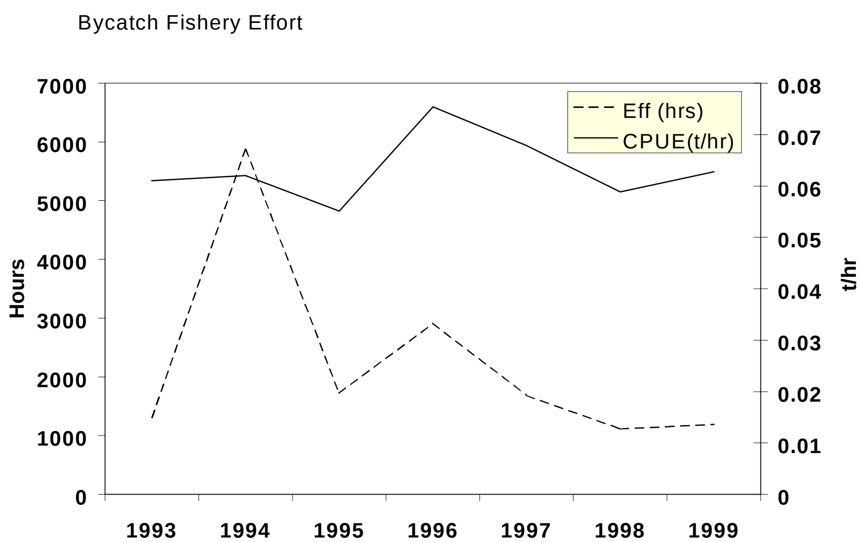

Fig. 25. Quota and catch for the directed monkfish fishery.




a.




b.




c.

Fig. 26a,b,c. CPUE and effort series for commercial and directed fisheries

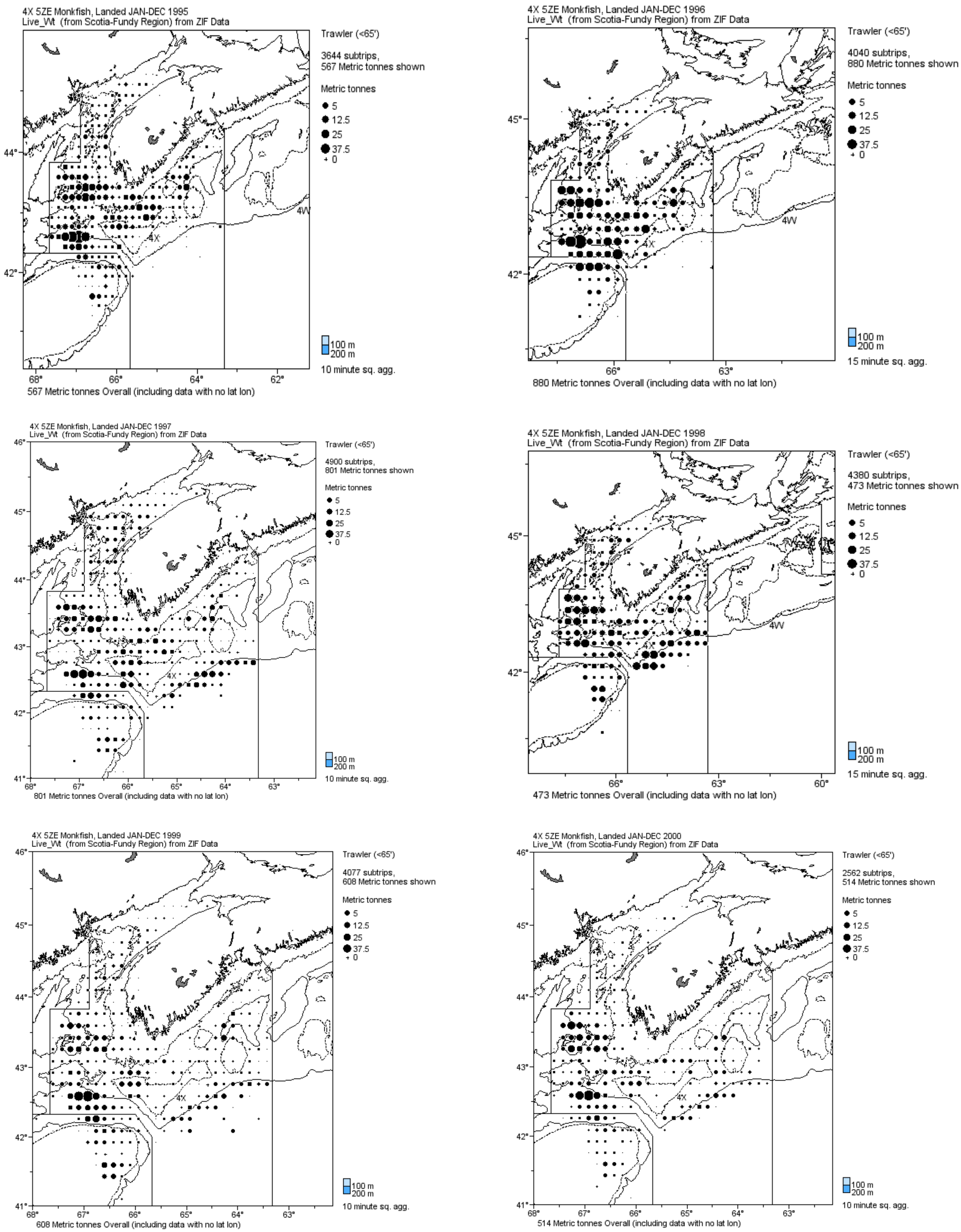



Fig. 27. Landings by mobile gear fleet < 65' in 4X. (Note: 2000 is to Aug. 30 only)

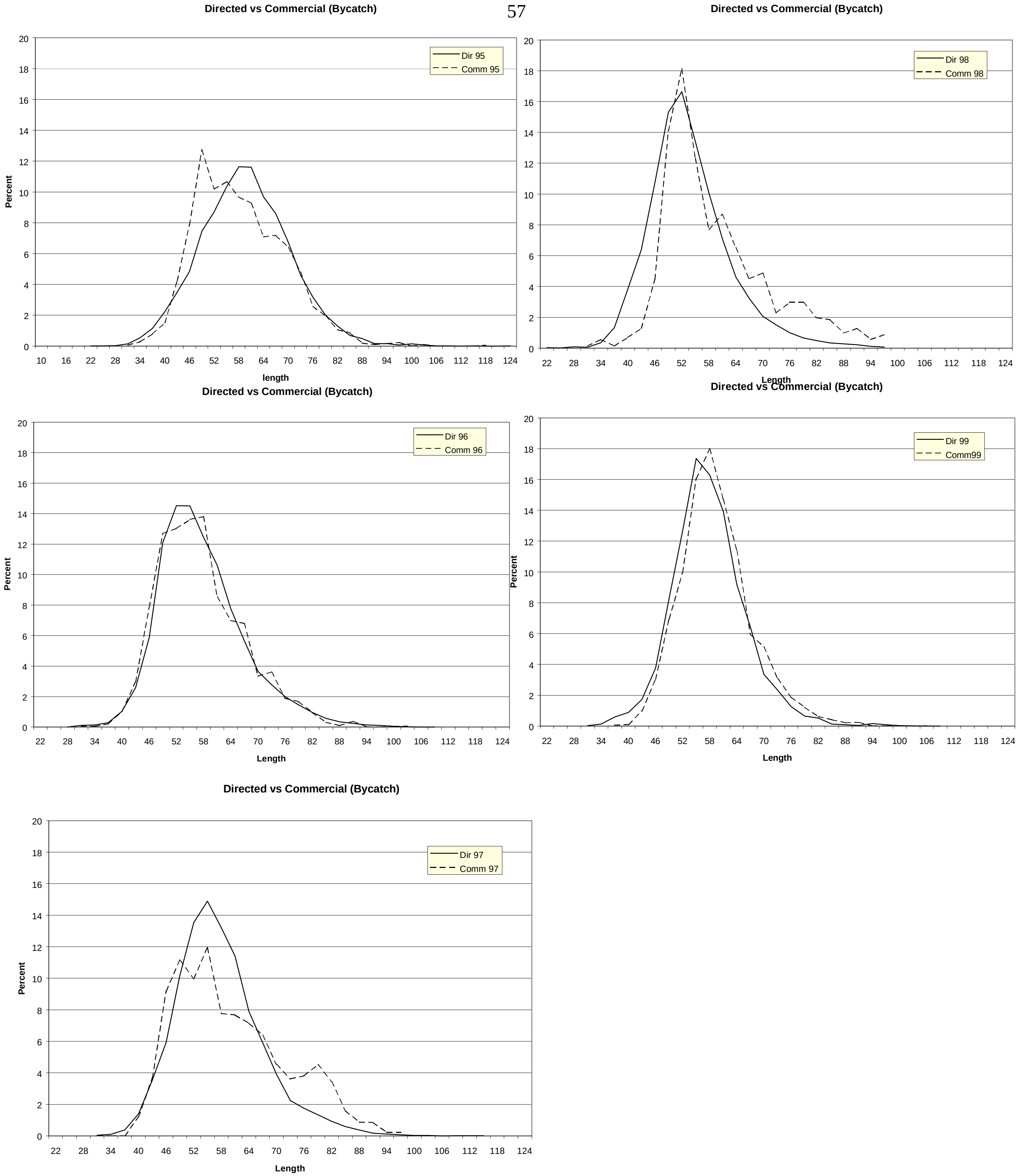
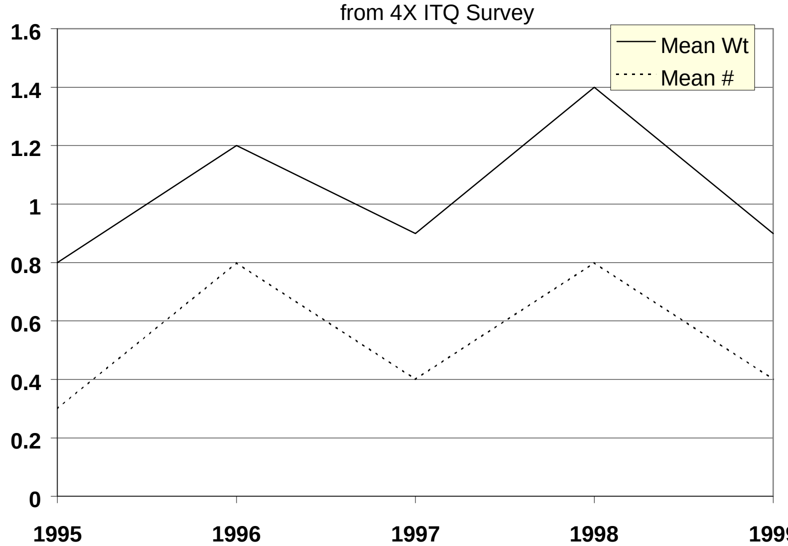
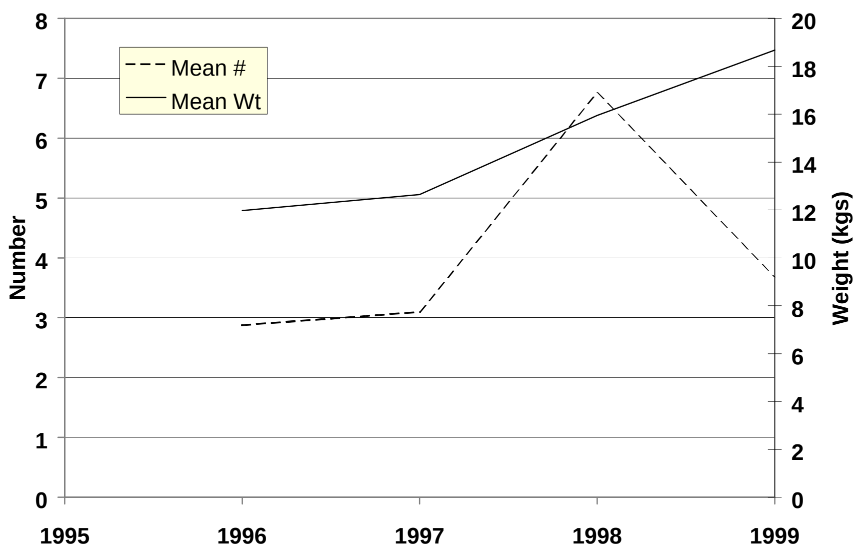



Fig. 28. Comparison of directed (203 mm) and commercial (130 mm) fisheries.

Mean Weight and Number per Tow for Monkfish
from 4X ITQ Survey

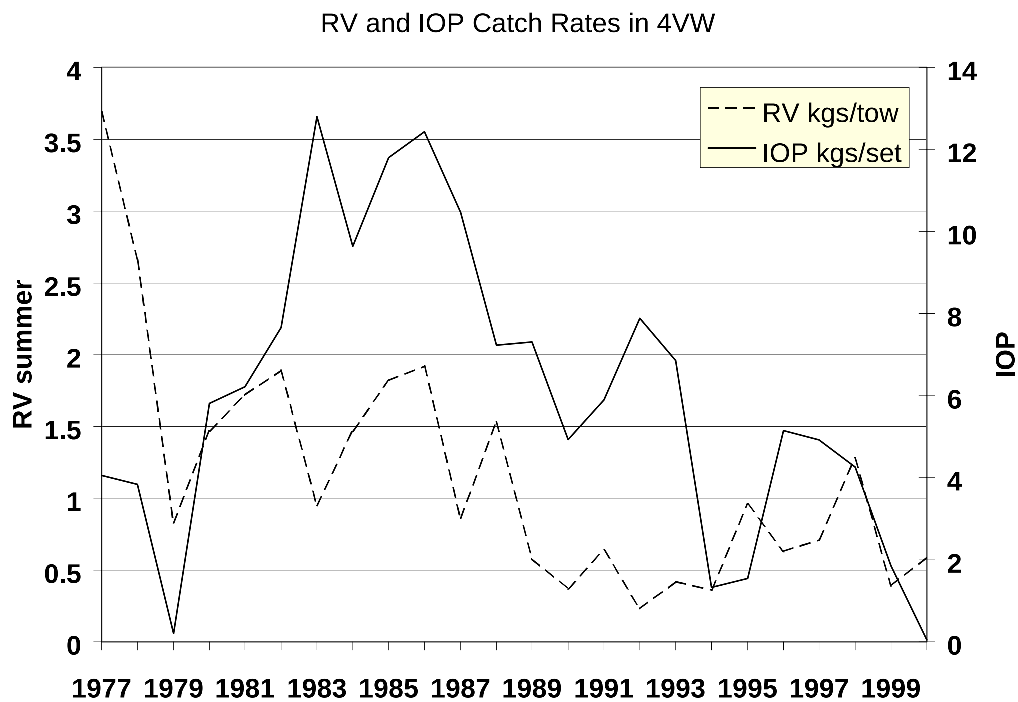



Stratified Mean # and Weight from Sentinel Survey




Mean Weight per Tow from Skate Surveys


Fig. 29. Catch rates from other industry surveys.



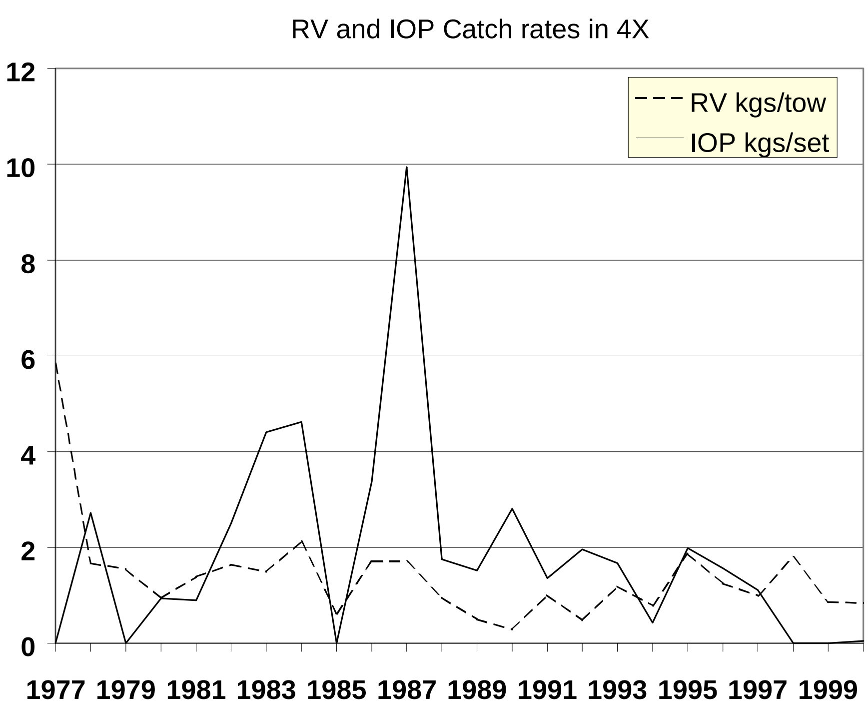




Fig. 30. Comparison of RV and IOP catch rates

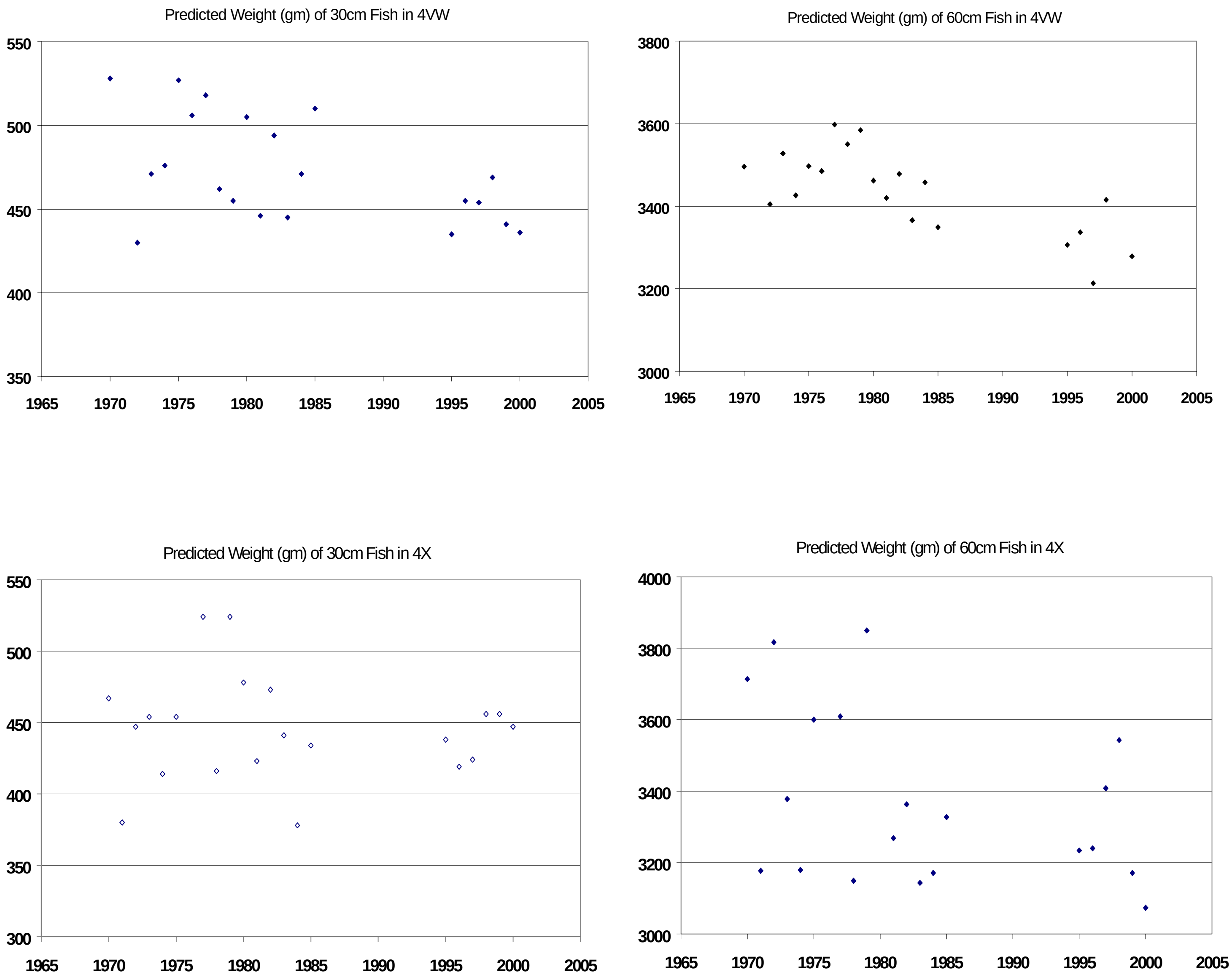



Fig. 31. Condition factor for 30cm and 60cm monkfish from summer research vessel survey.

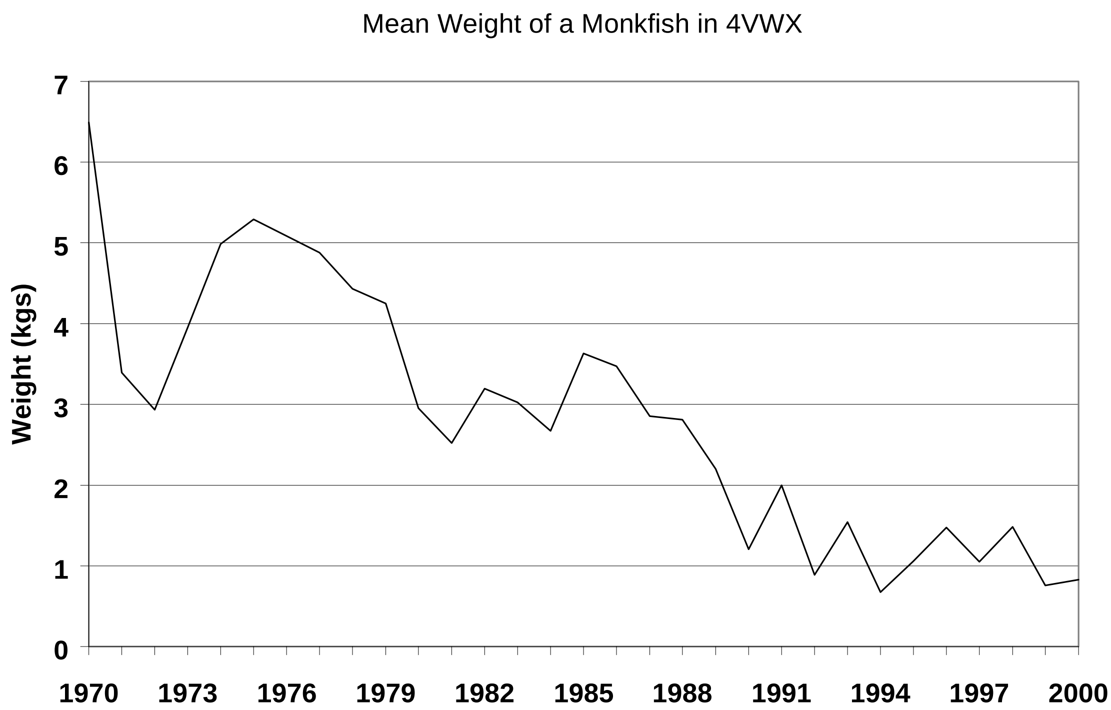



Fig. 32. Mean weight of a monkfish in 4VWX from summer RV surveys.

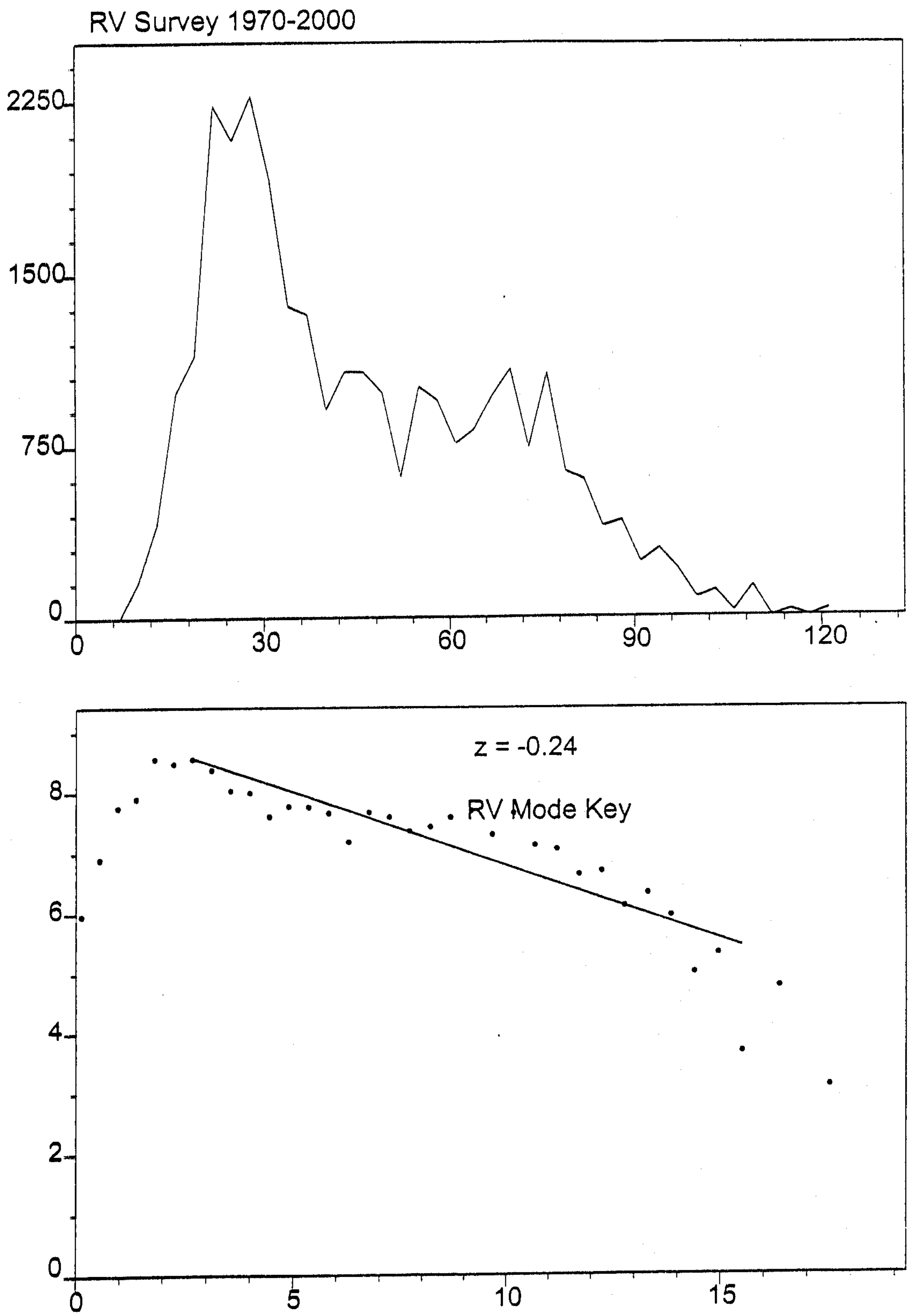
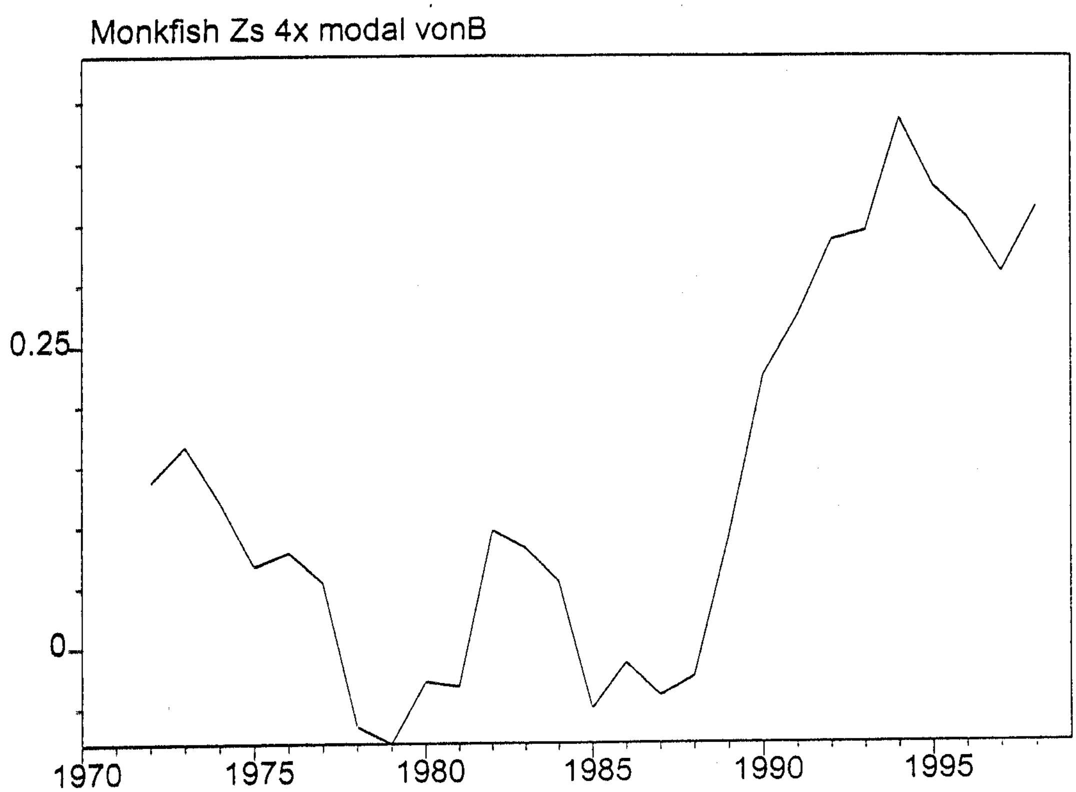



Fig. 33. Estimates of total mortality. In the upper graph, frequency is plotted against length. In the lower graph, the log (frequency) is plotted against predicted age.



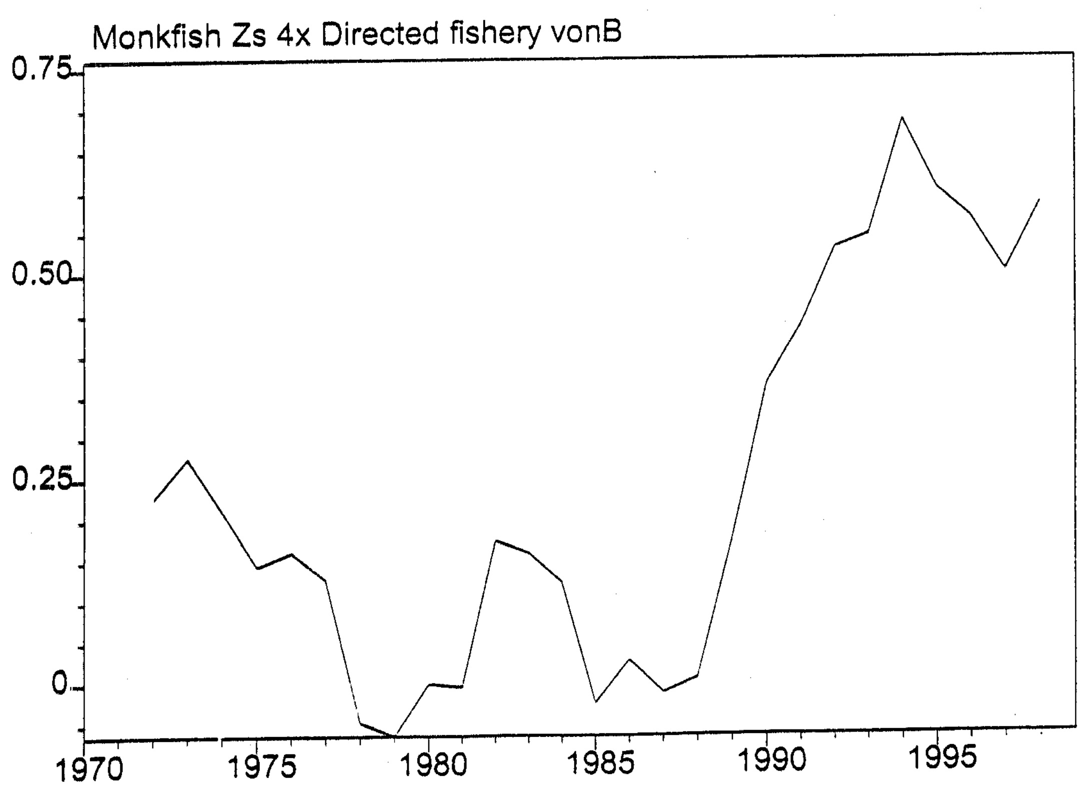




Fig. 34 a,b. Results of Catch Curve Analysis.

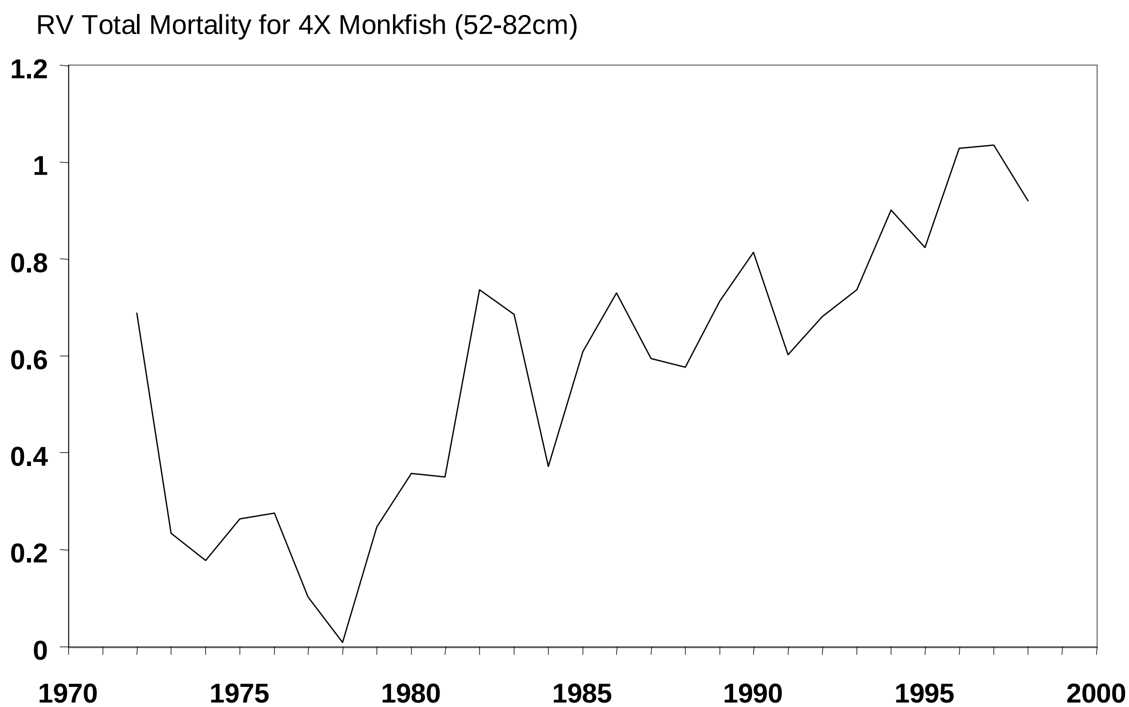



Fig. 35. Results of catch curve analysis on mature fish only.

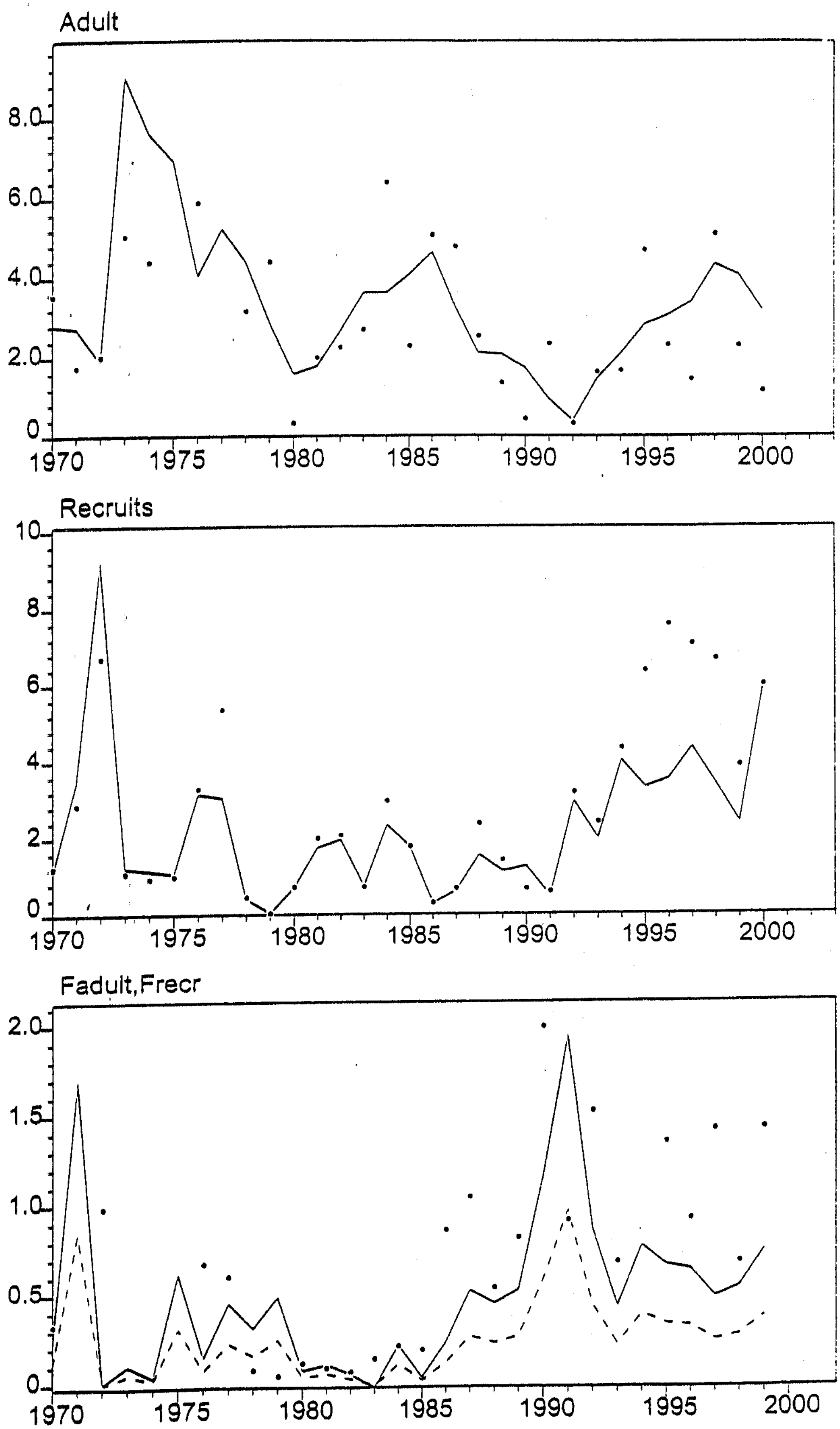



Fig. 36. Results of Conser's production model.

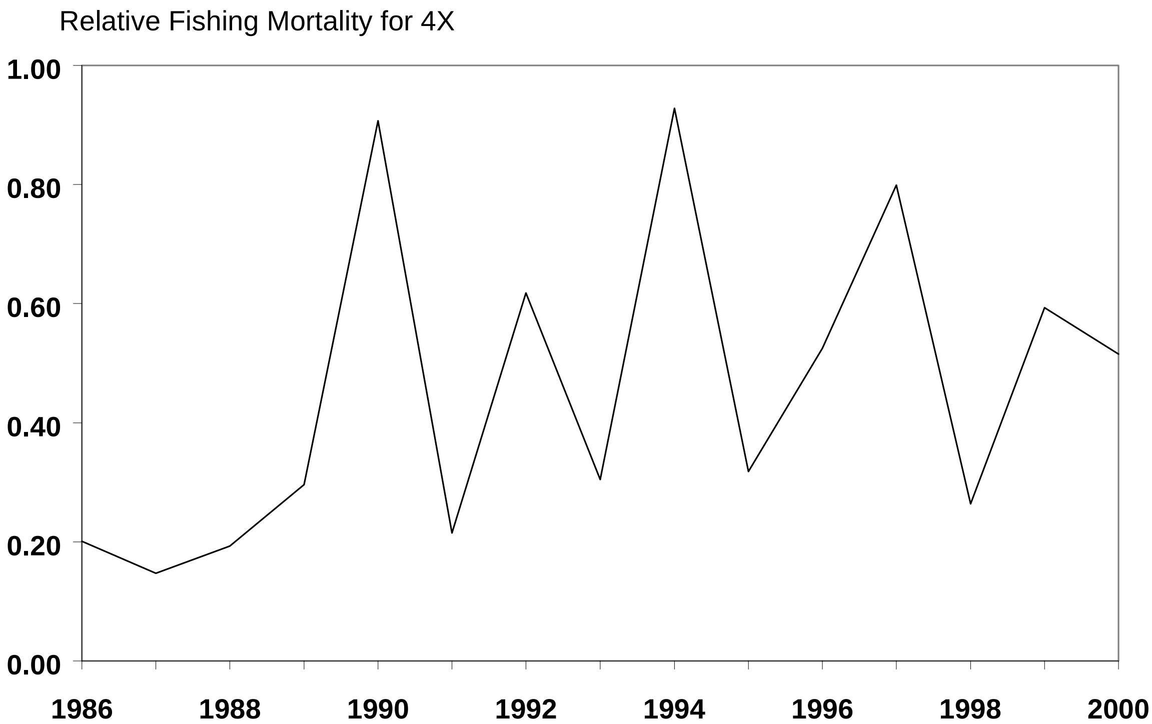



Fig. 37. Relative fishing mortality for monkfish in 4X.

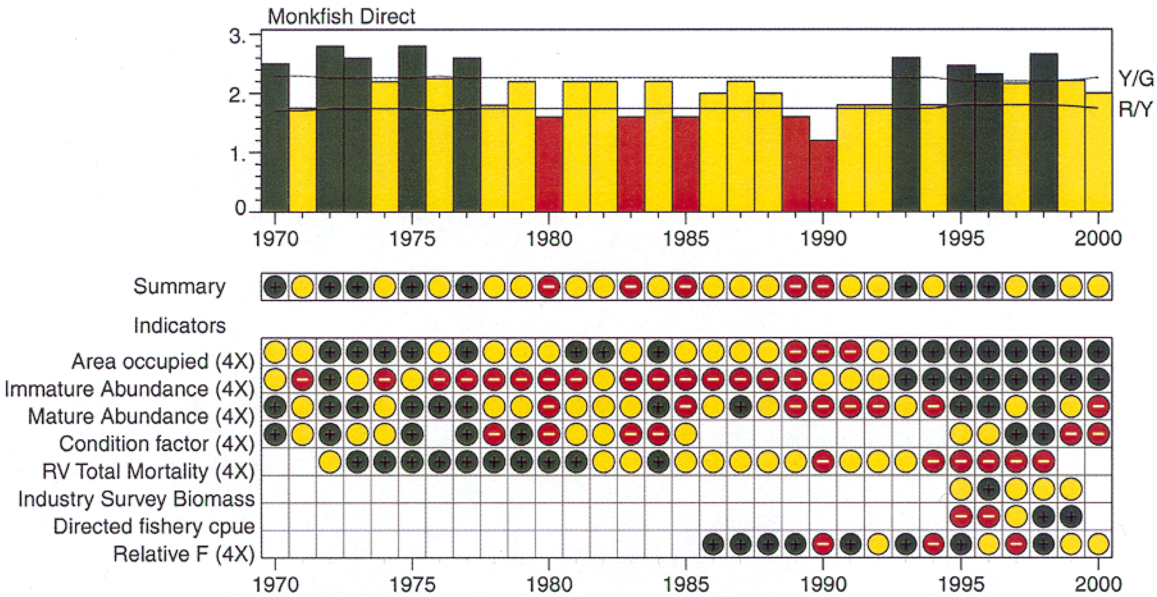



Fig. 38. Traffic Light Table for Monkfish from 4X. Green values ⊕ are good, Red values ⊖ are bad and Yellow values ● indicate caution.