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Status of Atlantic Wolffish (*Anarhichas lupus*) in the Maritimes (NAFO Sub-Area 4 and 5)

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Abstract

Recent concerns about declines in research vessel catches of wolffishes in Newfoundland waters prompted an examination of the available data collected in NAFO (Northwest Atlantic Fisheries Organization) Sub-areas 4 and 5. Research vessel surveys show that Atlantic wolffish in Sub-area 4 have increased in abundance through the 1990's. This is due to large numbers of small fish throughout the area. Adult abundance and biomass however, are presently low in Divisions 4VWX and 4T. Wolffish grow slowly and do not mature until the age of 10 or 11 years, so the recent good recruitment has not yet matured and entered the adult statistics. Fishing mortality has been low in recent years and should be kept low until the mature biomass has improved.

Résumé

Les baisses inquiétantes des quantités de loups atlantiques capturés récemment par les navires de recherche dans les eaux terre-neuviennes ont entraîné un examen des données connexes recueillies dans les sous-zones 4 et 5 de l'OPANO (Organisation des pêches de l'Atlantique nord-ouest). Des relevés de navires de recherche montrent que l'abondance du loup atlantique dans la sous-zone 4 a augmenté au cours des années 90 en raison du grand nombre de petits poissons dans ce secteur. Par contre, l'abondance et la biomasse des adultes sont faibles actuellement dans les divisions 4VWX et 4T. Comme les loups atlantiques croissent lentement et n'atteignent pas la maturité avant l'âge de 10 ou 11 ans, les poissons constituant le fort recrutement observé récemment n'ont pas atteint la maturité, et ils ne sont donc pas encore comptabilisés dans les statistiques sur les adultes. La mortalité par pêche est faible depuis quelques années, et il faudrait la maintenir ainsi jusqu'à ce que la biomasse des adultes augmente.

Introduction

Recent concerns about declines in research vessel catches of wolffishes in Newfoundland waters prompted an examination of the available data collected in NAFO (Northwest Atlantic Fisheries Organization) Sub-areas 4 and 5. Although there are three species of wolffish found in the northwest Atlantic, the Atlantic wolffish (*Anarhichas lupus)* is thought to be the most prevalent in catches in these subareas shelf (Scott and Scott1988). In contrast, both Atlantic and spotted wolffish (*Anarhichas minor)* have been reported in the landings off eastern Newfoundland. Wolffish landings in Sub-area 4 have been primarily as by-catch, and the species is of limited commercial importance. Although common in Scotian Shelf catches, the Atlantic wolffish has not been considered abundant (Scott 1982).

This research document describes the information from the fishery and the research that was used in the stock assessment of Atlantic wolffish. Thus, this document is complementary to the DFO Stock Status Report A3-31(2000).

Natural History

The Atlantic wolffish is a large demersal fish found across the North Atlantic. In the northwest Atlantic, they are found at West Greenland and from Labrador to Cape Cod (Fig. 1), in shallow coastal waters to depths of over 350 meters. On the Scotian Shelf, Grand Banks and the Gulf of St. Lawrence, depths less than 150 meters are favored, while in eastern Newfoundland they are found in depths of 100 to 350 meters. Atlantic wolffish tolerate a wide range of temperatures from -1^{o}C to 10^{o}C (Smidt 1981). Preferred bottom conditions on the Scotian Shelf are 3^{o}C to 6^{o}C in depths of 73 to 126 m and a salinity range of 32 to 34 parts per thousand (Albikovskaya 1982). Nothing is known of their stock structure.

The Atlantic wolffish is a non-schooling species that lives close to the bottom over hard substrates (rarely over mud), and is not known to make long migrations. In tagging studies conducted by Templeman (1984), the majority of recaptures were from within 8.0 km of the original tagging site. Kohler (1968) described seasonal inshore movements during the spring on the Scotian Shelf, and Keats et al. (1985) reported similar movements in coastal waters off Newfoundland, presumably for spawning. Keats et al. (1985) concluded that Atlantic wolffish less than 50 cm long inhabit depths greater than 30 m and do not enter shallow inshore waters until sexually mature. Sæmundsson (1949) also reported seasonal inshore-offshore migrations in Icelandic waters.

The Atlantic wolffish is not considered to be highly fecund but the survival of its well-developed eggs is usually high. The large, cohesive eggs range in size from 5.5 to 6.5 mm (Bigelowa and Schroeder.1953), and are laid in a mass adhering to rocks and gravel. They are guarded by an adult male until they hatch at about 17 to 18 mm in size. The transparent pelagic larvae remain close to the bottom until the yolk sac is absorbed. Later they may drift with the current but generally do not move far from where they were hatched. Spawning occurs over a variety of depths and times. In Newfoundland, Atlantic wolffish spawn in September, in the White Sea in July and in Iceland they spawn in January and February. Powles (1967) reported egg masses in abundance south of LaHave Bank in March and empty egg cases near Sable Island in February. Egg masses can be found in shallow inshore waters and have been reported in depths of 150 to 200 m (Saemundsson 1949).

Atlantic wolffish grow quickly during their first year, but growth rate slows considerably thereafter. Beese and Kändler (1969) showed that fish from sub-arctic waters were 5 years old at an average size of 24 cm, and those 50 cm and larger are at least 10 years old. However, Barsukov (1959) found wolffish were about 43 cm at age 5 and 72 cm at age 10 in the Barr

ents Sea. In Canadian waters, the largest size recorded was 124 cm long and weighed 19.5 kg and fish in excess of 100 cm are not uncommon but specimens up to 152 cm have been recorded (Barsukov 1959).

Atlantic Wolffish feed over rocky bottoms, on whelks, sea urchins, brittle stars, crustaceans, mollusca (shells crushed) (Albikovskaya 1983, Methven, D.A. 1999) and occasionally fish (mainly redfish). Echinoderms are a more important food of young wolffish, becoming less important as the fish grow (Templeman 1985). Little is known of predation on wolfish, but juvenile wolffish have been found in cod stomachs (Saemundsson 1949, Barsukov 1959) and seals (Hammill and Stenson 2000).

Materials and Methods

Commercial landings for foreign and domestic vessels were obtained from NAFO (1960-1999)and ZIF (Zonal Interchange File format, 1986-2000) data files. Atlantic wolffish are recorded in both data sets under generalized wolffish categories; 'wolffishes' (code 188) in NAFO and 'catfishes' (code 174) in ZIF. NAFO data from Sub-area 4 and 5 were used for all foreign landings and for Canadian landings untill 1990, after which ZIF data was used. US landings since 1994 have not yet been reported by NAFO. To estimate these, the landings from Div. 4X were multiplied by the mean of the ratios of landings in Div 5YZ and Div 4X between 1984 to 1993 and have been included in the Sub-area 5 totals from 1994 to 1999.

The spatial and temporal distribution of the commercial fishery (including gear types used) was described using ZIF data.Data with geo-coordiates have been available since 1990. About 54% of the tonnage landed from 1990 to 1994 was geo-referenced and 90% from 1995 to 1999.

Commercial fisheries statistics are collected on a trip and sub-trip basis. A trip is defined as time from the start of a fishing trip until the catch is landed. Sub-trips within this are defined by changes of several variables during the trip like fishing area, fishing gear, date, fishing depth, main species caught and breaking a trip without landing fish.

Estimates of wolffish abundance, biomass, maturity, size structure and spatial distribution were obtained from research vessel bottom trawl surveys that have used a stratified random survey design (Table 1). Abundance and biomass estimates were calculated as stratified mean numbers and weight per tow. Comparative fishing experiments have been conducted in most cases when vessels or trawls were changed, but conversion factors have not been developed or applied for wolffish.

Information from collaborative surveys with the fishing industry was also used (Table 1). Data from a sentinel survey conducted in Div. 4T was excluded because wolffish catches have been very low and highly variable.

Indices of resource concentration and area occupied were calculated. Resource concentration is the proportion of the stock area encompassing 75% of the annually estimated biomass and as the index falls, the resource is becoming more concentrated. Data was aggregated into 10 minute squares and the annual index value was the fraction of the area containing 75% of the total. Area Occupied is defined as the proportion of the annual RV survey sets in which a species occurs. The annual index values were the proportion of non-zero sets each year.

An analysis of total mortality in Div. 4VWX was conducted using length frequencies from the 4VWX Summer RV survey. The approach used Von Bertalanffy growth parameters to determine catch at age curves based on length composition data (Sparre 1985). Due to the low numbers of wolffish

caught and the variability between yearly length frequencies, annual estimates were calculated using 5 year moving blocks.

Condition indices for 35cm and 70 cm wolffish in 4VWX were produced using predicted and measured values. These lengths were chosen to represent immature and mature fish, respectively. Annual values were calculated of fish weight at these lengths using the length-weight relationship for each year, referred to as 'predicted " values. Annual measured values were the mean value of all fish caught between 33-37 cm and between 68-72 cm. for that year.

Relative fishing mortality was examined for Div. 4VWX, the only area where landings were sufficiently high to warrant its use. This index is defined as the total landings divided by the estimated RV survey biomass for a given year (Sinclair 1968).

A Traffic Light table (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. 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 wolffish 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, 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 yellow/green 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 mathematical method used, the boundary values, the weights (circles) and the scalar used to set the boundary (squares) are shown on the slide bars in the bottom right hand corner of the table.

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).

The characteristics, Abundance, Production and Fishing Mortality of the population are also shown. These are derived by the same method as the summary line, but using only the indices that contribute to the characteristic.

Results

Description of the Fisheries

Although the landing statistics lump all species of wolffish together under the generalized category 'catfish', landings in Sub-areas 4 and 5 are almost exclusively Atlantic wolffish. There has not been

a directed fishery for Atlantic wolfish in Sub-areas 4 and 5, and the landings are mainly the result of by-catch in other fisheries (but see below). As a result, the levels of exploitation on wolffish are primarily determined by fisheries targeting other species. There have been restrictions on the catch of wolffish in the Canadian zone in recent years through by-catch limits and regulations in other fisheries. Presently, there is a 20% by-catch limit for wolffish in the Div. 4X mobile gear fishery from April to October, landing restrictions (caps) under the Conservation Harvesting Plan and a 10% limit for the remainder of the year.

From 1960 to 1978, the total landings in Sub-area 4 and Div. 5YZ averaged 1,800 tonnes but increased sharply thereafter reaching a peak of over 4,000 tonnes in 1983 (Table 2 and Fig. 2). Landings dropped quickly over the next 5 years and are thought to have averaged 620 tonnes since 1995 (US landings estimated). The majority of these landings have come from Div. 4X. Prior to 1993, divisions 4R,S,T,V and W contributed between 30% and 40% to the total landings, but since 1993 their contribution has been less than 15%. Foreign landings since 1960 have been small except for the US (Table 3).

The pattern in the landings in Subarea 4 is not unlike that observed in Newfoundland (Sub-areas 2 and 3) where the reported landings of all wolffishes were between 5,500 and 13,500 tonnes, about half of which was Atlantic wolfish (Kulka and DeBlois 1997). After 1991, when many fisheries were closed, the landings off Newfoundland dropped to below 3,000 tonnes, and are currently below 1,000 tonnes.

Canadian landings in most of the divisions of Sub-area 4 have declined since 1986. In Div. 4R, landings declined from their maxima in the early 1980s to less than 100 tonnes per year after 1991. In divisions 4S and 4T, the landings followed a similar pattern, declining in the early 1990s to historical low levels for the series. Landings in Divisions 4V and 4W started to decline after 1980. The landings in Div. 4W remained stable from 1987-1993, but in Div. 4V they continued to decline until 1994, after which they dropped in both divisions to the present low levels of from 3 to 11 tonnes. The landings in divisions 4X and 5YZ declined from maxima in excess of 1,200 tonnes in the early 1980s to recent levels that are less than 300 tonnes.

From 1986 to 2000, Canadian landings of wolffish were primarily otter trawls and longlines (Fig. 3). Otter trawlers landed 40% to 81% of all wolffish (mean 58%), while longliners were responsible for between 17% and 42% (mean 29%) of the landings. In Divisions 4V and 4X, otter trawlers dominated the landings, as they did in Div. 5Ze (with the exception of the years 1989 to 1994 in which longliners landed as much or more). In the remainder of Sub-area 4, the greatest proportion of the landings was taken by longliners. Fishing effort by otter trawlers in the Gulf of St. Lawrence has been greatly reduced since the imposition of the cod moratorium in 1994 and the number of wolffish caught has been reduced by the required use of 'Nordmore grates' in the shrimp fishery in the northern Gulf in 1983.

As stated above, Atlantic wolffish are primarily landed as by-catch in other fisheries, but they have been the 'main species caught' in sub-trips accounting for an average of 26% of all the wolffish landed from 1986 to 2000, mainly when fishing in Div. 4X (Fig. 4). This value ranged from 11% to as high as 46%, among years. This indicates that, in this Division, there is a directed component to the fishery.

On the Scotian Shelf, most of the landings occur in Div. 4X, with the largest catches taking place north of Browns Bank to off Yarmouth (Fig. 5). In the early 1990s, catches were reported in 4Vs and along the edge of the Laurentian Channel in 4Vn but these dropped to very low levels following the closure of other fisheries.

In the Gulf of St. Lawrence, the geographic distribution of the landings has remained fairly constant (Fig. 5). The majority of the wolffish landed in the Gulf has been from north of the Laurentian Channel in Div. 4R. Very few landings have been reported from the deepest part of the channel, and most of these were from off Anticosti Island. South of the channel, the landings have mainly come

from along the edge of the Magdalen Shallows and in the Cape Breton Trough. From 1990 to 1994, landings were reported from the mouth of the Baie de Chaleur and the northern parts of the Magdalen Shallows, but landings from these areas have diminished since then, probably reflecting the closure of the cod fishery (1993 - 1998) and redfish (1995-present) fisheries.

Seasonally, landings have tended to peak between May and July but in recent years the majority of the landings have occurred between June and July, which may be the result of regulation changes in other fisheries (Fig. 6 & 7). Lesser quantities are landed in April and in the period from August through October. The landings almost cease during the winter when only small amounts are landed.

Geographic Distribution of the Resource

The general pattern of distribution in Div. 4VWX has remained relatively consistent over the 30-year history of the summer RV survey, with greater numbers of wolffish occurring in divisions 4V and 4X, and lesser numbers in 4W (Fig. 8). Nevertheless, the distribution of catches tended to be more evenly distributed during the earlier years of the survey. In the past 10 years the distribution of wolffish in Div. 4W became more concentrated in eastern areas, and in Div. 4V abundance increased. Eastern Scotian Shelf Spring surveys, which exclude Sydney Bight (4Vn) because of ice cover, show a similar distribution as in summer surveys (Fig. 9). Scotian Shelf fall surveys from 1979 to 1984 (Fig. 10) also gave results similar to summer surveys. The 4VWX surveys do not sample most inshore areas but in recent years, these areas have been surveyed by the sentinel surveys conducted on the eastern shelf and the ITQ survey conducted in southwest Nova Scotia. The ITQ Survey (Fig. 11) caught only small numbers of fish in waters shallower than 50 meters but substantial numbers were captured in inshore areas by the sentinel survey in 4VsW (Fig. 12). Despite ITQ survey results, there are industry reports that wolffish are common also in nearshore areas of 4X .

Although few wolffish are caught during the fall surveys of the southern Gulf (Div. 4T), it is apparent that the distribution of wolffish has gradually expanded (Fig. 13). In early years, wolffish catches were restricted to a few areas along the slope of the Laurentian Channel, but their distribution has broadened to include more areas along the channel and onto the Magdalen shallows. In recent surveys, wolffish have been caught along most of the slope of the Laurentian Channel, into the Cape Breton Trough, with small catches in shallower water (i.e., < 100m) off the coasts of eastern PEI and the Acadian Peninsula.

The 4RST RV surveys (Fig.14) show that wolffish are concentrated mainly in Div.4R along the coast of Newfoundland and in eastern 4S. Similar distributions are seen from the Summer and Fall Sentinel Surveys (Fig. 15) conducted since 1995. The Fall series, however, shows the fish further offshore than the Summer sentinel surveys suggesting the fish may move to deeper water in the fall.

The index of resource concentration for wolffish (Fig. 16) indicated that distribution became more concentrated in Div. 4VWX during the 1980's and has remained so through the 1990's. In contrast, in Div. 4T resource concentration decreased in the 1980's and the species remained marginally more wide spread through the 1990's. The area occupied index for Div. 4VWX wolffish (Fig. 16) has been lower in the 1990's following a decline in the 1980's. In Div. 4T, the area occupied index increased during the early 1980's and has remained at higher values. Thus, indices for both resource concentration and area occupied for Divisions 4T and 4VWX show opposite trends. An index was not produced for Div. 4RST survey.

SSIP surveys from 1976 to 1982 show the distribution of larval wolfish to be similar to that of older fish (Fig. 17). This species has been included in a larval species assemblage with a distribution characterized as shallow and cold (Shackell and Frank 2000).

The depth range of wolffish caught on the Summer RV survey of 4VWX was from 35 to 350 m with a mean of 118.2 m (Fig. 18). This distribution is similar to that of the depths sampled by the surveys, indicating wolffish are found in most of the range of depths sampled by the Summer RV survey. In 4T the depth distribution is similar (Fig. 19), with most fish caught between 100 and 150 m along the slope of the Laurentian Channel. Smaller numbers of fish are caught in the deeper slope waters and in shallower water of 4T.

Abundance and Biomass

Abundance indices in Div. 4VWX from the summer RV surveys (Fig. 20, Table 5) show an increase in the abundance of wolffish in recent years. From 1970 to 1986 the numbers per tow ranged from 0.45 to 0.94 (mean 0.64) with no discernible trend. After 1986 the estimates ranged from 0.5 to 1.49 (mean .94) fish per tow, with a peak in 1989, and a decreasing trend since. The estimates have been quite variable but the most recent are still above the long term average of 0.77 fish per tow and most of those prior to 1987 were below the average. The change was primarily driven by catches in the eastern part of the survey (Div. 4VW). Wolffish catches from Div. 4X were quite variable through the entire summer series and exhibited no discernible trend or pattern but are presently the lowest in the series. Biomass indices for 4VWX (Fig. 20) were variable and ranged from 0.41 to 2.67 kg per tow (mean 1.55 kg) but were above the long term average until 1982, when they dropped to below the long term average and have remained low since. Presently, it is almost the lowest in the series. The time series of data from the Sentinel and ITQ Surveys (Fig. 21 & 22) are short but show no change in abundance or biomass over the periods sampled.

The time series of abundance estimates for Div. 4RST (Fig. 23, Table 6) indicates an upward trend in abundance from the early to late 1990's. Estimates of biomass also show an upward trend.

Abundance indices from the Fall RV Surveys in Division 4T (Fig. 23, Table 7) were very low until 1986 but increased substantially after 1987. The mean number per tow remained high but variable until 1997. The most recent estimates (1998 and 1999) are lower and it is uncertain whether this marks a return to earlier low values or simply the variability in sampling small populations. The biomass indices follow a similar pattern, low and variable until 1986, and then quite variable afterwards but higher overall than during the earlier period. Like abundance, biomass is presently low.

Length frequency plots from the RV surveys reveal larger numbers of smaller fish (< 55 cm.) since 1985 in Div. 4VWX (Fig. 24), and since 1988 in Div. 4T (Fig. 25). Since 1997, the 4RST RV survey has caught an increasing number of very small fish (7 to 22 cm.), with the largest catches in the most recent survey (Fig. 26).

Abundance and Biomass of Mature and Immature Population Components

The length at maturity of Atlantic wolffish was determined by Templeman (1986) as 51-68 cm for females in Sub-areas 2 and 3 (Fig 27). Length at maturity in Sub-area 4 is not known but is assumed here as being 55 cm for both sexes to provide indicators in mature and immature components of the population. Based on length-at-age estimates from the literature (see below), fish of 55 cm are approximately 10 years old.

Fish greater than 55 cm length have varied without trend in Div. 4VWX from 1970 to the 1980's (Fig. 28). Their numbers, dropped in the early eighties and have been reasonably constant since, but are presently near the lowest in the series. There was an increase in the number of fish, 55 cm and below. Their numbers were low in the early years of the survey, increased through the early eighties and have remained higher although variable since. In Div. 4T, the numbers of fish greater than 55 cm have been higher than the long term mean in several years since 1982, however, the last three estimates have been below the mean (Fig. 28). The numbers of immature fish increased

dramatically after 1987 and have been high but variable since, although dropping close to the long-term mean in 1999. Immature fish have made up most of the abundance in both Div. 4T and Div. 4VWX since the mid 1980's. Length frequencies indicate that immature fish have also shown a steadily increasing trend through the 1990's in Div. 4RST (Fig. 26).

The weight per tow of mature fish (> 55 cm) in Div. 4VWX is presently close to the lowest in the RV series (Fig. 29). It was variable, above average and without trend until 1982, after which it declined to below average values where it remained through the 1990's. In Div. 4T, the mature biomass was low and variable through most of the series, with several surveys in the earlier years in which no mature fish were caught. Mature biomass has been low since 1982 except a few years, which were higher than the mean. The Div. 4RST survey, which does not sample mature fish well, was not examined.

Length and Weight of Fish in the Population

The mean lengths and mean weights of fish caught (Fig. 30) in the RV surveys conducted in Div. 4VWX and Div. 4T are smaller now than earlier in the series. In Div. 4VWX, the mean length and weight were high until 1984 (mean 55.4 cm and 2.5 kg) and then dropped to lower values (mean 37.9 cm and 1.4kg). The 4VWX Fall RV Survey and the Spring 4VsW cod RV Survey show similar trends in mean length as the 4VWX Summer survey (Fig. 31). The mean length and weight from the surveys in Div. 4T (Fig. 30) exhibit a similar pattern, being higher (mean 63.8 and 2.8 kg) until 1987 and then lower (mean 43.1 cm and 1.25 kg) but variable since. In Div. 4RST (1990-2000 series), the mean length and weight are lower than in the other Divisions, with a mean length of 26.7 cm and weight of 0.39 kg. This 4RST RV survey does not catch large wolffish (the largest fish caught was 79 cm. long). This may result from the use of a URI shrimp trawl, in contrast to the other RV surveys in Sub-area 4 that use the Western IIA trawl, and may explain the low length and weight in the series. An examination of the mean weight of fish from the Winter RV Survey on the Gadus Atlantica (1984 to 1994) and the summer and fall Sentinel Surveys (Fig. 32), shows that larger fish are found in the survey area.

Condition

The juvenile (35 cm) condition index did not change over time for either predicted or measured values from the 4VWX Summer RV Survey (Fig. 33). The adult (70 cm) condition index using predicted values did appear to show a decline from a period early in the survey series to the most recent years, particularly during the last three years. Mean measured values for 70 cm fish also tended to show a decline but there was a lot of scatter and the last three years were in the range of most of the points in the series. The predicted values are generally thought to be more accurate because they use all of the fish caught for the estimate. However, changes in the length range used in the length-weight regression from year to year and vastly greater numbers of observations for small fish in latter, than in earlier years may have biased the estimates. Predicted condition of 50 and 60 cm. fish also exhibited a decline but it was smaller in magnitude than for 70 cm fish. The case for a lower condition of the adults in recent years is therefore weak.

Growth and Mortality

Composite length-weight relationships were derived for wolffish from the 4VWX summer RV survey and the 4T fall RV survey based on data from the entire series (Fig. 34). The resulting equations are

4VWX Summer RV	$W = 0.0054\ L^{3.132937}$
4T Fall RV	$W = 0.0062\ L^{3.087433}$

These are very similar to the composite relationship derived for wolffish from the North Sea, Norway and Iceland (Beese and Kändler 1969)(Fig. 35).

Length-at-age data are not available for Atlantic wolffish in Sub-Area 4 but several length-at-age relationships in the form of von Bertalanffy equations were found in the literature (Table 4, Fig. 36), which are not dissimilar. The Gulf of Maine (Nelson and Ross 1992) and North Sea/Norway (Beese and Kändler 1969) von Bertalanffy equations showed relationships showed the slowest and fastest growth found in the literature, respectively were used to determine the possible age of wolffish in Sub-area 4, and to estimate total mortality. The Gulf of Maine, although showing the second slowest growth, was substituted for Greenland because it was closer to both the area of study and the time of most interest.

From the catch curve analysis, the mean total mortality for the entire series using the Gulf of Maine parameters was Z=0.18, and was slightly higher (Z= 0.21) when the NorthSea/Norway parameters were used (Fig.37). Trends in the annual estimates (Fig. 39) are the same for both sets of parameters but the values are slightly higher using the NorthSea/Norway parameters. The annual indices declined until the early 1980's when they increased steadily to a peak in 1992, and then declined until 1997. The patterns of Z's available from catch curve analysis are based on the assumption of a stable age distribution. The recent strong abundance of young fish makes this assumption suspect and there will be biases associated with that. While accepting the trends in Z at face value is difficult, it is reasonable to interpret these estimates as indicating that the proportions of older fish declined in the 1980's and since 1992 have increased.

The relative fishing mortality in Div. 4VWX is presently low (Fig. 38). It increased steadily from 1975 to 1986 and dropped quickly to low levels where it has remained to the present. The period of increasing fishing mortality is reported by industry to have been due to decreasing availability of other more valuable species and not due to increased availability or increased prices for wolffish. It is interesting to note however, that the sharp decline occurred immediately following the decline in the mature biomass.

Summary of Stock Indicators

The traffic light table (Fig. 39) was constructed using a subset of the indicators of stock status examined above. These are:

- RV mature and immature biomass (kg/tow) from both the 4VWX Summer Surveys and the 4T Fall Surveys and the total RV survey biomass from the 4RST surveys,
- Area occupied (proportion of sets in which wolffish were caught) from the 4VWX and 4T surveys,
- Total mortality (Z) from catch curve analysis from 4VWX surveys,
- Condition (predicted weight at 70 cm) from 4VWX surveys,
- Relative fishing mortality (commercial landings/RV survey biomass) from 4VWX surveys,

for a total of 10 indicators. The "sliders" at the right of the main body of the table, beside the individual indicators, represent the values used in combining the indices. The upper slider shows where the scalar used for the green/yellow and yellow-red boundaries (squares) were set for each indicator. All were set at the arbitrary default levels. The lower slider shows the weight it is given in the summaries above the main part of the table. All indicators were given full weight (circles fully to the right) except for the RV biomass (4RST) which received a 10% weight. This indicator's influence was down weighted because the data series was much shorter than for other indicators. The numbers to the right of the sliders in Fig. 41 show the minimum and maximum values for each data series. The abbreviation on the extreme right, "ave" and "pctile" denote that the traffic light boundaries are set using the average of the data series or using percentiles to divide the data into three groups.

Other indicators were omitted from the table for a variety of reasons. Industry surveys are still of too short a duration to provide useful information on trends. 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.

The summary of the indices used, is shown in the bar chart at the top of the table and in the traffic lights, labeled Summary Direct, immediately below. Stock status has fluctuated between green and yellow from 1970 to 1998 except for 1974. The last two years have been red and yellow. A reduced number of indices in the final two years may be influencing these results.

Characteristics of abundance, production and fishing mortality for Atlantic wolffish are also summarized. The abundance indices used were mature biomass and area occupied for Divisions 4VWX and 4T, and the biomass index for Div. 4RST. This characteristic has a history of being yellow and green, but has been yellow through most of the 1990's. The production indices included were immature abundance from Divisions 4VWX and 4T, and total mortality and condition from Div.4VWX. The traffic light for production is yellow through most of the series with some green and red intermittently. Fishing mortality consists of one index, relative fishing mortality, and it is presently green after a drop through yellow to red from 1979 to 1986.

Discussion

Wolffish populations in Sub-area 4 have increased in abundance since the mid to late 1980's. Large numbers of small fish have contributed to this increase particularly in Div. 4V and 4T, and more recently in Div. 4RS. However, the low number of larger fish and decline in total biomass in Div. 4VWX are a concern. The biomass in this area, which has been the main fishing area, dropped subsequent to a period of high landings in the late 1970's and early 1980's. The total mortality increased markedly during this period, as well, and continued to the early 1990's but these mortality estimates have low reliability. Relative F also suggests that fishing mortality increased in the early 1980's but was low after 1986. In other areas of Sub-area 4 the biomass shows positive signs. The biomass estimates for Div. 4T have been higher through the 1990's than during earlier periods, and in Div. 4RS the biomass has also shown an increasing trend. An upward trend has also occurred in the most recent RV surveys in Sub-area 3, which experienced the most substantial decline in biomass in the early 1980's (Kulka and DeBlois1997 and Kulka-pers.comm). Until the recently recruited yearclasses mature, and the mature biomass improves, care must be taken not to increase fishing mortality beyond the status quo.

The more widespread distribution of Atlantic wolffish in Div. 4T was associated with a greater abundance of both large and small fish. It is possible that migration from adjacent areas (i.e., Divs. 4RSV) may have contributed to this change. The reduced number of wolffish in Div. 4W in recent years and increased numbers in Div. 4V also suggest a movement of fish over time towards the east. However, the wider distribution in Div. 4V is primarily due to the larger numbers of small fish in the early 1990's. Tagging studies (Templeman, 1984) have shown that wolffish do not undertake extensive migrations and only limited inshore/offshore movements have been described by others (Kohler 1968, Keats et al 1985). Thus, observed changes in the distribution of wolffish likely result from differences in productivity and mortality between and within areas.

Very little biological information is presently available for wolffish. More information is needed on many aspects of this species: reproduction, growth and stock structure before the assessment this resource can be improved significantly.

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Table 1 Description of Surveys in Sub- area 4

Survey	Duration	Month	Area	Vessel	Gear	Year
Research Vessel Surveys						
Scotian Shelf Summer	1970 - 2000	July	4VWX	A.T.Cameron	Yankee 36	1970 - 1981
				Lady Hammond	Western IIA	1982 - 1982
				Alfred Needler	Western IIA	1983 - 2000
Eastern Scotian Shelf cod Spring	1986 - 2000	March	4VsW	Alfred Needler	Western IIA	1986 - 2000
Georges Bank	1986 - 2000	February	5Ze	Alfred Needler	Western IIA	1986 - 2000
Scotian Shelf Fall	1978 - 1984	October	4VWX	Lady Hammond	Western IIA	1978 - 1982
				Alfred Needler	Western IIA	1983 - 2000
Southern Gulf of St. Lawrence Fall	1971 - 2000	September	4T	EE Prince[1]	Yankee 36	1971 - 1985
				Lady Hammond	Western IIA	1985 - 1991
				Alfred Needler	Western IIA	1991 - 2000
Northern Gulf of St. Lawrence Winter	1978 - 2000	January	4RST[2]	Gadus Atlantica	Engels145	1978 - 1994
		January	4RST[2]	Lady Hammond	Western IIA	1985 - 1989
		August	4RST[2]	Alfred Needler	URI Shrimp Trawl	1990 - 2000
Industry Surveys						
Individual Transferable Quota (ITQ)	1995 - 2000	July	4X / 5Zc	Mobile		
Eastern Scotian Shelf Sentinel	1995 - 2000	Sept - Oct	4VsW	Longline		
Sidney Bight Sentinel	1995 - 2000	Sept - Oct	4Vn	Longline		
Northern Gulf of St. Lawrence Summer Sentinel	1995 - 2000	July	4RST[2]	Mobile		
Northern Gulf of St. Lawrence Fall Sentinel	1995 - 2000	October	4RST[2]	Mobile		

1. Daylight fishing only
2. Coverage includes part of 3Pn and in 4T is limited to strata >200m in the Laurentian Channel

Table 2 Wolffish landings from NAFO data (1960-90) and from ZIF data (1991-1999) for Div. 4. Landings for Subarea 5 are from NAFO data (1960-1990) plus NAFO foreign landings (1991-1999) plus ZIF data (1991-1999) plus estimates of US landings not yet reported to NAFO for 1994 to 1999 (shaded gray)

Year	4R	4S	4T	4V	4W	4X	5	Total
1960	6	5	4	81	371	1053	218	1738
1961	5	1	2	229	376	959	215	1787
1962	14	23	17	282	438	658	216	1648
1963	8	25	29	242	288	484	255	1331
1964	29	74	66	241	222	689	290	1611
1965	16	0	6	22	26	48	238	356
1966	53	0	4	70	31	29	507	694
1967	41	20	49	240	143	620	276	1389
1968	117	13	70	282	350	1023	350	2205
1969	234	59	52	247	335	1013	273	2213
1970	378	61	86	243	318	899	243	2228
1971	270	57	86	451	395	1149	287	2695
1972	195	54	69	282	224	899	285	2008
1973	180	58	51	182	202	893	431	1997
1974	220	69	53	194	112	907	366	1921
1975	148	68	43	153	133	864	392	1801
1976	153	12	43	120	114	969	483	1894
1977	296	16	10	190	151	1225	481	2369
1978	134	14	9	310	211	714	780	2172
1979	169	25	18	297	211	1250	785	2755
1980	212	113	19	417	231	1759	1049	3800
1981	247	101	42	493	281	1538	840	3542
1982	276	119	20	492	211	1611	1075	3804
1983	567	97	78	474	153	1420	1285	4074
1984	467	14	24	309	73	1269	1123	3279
1985	282	14	6	364	39	1401	1023	3129
1986	318	44	26	234	76	1236	920	2854
1987	167	65	18	304	66	765	806	2191
1988	92	35	4	226	45	657	700	1759
1989	96	37	5	198	30	359	595	1320
1990	114	40	19	181	72	372	483	1281
1991	122	32	13	99	49	308	541	1164
1992	93	12	11	107	71	519	527	1339
1993	99	6	6	51	28	483	562	1236
1994	8	1	1	7	6	360	417	801
1995	13	0	1	5	6	227	245	497
1996	7	1	7	3	6	357	371	752
1997	70	3	1	6	11	565	595	1250
1998	52	1	1	7	5	279	298	643
1999	76	1	3	4	4	267	283	637
Average								
1972-85	253	55	35	306	168	1194	743	2753
1986-99	95	20	8	102	34	482	525	1266

Table 3. International Wolffish landings in Subarea 4 and 5 from NAFO data (1960-1990) plus NAFO foreign landings (1991-1999) plus ZIF data (1991-1999) plus estimates of US landings not yet reported to NAFO for 1994 to 1999 (shaded gray)

Year	SUN	CAN	CUB	DDR	DEU	FRA	FRD	GBR	ISR	NOR	POL	PRT	USA	Total Wolffish
1960		1354						3					381	1738
1961		1498											289	1787
1962		1362											286	1648
1963		984						1					346	1331
1964	5	1291			6			2					307	1611
1965	53	44			1								258	356
1966	389	88											217	694
1967		1152						6					231	1389
1968		1986				7							212	2205
1969	31	1955		1		5			1				220	2213
1970	2	1972				1	1						253	2229
1971		2434				1							260	2695
1972	1	1719				4		12					272	2008
1973		1580		1		3					150		263	1997
1974		1544				4		9		3			361	1921
1975	22	1366				3				1		49	360	1801
1976		1416				4							474	1894
1977	2	1912				5							450	2369
1978		1527				7							638	2172
1979		2017				46							692	2755
1980		2892				10							898	3800
1981		2781				18							743	3542
1982		2899				10							895	3804
1983		2853				16							1205	4074
1984		2221				2							1056	3279
1985		2173	3			1							952	3129
1986		2003				6							845	2854
1987		1461											730	2191
1988		1160											599	1759
1989		811				8							501	1320
1990		881											400	1281
1991		678											487	1165
1992		876	1										463	1340
1993		736											500	1236
1994		441											359	801
1995		270											226	497
1996		395											356	752
1997		687											563	1250
1998		364											279	643
1999		371											266	637

Table 4 Von Bertalaffy Growth Parameters for Atlantic Wolffish

Location	L_∞	k	t	Source
North Sea & Norway	213.4402	0.0314	0.4836	Beese and Kändler 1969
Northeast Atlantic	192.5	0.0349	0.0570	Beese and Kändler 1969
Iceland	158.2517	0.0460	0.6948	Jónsson 1983
Gulf of Maine	162.6	0.04	0.43	Nelson and Ross 1992
Greenland	157.2365	0.0408	0.6494	Beese and Kändler 1969

Table 5 Research vessel estimates of the mean numbers and mean weight per tow, abundance and biomass estimates for Atlantic wolffish (ages 0+) on the Scotian Shelf (NAFO Division 4VWX)

Year	Stratified Mean Number per Tow	Standard Error	Stratified Mean Wt(kg.) per Tow	Standard Error	Estimated Abundance (x 1000)	Standard Error	Estimated Biomass (x 1000)	Standard Error
1970	0.48	0.16	1.23	0.34	1951	636	5029	1387
1971	0.69	0.22	1.56	0.42	2882	926	6473	1729
1972	0.49	0.13	1.50	0.40	2097	544	6342	1683
1973	0.65	0.18	1.18	0.29	2770	781	5022	1209
1974	0.62	0.17	0.86	0.16	2567	714	3530	664
1975	0.94	0.21	2.67	0.69	3984	878	11339	2934
1976	0.67	0.14	1.38	0.33	2624	546	5384	1298
1977	0.57	0.09	2.12	0.42	2427	390	9009	1801
1978	0.66	0.13	1.27	0.24	2756	562	5292	1010
1979	0.47	0.13	1.39	0.34	1936	528	5709	1386
1980	0.73	0.28	2.06	0.53	3087	1170	8753	2253
1981	0.46	0.09	1.57	0.32	1954	370	6664	1364
1982	0.83	0.16	1.78	0.37	3514	682	7537	1565
1983	0.54	0.14	1.40	0.39	2300	594	5922	1674
1984	0.45	0.13	1.27	0.40	1896	541	5377	1703
1985	0.82	0.24	1.13	0.27	3484	1006	4771	1157
1986	0.54	0.14	0.80	0.18	2294	594	3413	768
1987	0.77	0.19	1.21	0.35	3269	816	5142	1467
1988	0.87	0.21	1.21	0.33	3692	889	5129	1405
1989	1.49	0.37	0.91	0.30	6311	1578	3838	1289
1990	1.08	0.28	0.89	0.18	4465	1163	3669	743
1991	1.22	0.35	1.03	0.35	5151	1492	4353	1481
1992	0.43	0.13	0.41	0.11	1822	570	1733	454
1993	1.28	0.34	0.88	0.21	5439	1444	3749	886
1994	0.94	0.38	0.59	0.17	3982	1593	2517	721
1995	0.83	0.25	0.86	0.24	3519	1042	3637	1022
1996	0.94	0.26	1.21	0.49	3909	1079	5038	2053
1997	0.78	0.17	1.07	0.36	3248	716	4437	1509
1998	1.15	0.43	0.83	0.18	4862	1831	3523	758
1999	0.51	0.12	0.51	0.12	2112	510	2141	490
2000	0.95	0.65	0.50	0.22	4042	2743	2125	952
Average	0.77		1.20		3237		5051	

Table 6 Research vessel estimates of the mean numbers and mean weight per tow for Atlantic wolffish (ages 0+) in the northern Gulf of St Lawrence (NAFO Division 4RS and strata>200m in Div. T)

Cruise	Year	Stratified Mean Number Per Tow	Std. Error Mean Number Per Tow	Stratified Mean Wt. (kg.) Per Tow	Std. Error Mean Wt. (kg.) Per Tow	Total Number Caught	Total Wt. (kg.) Caught	Total Number of Stations Surveyed
N141	1990	0.18	0.14	0.10	0.09	38	34.31	190
N055	1991	0.22	0.12	0.07	0.04	69	22.99	248
N177	1992	0.18	0.09	0.08	0.04	46	20.54	239
N192	1993	0.07	0.39	0.02	0.02	25	8.25	209
N209	1994	0.21	0.17	0.11	0.08	54	24.85	176
N229	1995	0.18	0.17	0.08	0.06	45	34.75	182
N248	1996	0.22	0.08	0.11	0.04	95	51.34	217
N262	1997	0.95	1.71	0.17	0.09	233	47.76	185
N280	1998	0.27	0.21	0.07	0.05	126	40.48	205
N294	1999	0.30	0.18	0.16	0.12	111	48.97	224
N011	2000	0.66	0.35	0.18	0.10	236	63.09	209
	AVERAGE	0.31		0.10		98	36.12	208

Table 7 Research vessel estimates of the mean numbers and mean weight per tow, population numbers and population biomass for Atlantic wolffish (ages 0+) in the southern Gulf of St. Lawrence (NAFO Division 4T)

Cruise	Year	Stratified Mean Number Per Tow	Variance	Stratified Mean Wt. (kg.) Per Tow	Variance	Estimated Population Numbers (x 1,000) in NAFO 4T	Variance	Estimated Population Biomass (t) in NAFO 4T	Variance
P091	1971	0.01	0.00	0.15	0.02	20	412	264	69602
P106	1972	0.02	0.00	0.03	0.00	30	241	52	235
P122	1973	0.05	0.00	0.09	0.00	87	1946	162	9046
P143	1974	0.00	0.00	0.00	0.00	8	61	0	0
P157	1975	0.05	0.00	0.03	0.00	90	3837	58	1459
P172	1976	0.00	0.00	0.00	0.00	0	0	0	0
P188	1977	0.04	0.00	0.13	0.02	68	2291	227	51606
P204	1978	0.00	0.00	0.00	0.00	0	0	0	0
P229	1979	0.02	0.00	0.04	0.00	29	342	76	2516
P244	1980	0.03	0.00	0.10	0.01	56	1103	181	22886
P260	1981	0.02	0.00	0.02	0.00	36	1294	36	1294
P278	1982	0.04	0.00	0.06	0.00	62	2030	105	5544
P296	1983	0.02	0.00	0.08	0.00	31	494	142	10693
P312	1984	0.02	0.00	0.06	0.00	41	601	96	4656
P327	1985	0.05	0.00	0.12	0.00	82	1573	214	12765
H159	1986	0.02	0.00	0.11	0.00	40	369	186	8883
H179	1987	0.06	0.00	0.14	0.00	98	1391	244	14225
H192	1988	0.19	0.01	0.29	0.03	330	23048	499	87171
H204	1989	0.06	0.00	0.05	0.00	96	2159	78	1412
H219	1990	0.15	0.00	0.09	0.00	264	13645	163	8014
H232	1991	0.10	0.00	0.11	0.00	169	4215	195	8854
N178	1992	0.20	0.02	0.16	0.01	349	71483	270	16586
N192	1993	0.02	0.00	0.06	0.00	42	867	96	5039
N210	1994	0.13	0.00	0.26	0.02	230	10754	455	64978
N230	1995	0.08	0.00	0.05	0.00	137	7996	94	3411
N249	1996	0.14	0.00	0.20	0.01	239	10464	344	20704
N746	1997	0.10	0.00	0.10	0.00	176	2409	167	3542
N846	1998	0.05	0.00	0.06	0.00	92	1733	112	3021
N941	1999	0.02	0.00	0.03	0.00	38	506	60	2469
	AVERAGE	0.06		0.09		101		157	

(Note: Survey strata 415-439 in NAFO Division 4T are included).

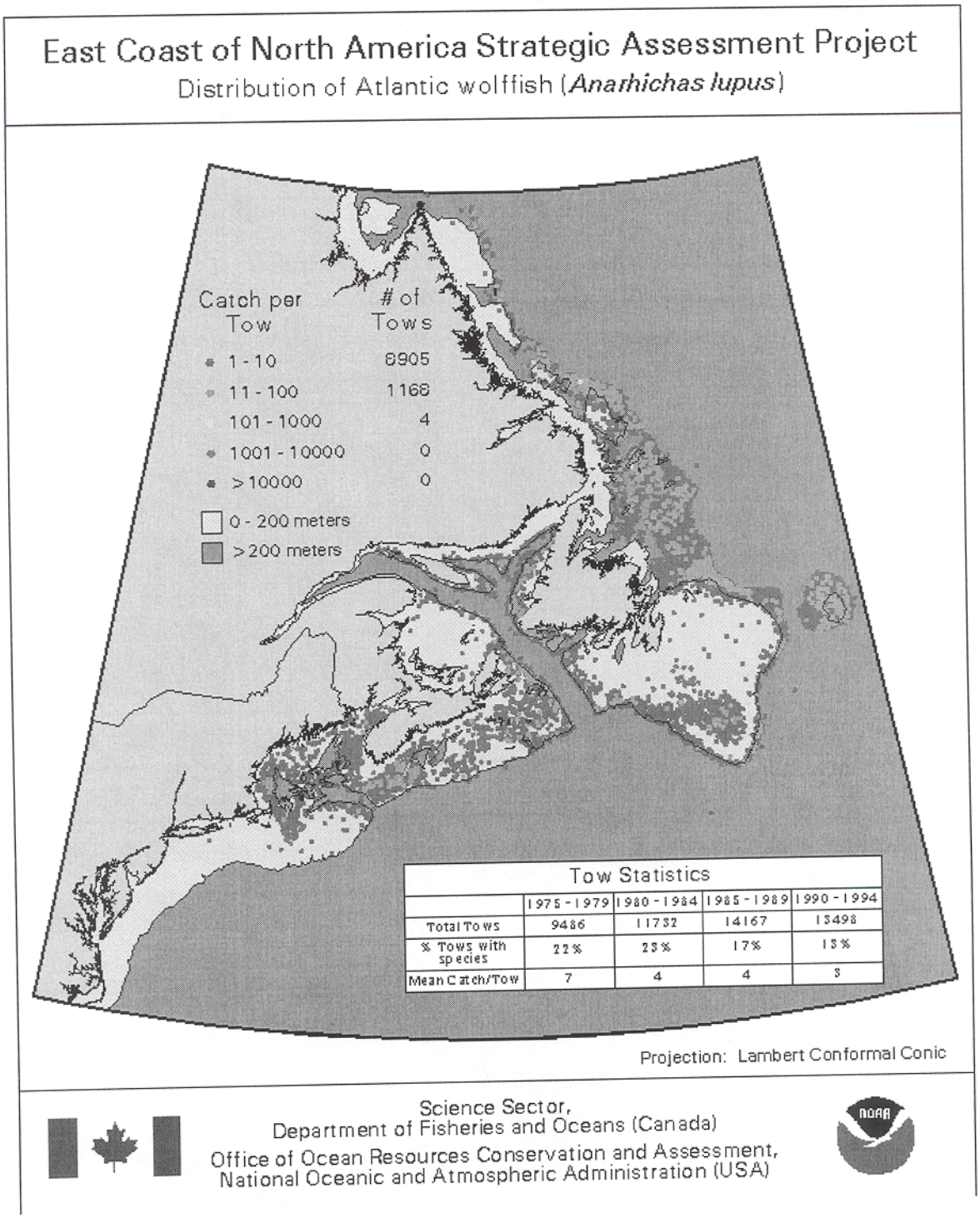

Figure 1 Distribution of Atlantic Wolffish (Anarchichas lupus) in the north-west Atlantic from ECNASAP (Brown et al 1996)

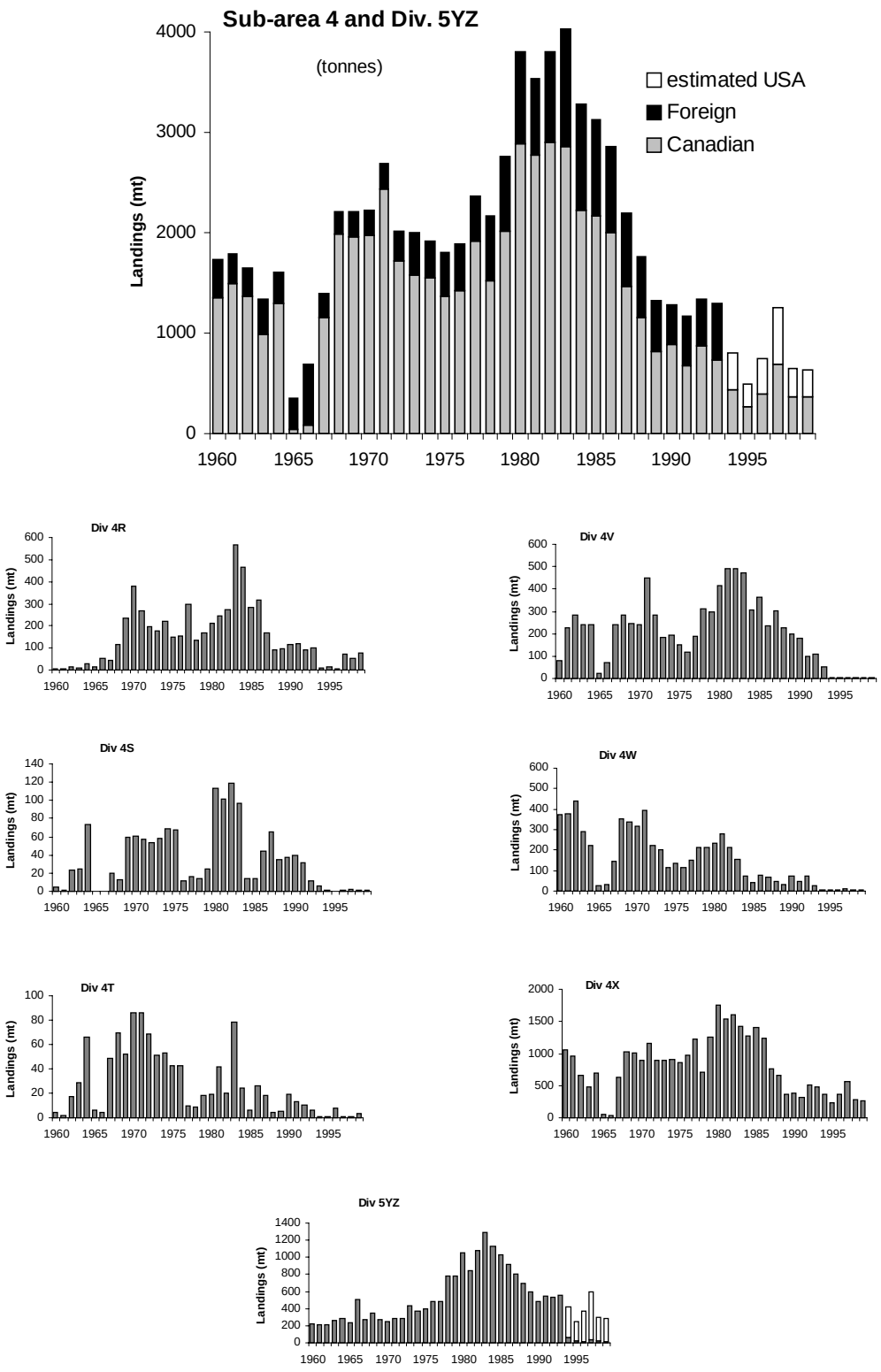

Figure 2 Atlantic Wolffish landings for NAFO Sub-area 4 and Div. 5YZ (1960-1999). US landings from Div. 5Ze are estimated from 1994 to 1999

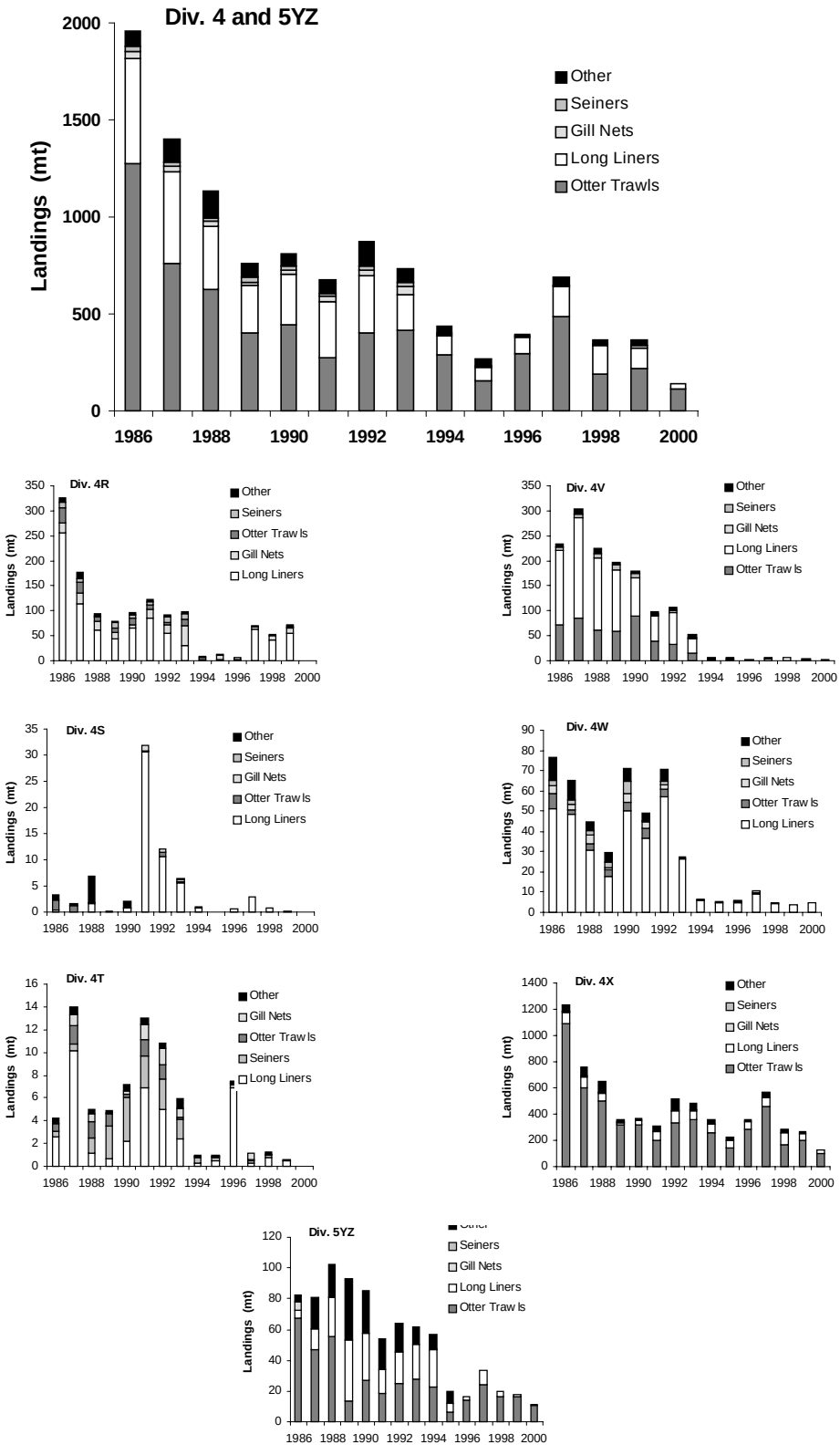

Figure 3 Canadian of landings Atlantic Wolffish by gear and NAFO Division 1986 to 2000

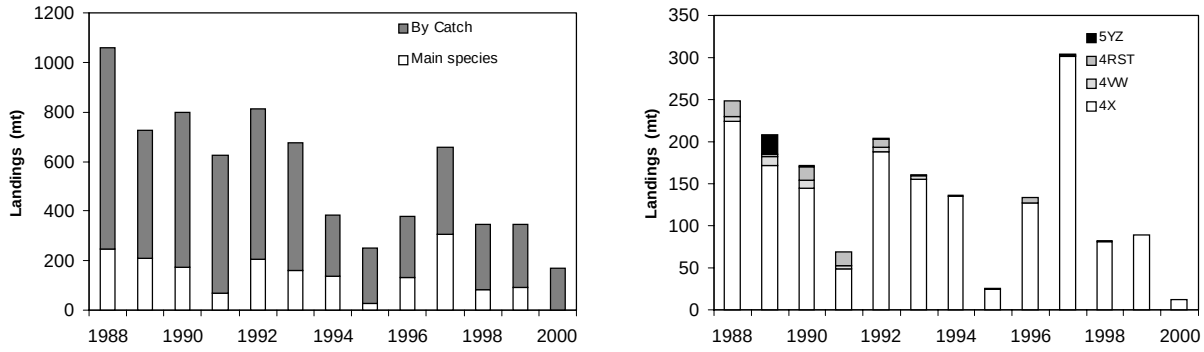

Figure 4 Total wolffish landings as bycatch and when specified as 'main species caught' in Sub-area 4 (left) and landings specified as 'main species caugh' by NAFO Division (right).

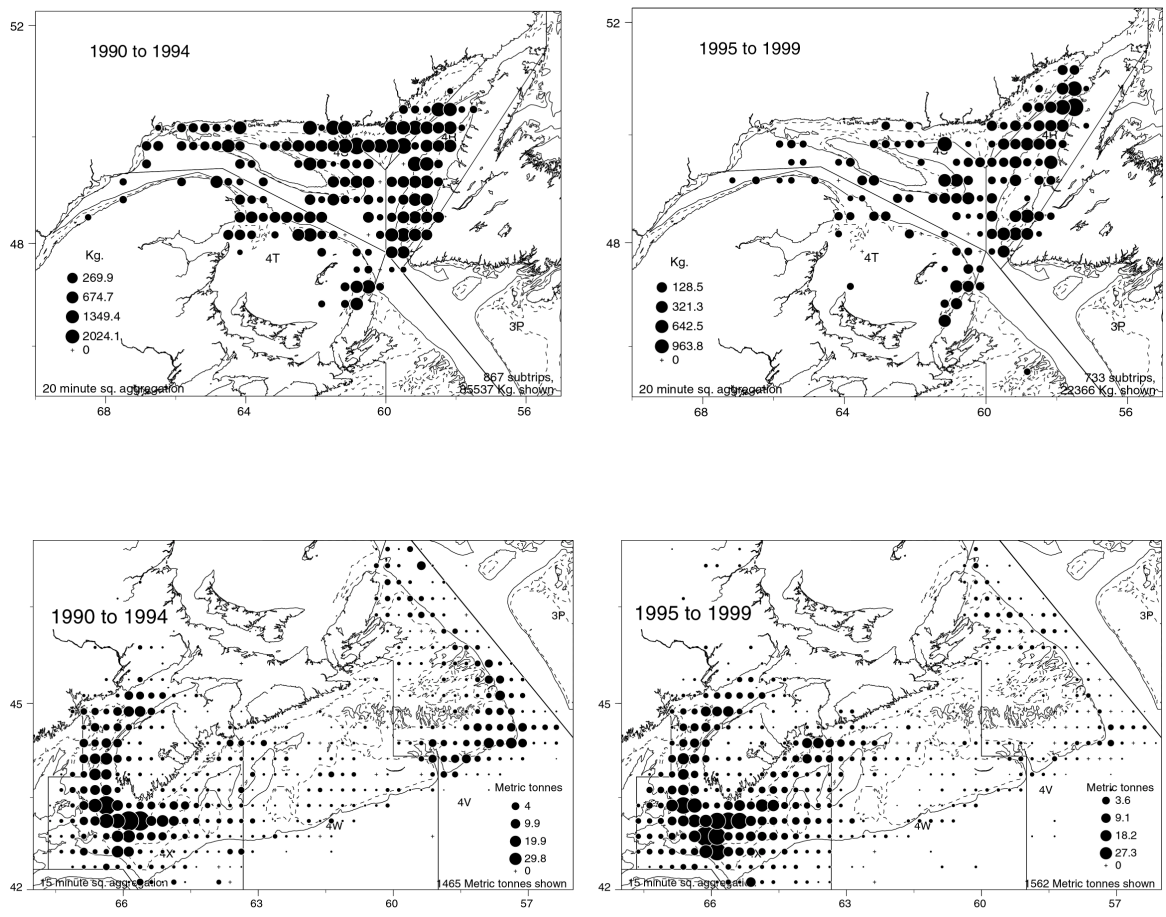

Figure 5 Distribution of commercial landings of Atlantic Wolffish in the Gulf of St. Lawrence and on the Scotian Shelf from 1990-1994 and 1995-1999. (note the different scales)

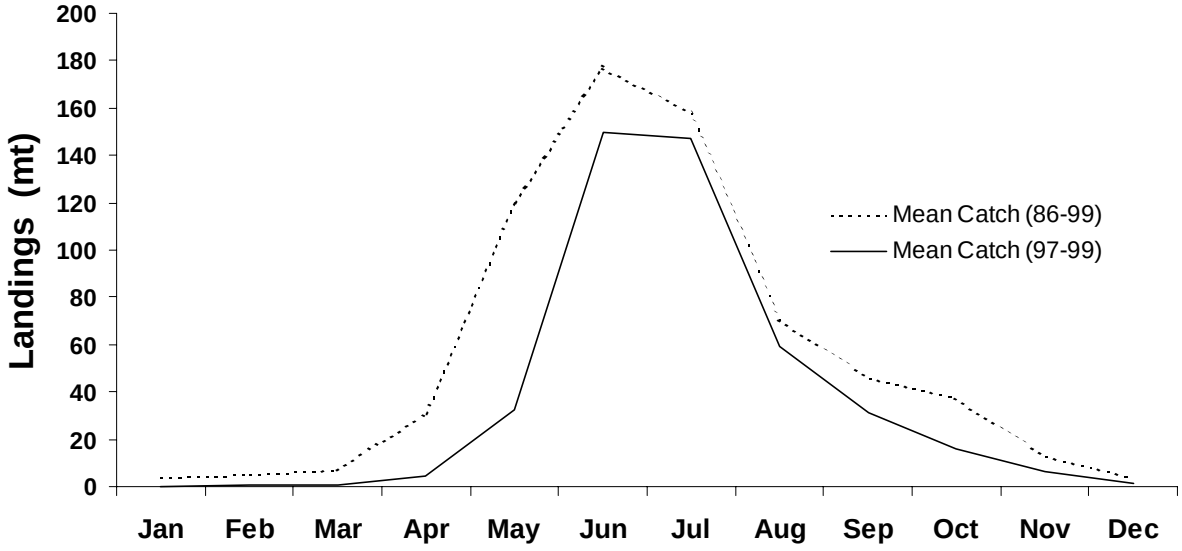

Figure 6 Canadian mean monthly landings of Atlantic wolffish in Sub-area 4 and Div. 5YZe

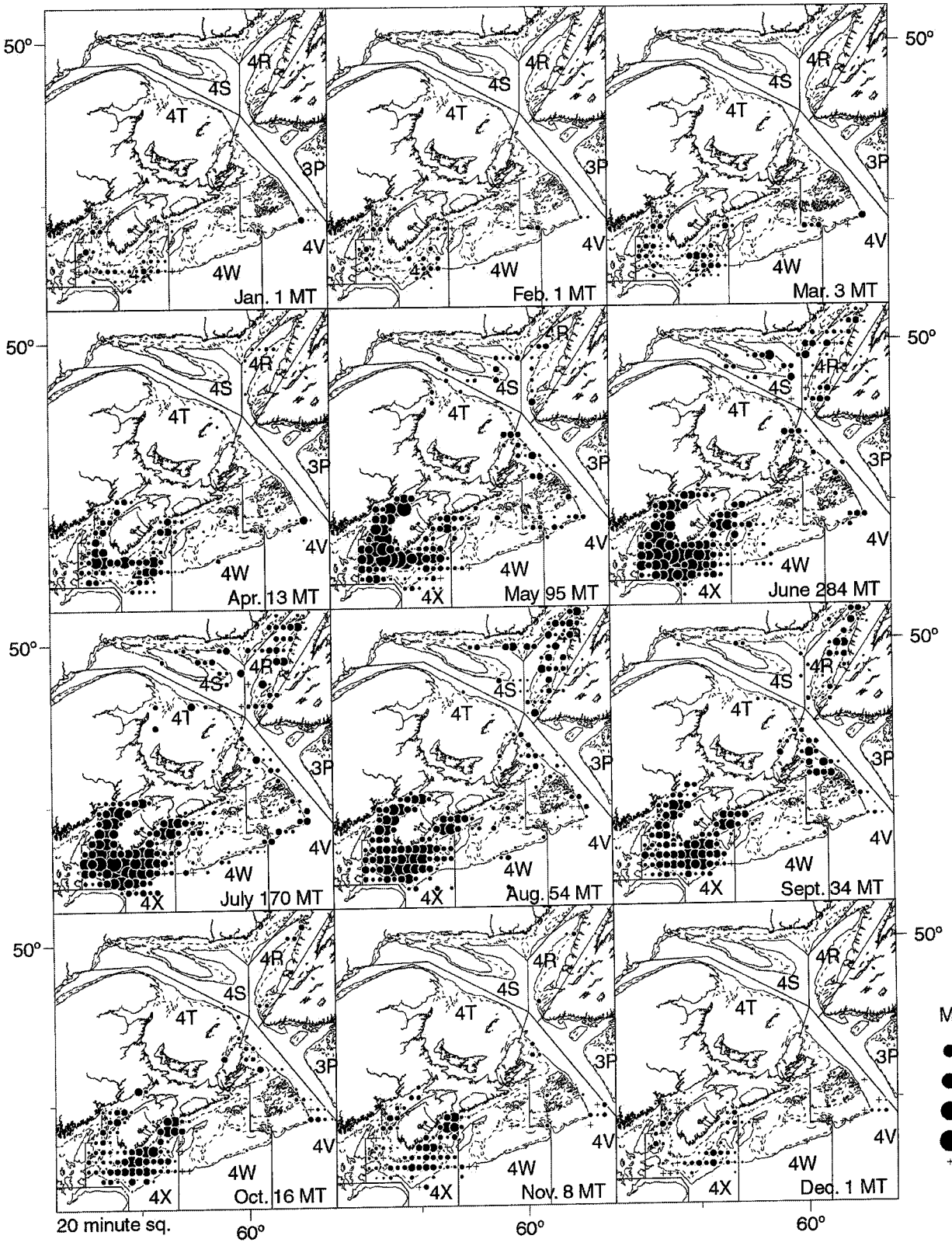

Figure 7 Monthly landings of Atlantic Wolffish in Sub-area 4 from ZIF data base 1998 to 2000

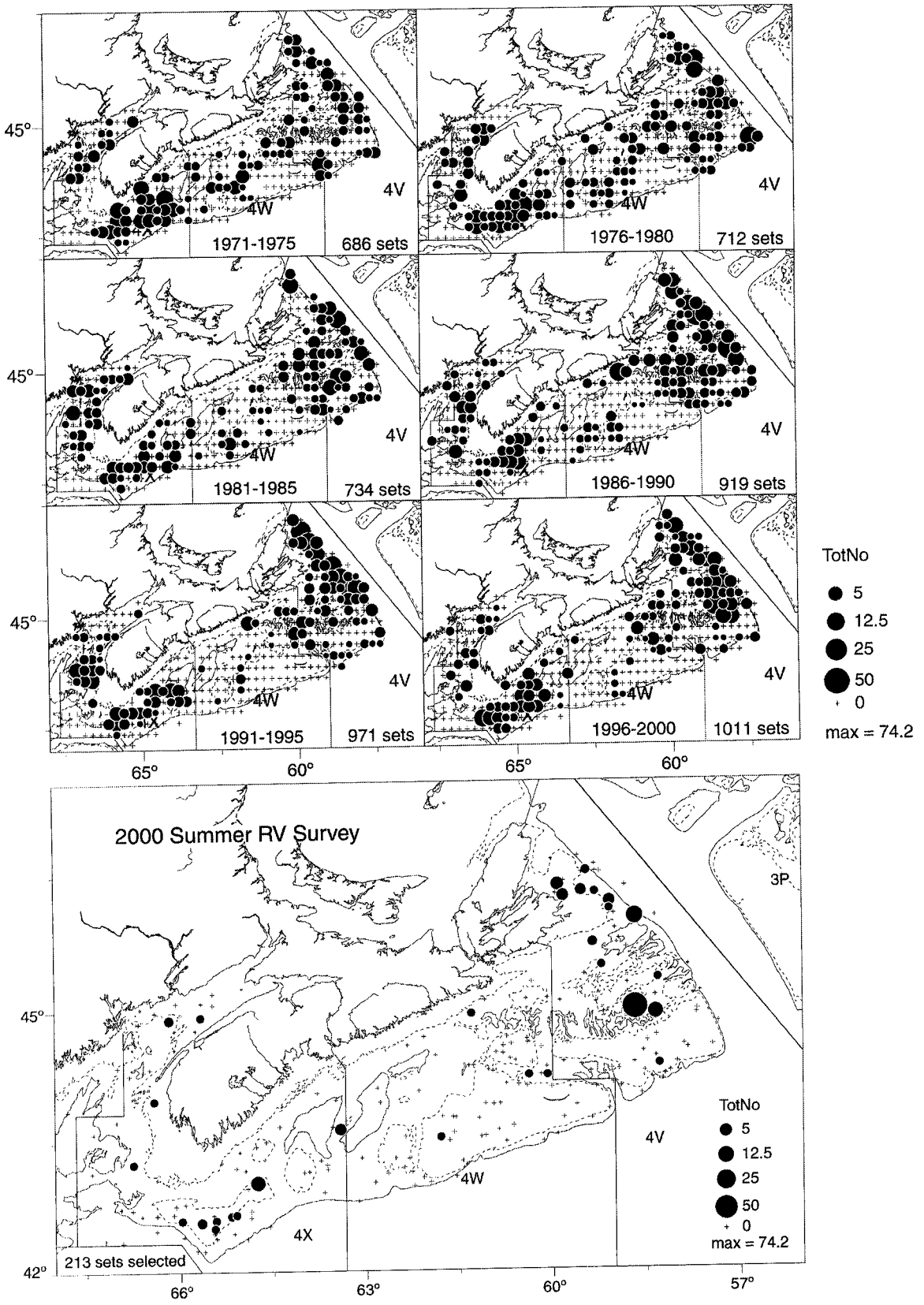

Figure 8 Distribution of Atlantic Wolffish from the 4VWX Summer RV Surveys, 1971 to 2000 (adjusted number per tow)

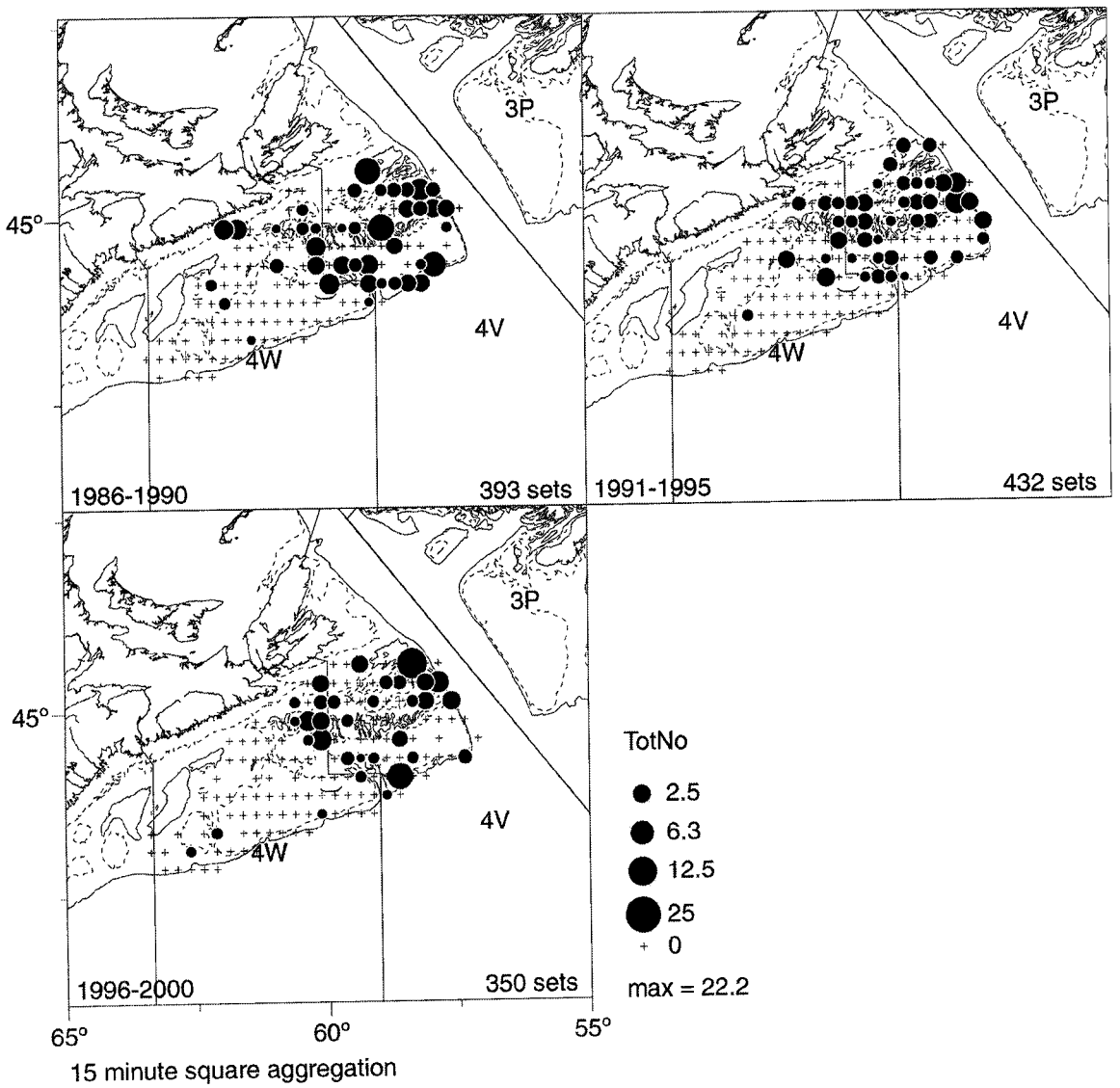

Figure 9 Distribution of Atlantic Wolffish from the 4VW spring RV surveys, 1986 to 2000 (adjusted number per tow)

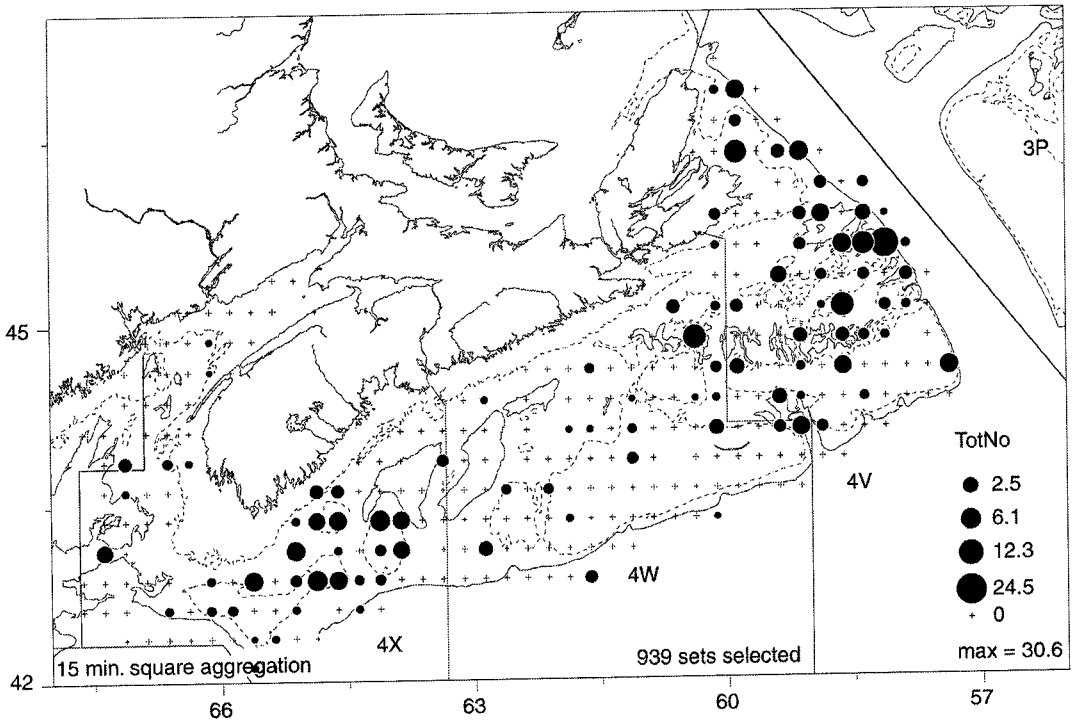

Figure 10 Distribution of Atlantic Wolffish from the 4VWX Fall RV Surveys, 1978 to 1984 (adjusted number per tow)

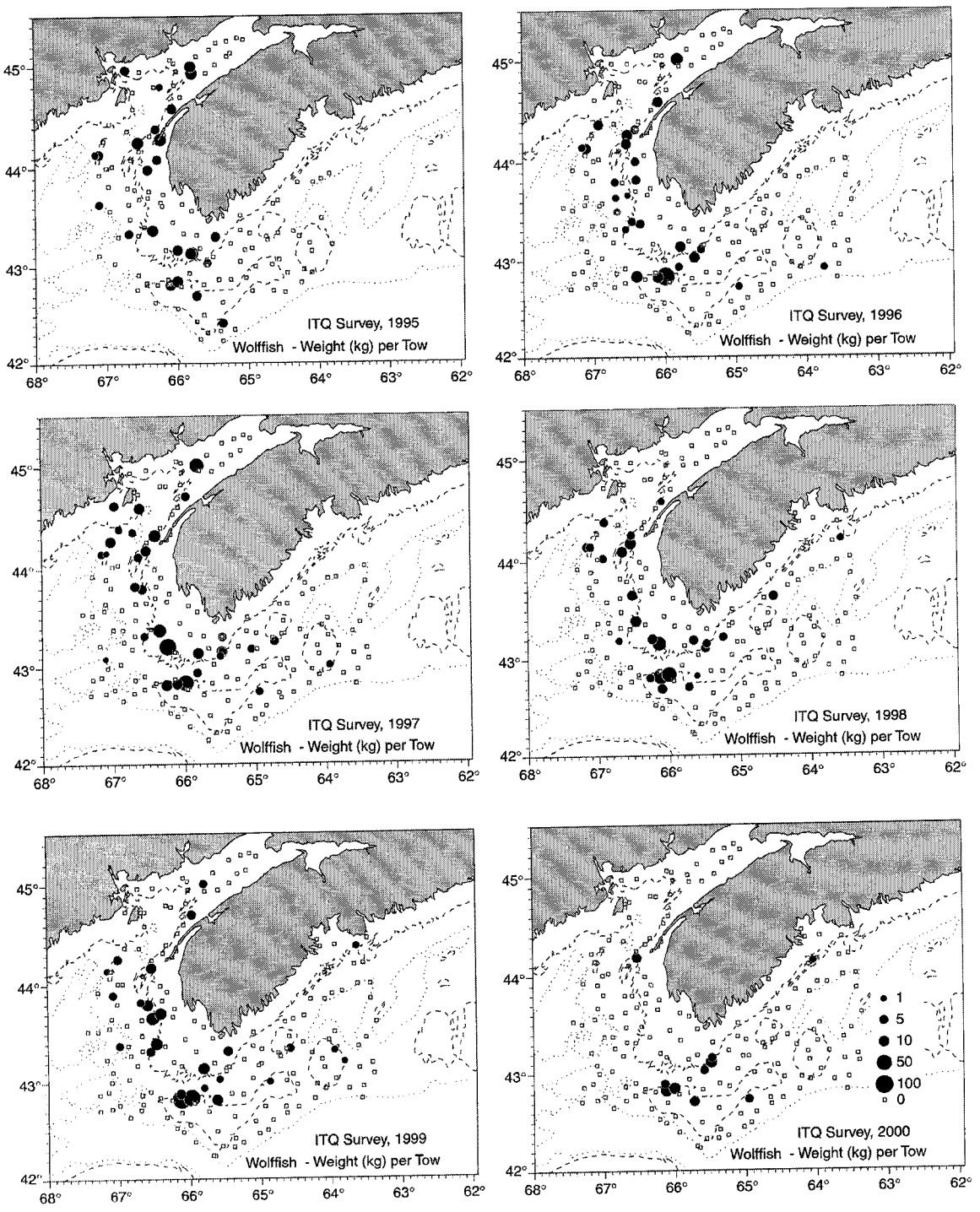

Figure 11 Distribution of Atlantic Wolffish from the mobile ITQ Survey in Southwestern Nova Scotia 1995 to 2000

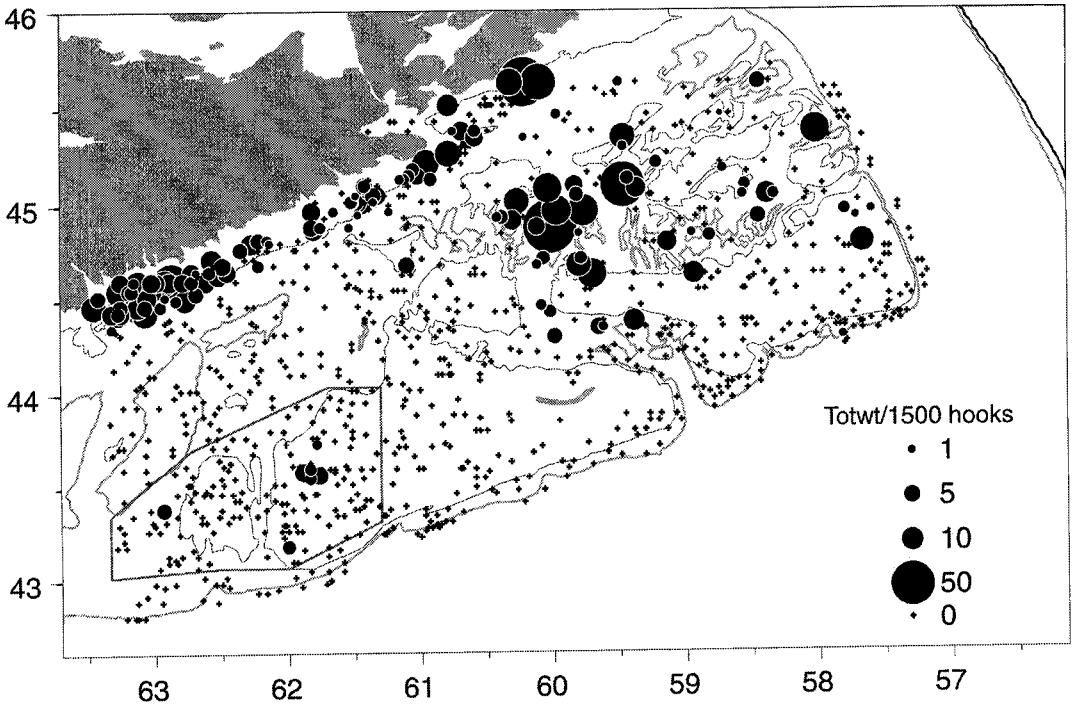

Figure 12 Atlantic wolffish catch (kgs per 1500 hooks) from the 4VsW Sentinel survey 1995 to 1998

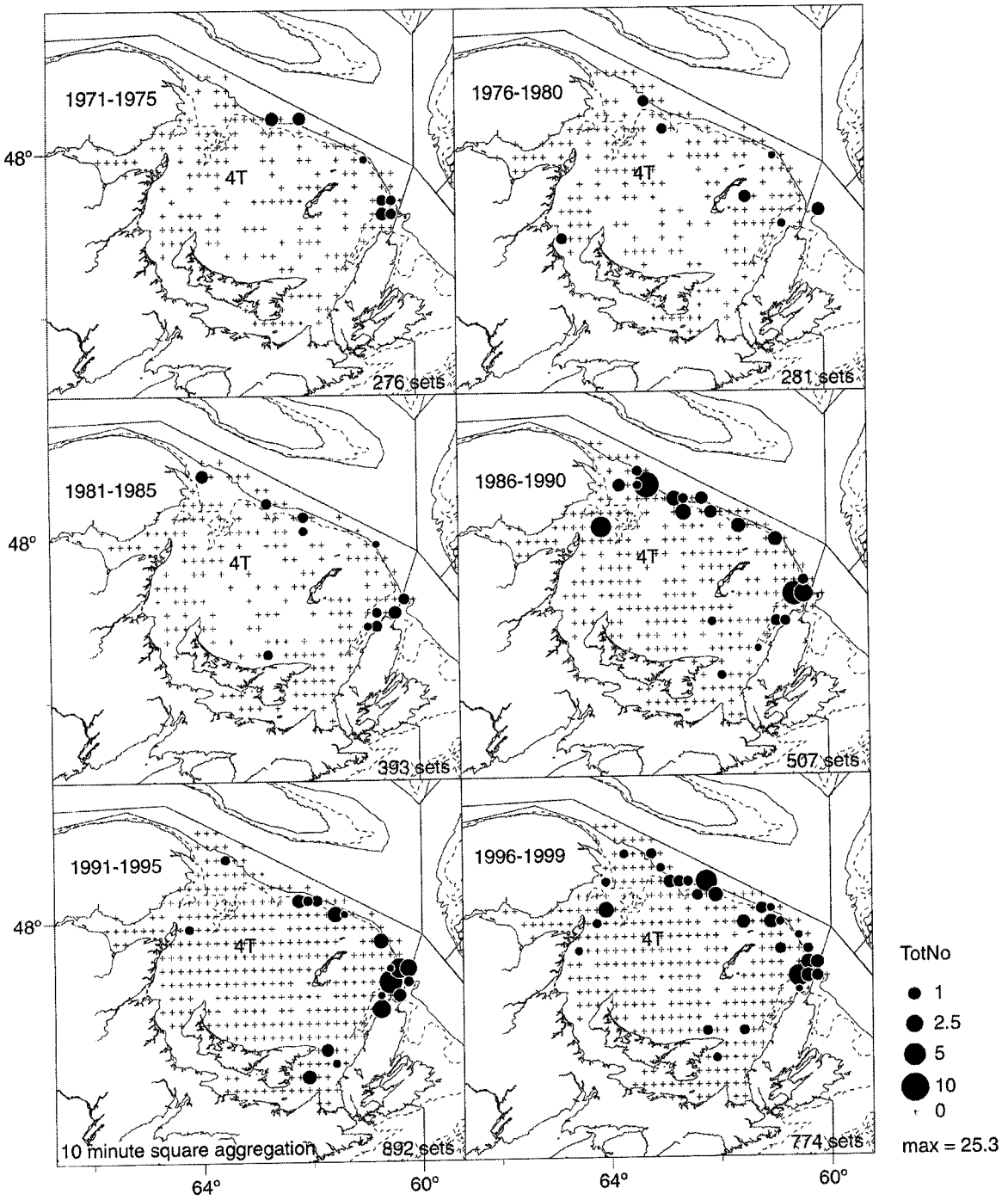

Figure 13 Distribution of Atlantic Wolfish from the 4T fall RV surveys, 1971 to 1999 (adjusted number per tow) (**Note**: right-bottom fig is 1996 to 1999)

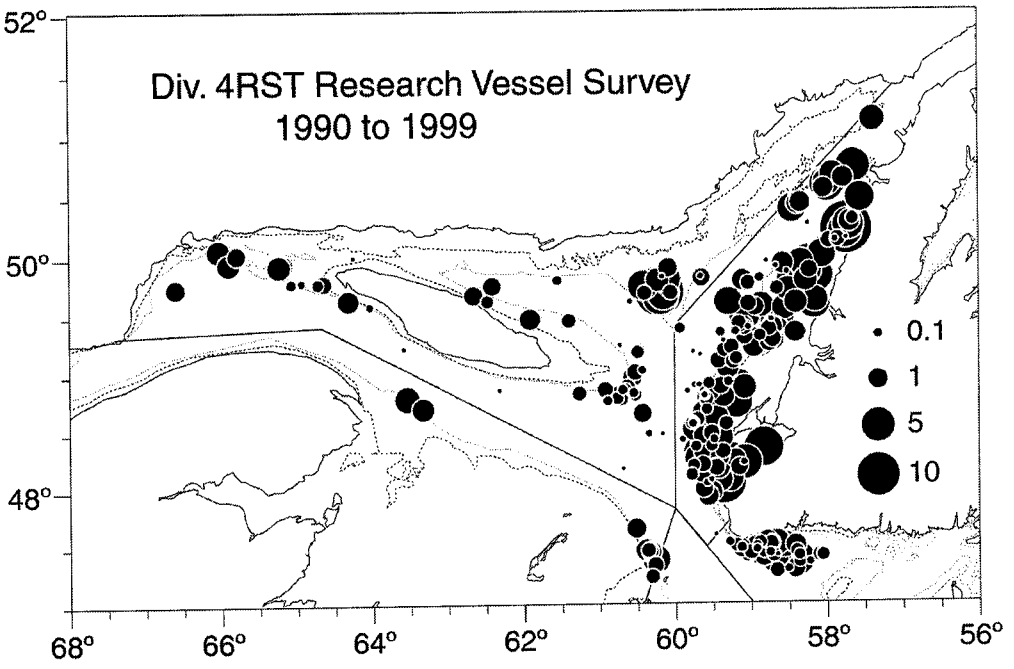

Figure 14 Distribution of Atlantic wolffish catch from the summer research survey of the northern Gulf of St Lawrence 1990 to 1999 (numbers per tow)

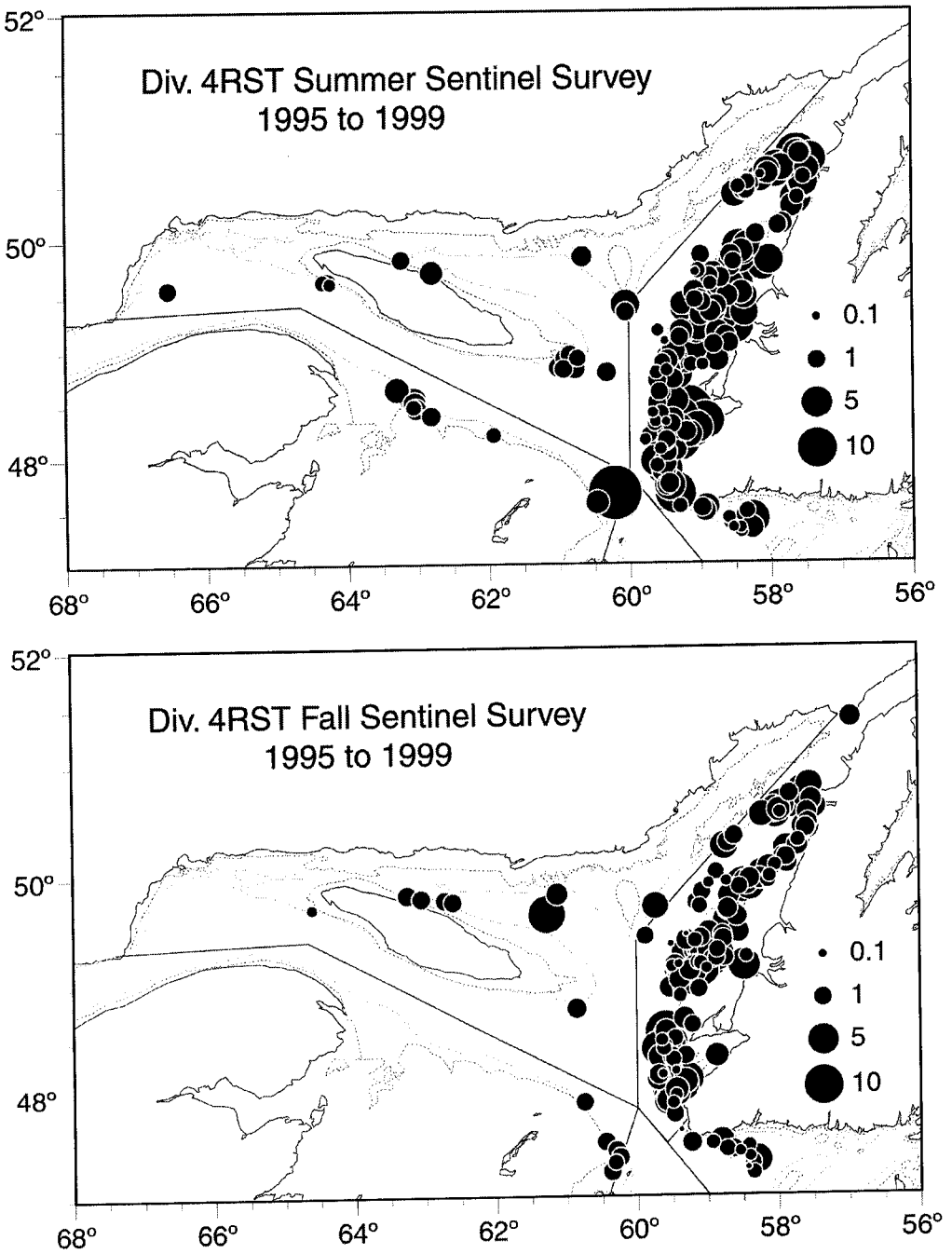

Figure 15 Distribution of Atlantic wolffish catch from sentinel surveys of the northern Gulf of St Lawrence July 1995 to 1998 (top) and October 1995 to 1999 (bottom) (numbers per tow)

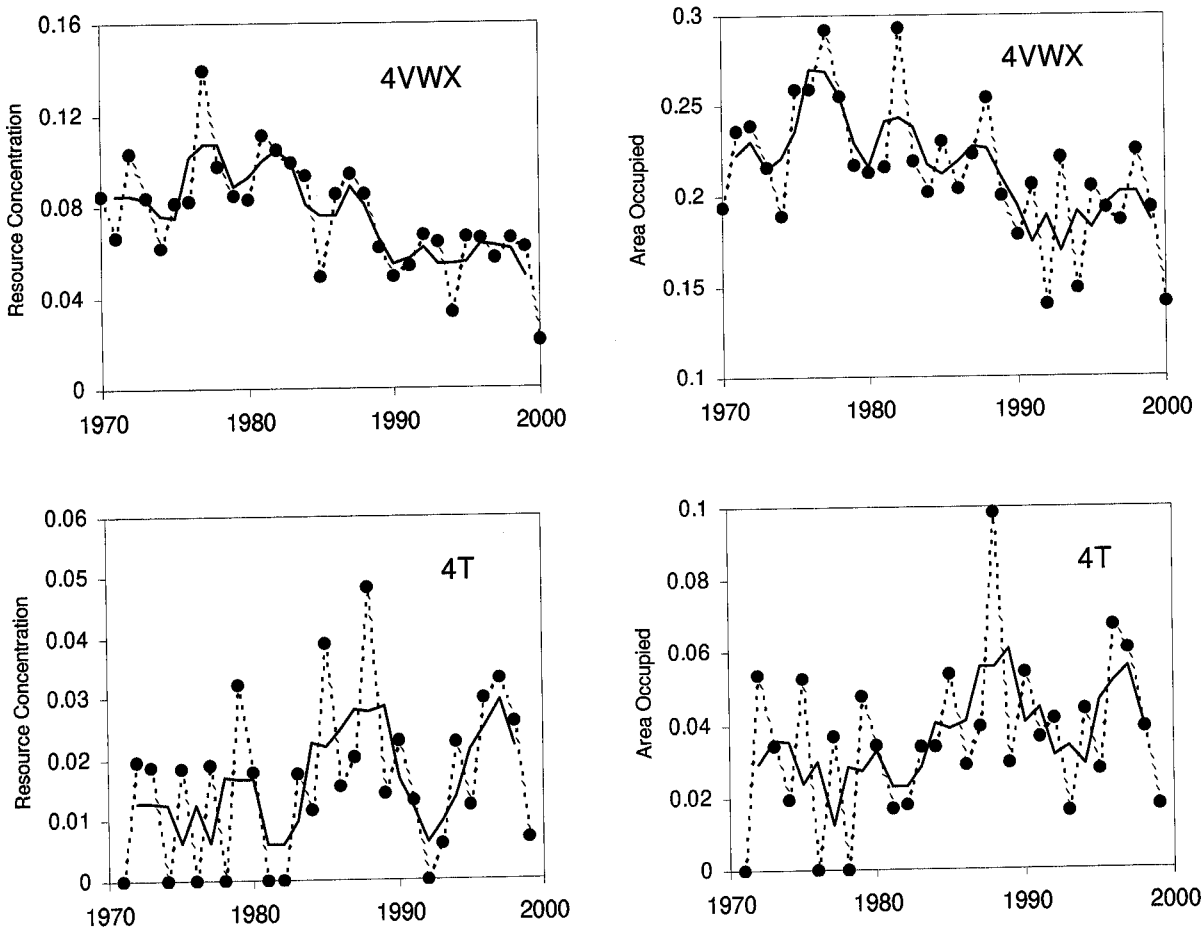

Figure 16 Atlantic wolffish resource concentration (left) and area occupied (right) for NAFO Divisions 4VWX and 4T from RV surveys. Solid line is a 3 year running mean.

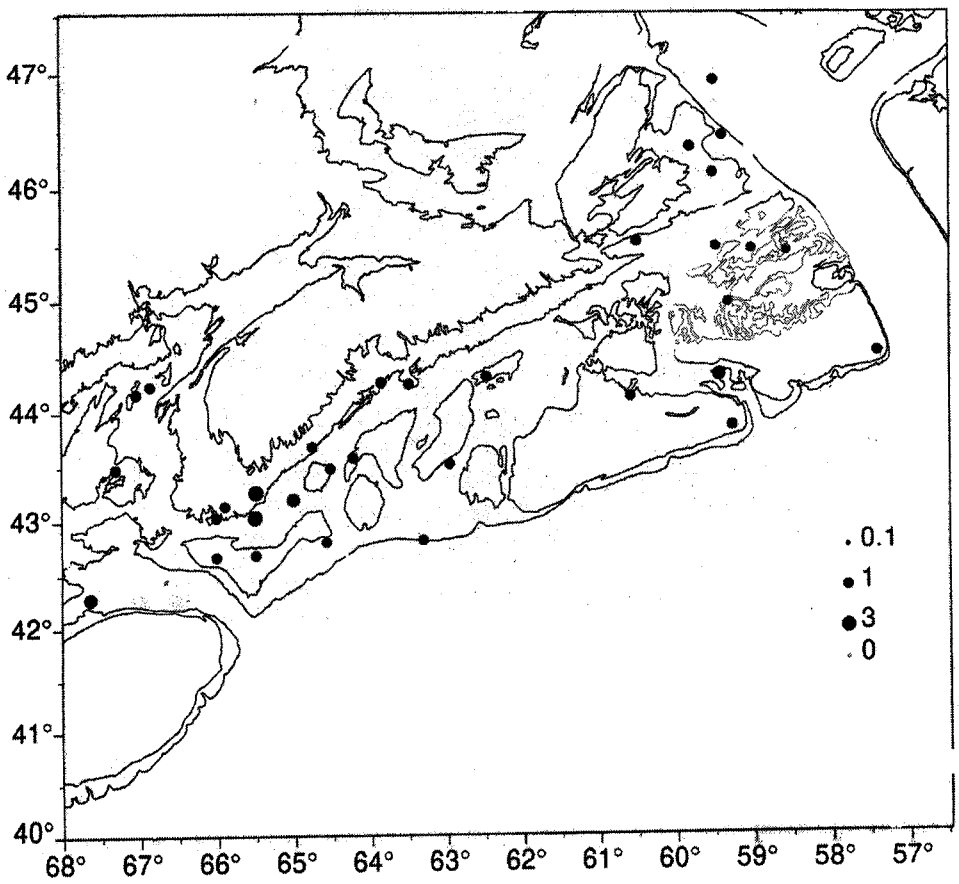

Figure 17 Distribution of Atlantic Wolffish larvae on the Scotian Shelf from SSIP surveys (1978-1982).

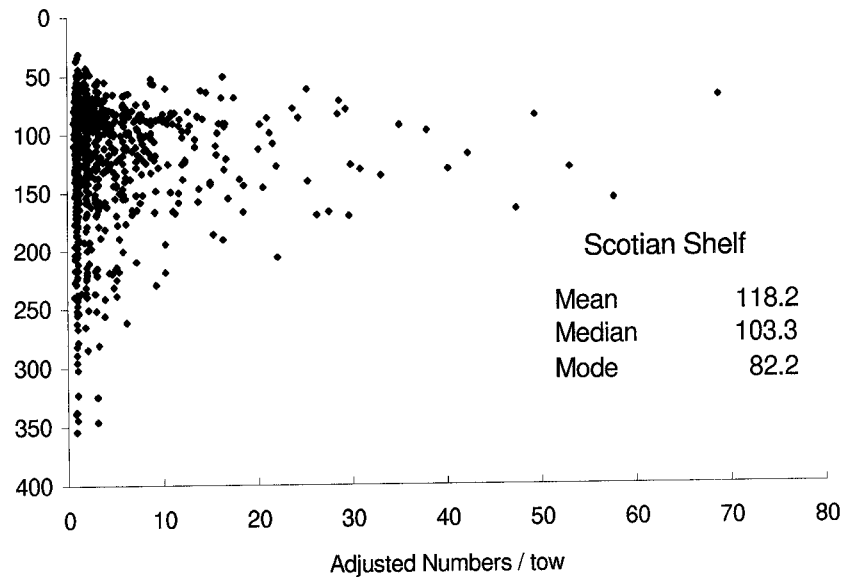

Figure 18 Distribution by depth of Atlantic wolffish in groundfish surveys of the Scotian Shelf (1970-1999).

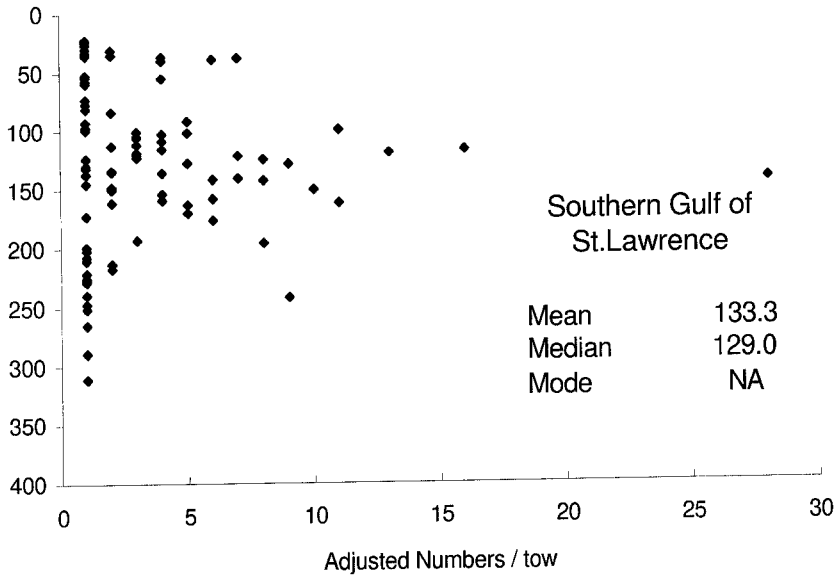

Figure 19 Distribution by depth of Atlantic wolffish in groundfish surveys of the southern Gulf of St. Lawrence (1971-1999).

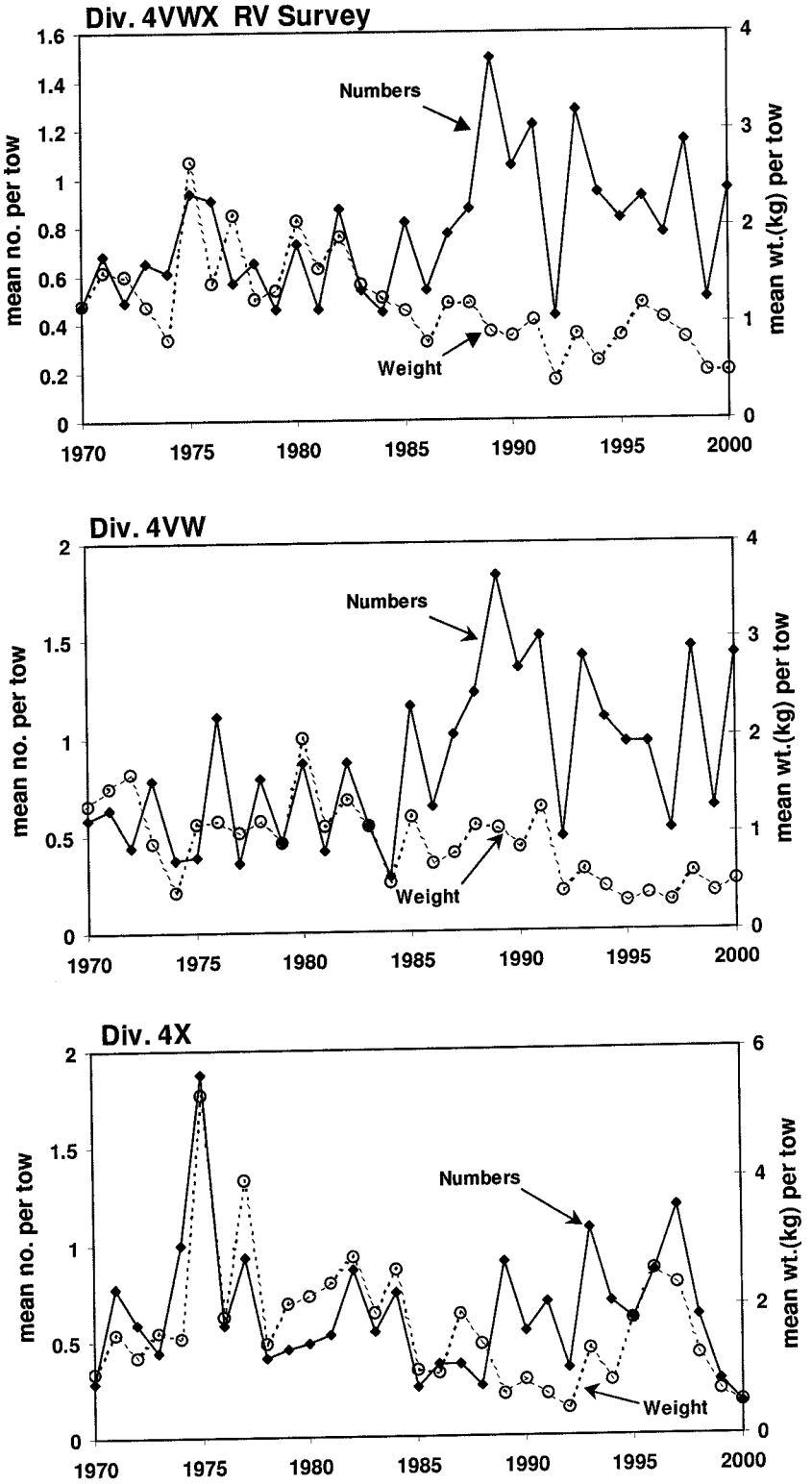

Figure 20 Indices of abundance and biomass from RV Summer Surveys for NAFO Div. 4VWX (top) and for Div. 4VW (middle) and Div. 4X (bottom)

4VsW Sentinel Surveys

Year	Stratified no/1500 hooks	Stratified kg/1500 hooks
1995	0.658	0.976
1996	1.414	1.352
1997	0.520	0.533
1998	1.300	1.352
Average	*0.973*	*1.053*

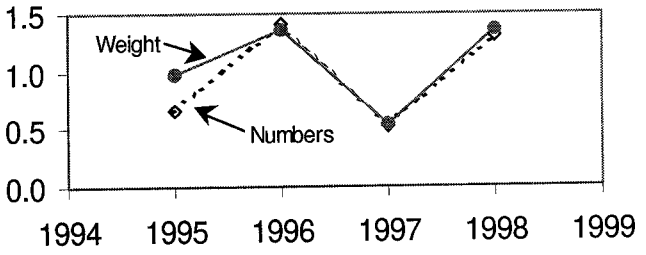

Figure 21 4VsW Sentinal Survey Wolffish catch per 1500 hooks from 1995 to 1998. Weight estimates are the solid line and numbers estimates are the dotted line.

Wolffish 4Vn Sentinel Survey

Year	kg/1000 hooks
1994	7.58
1995	9.31
1996	4.69
1997	9.87
1998	9.01

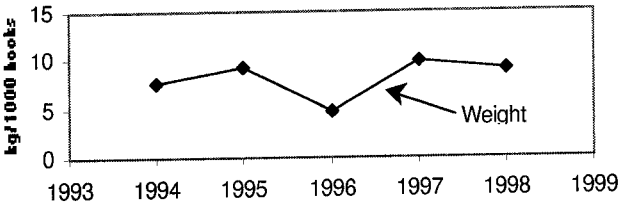

Figure 22 4Vn Sentinel Survey Wolffish catch per 1000 hooks from 1994 to 1998.

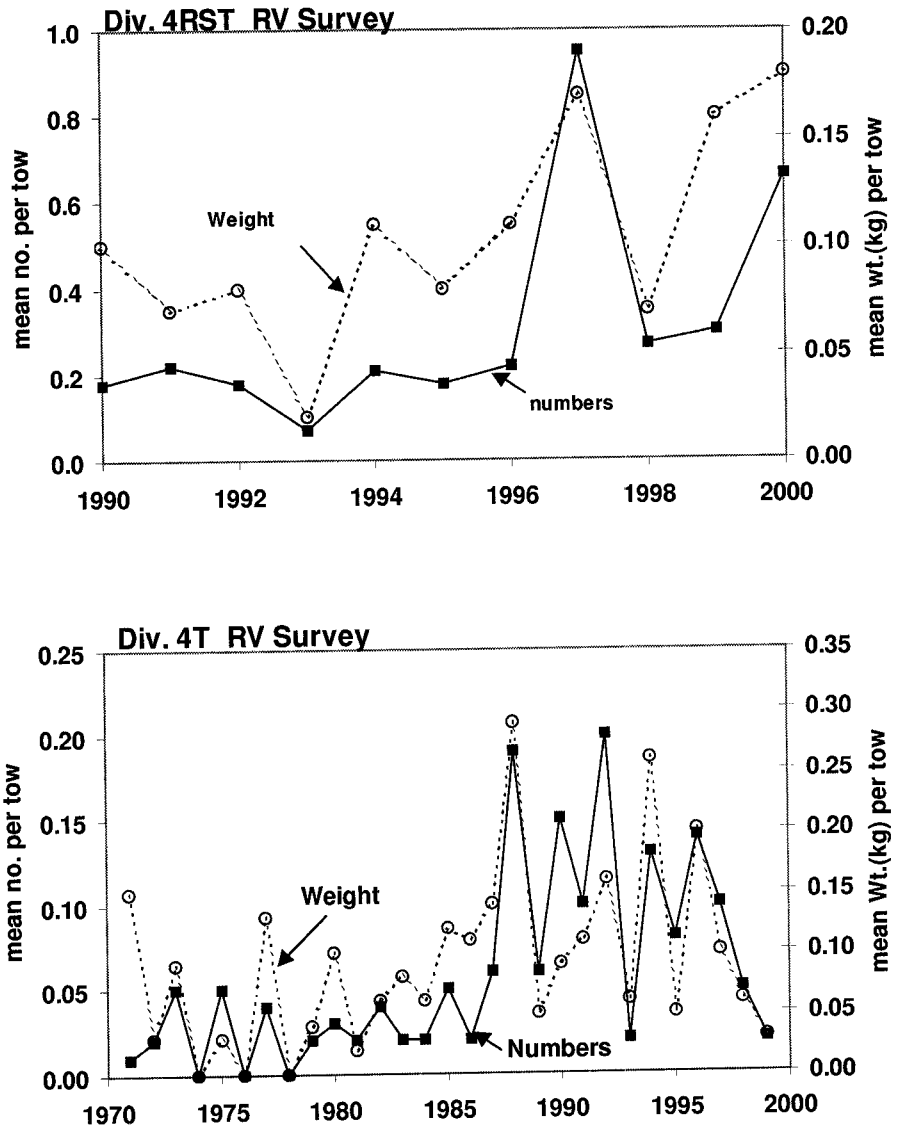

Figure 23 Indices of abundance and biomass from Summer and Fall RV Surveys in Sub-area 4

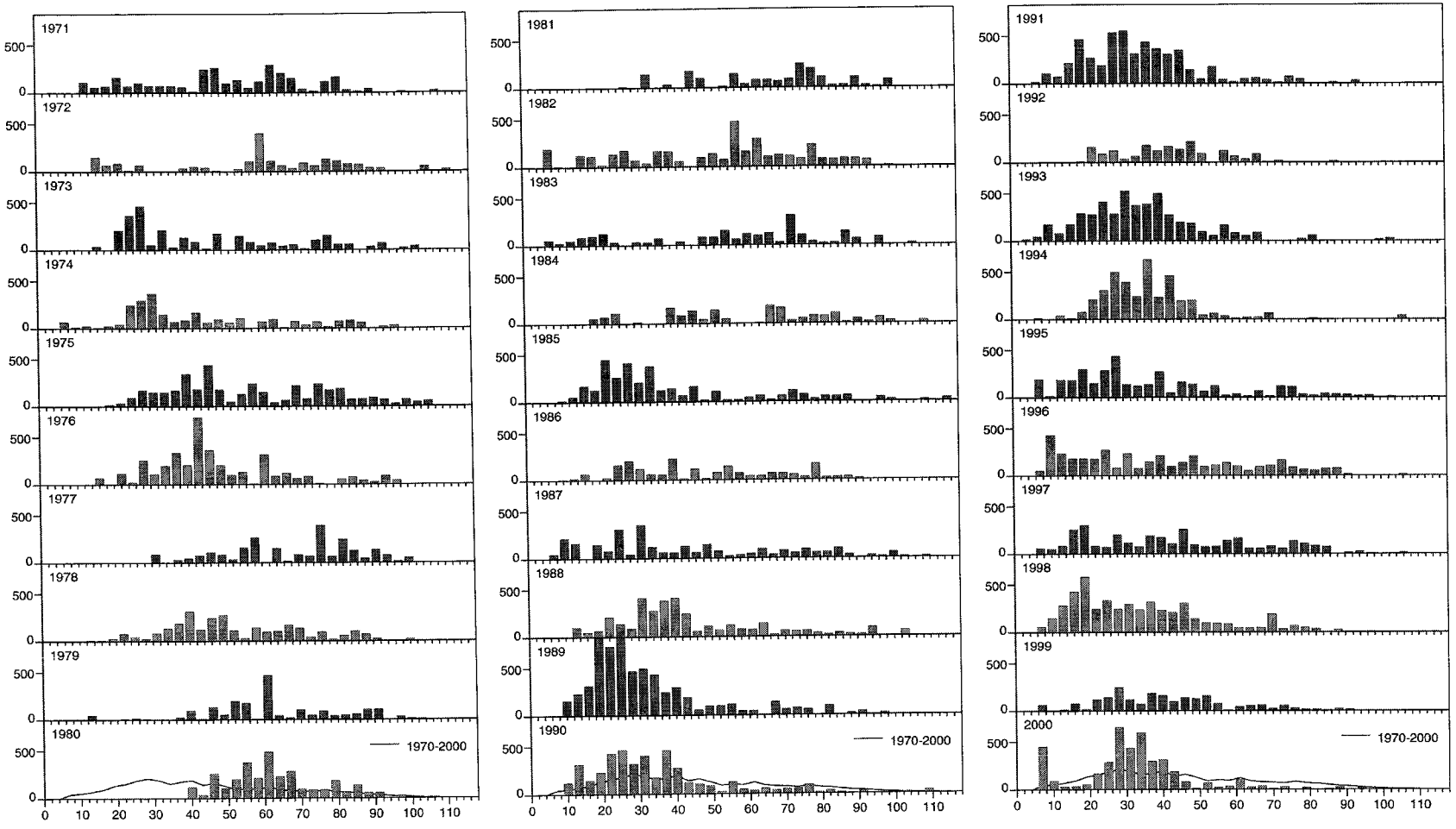

Figure 24 Atlantic Wolffish length freqencies in NAFO divisions 4VWX from summer RV surveys 1971 to 2000 (stratified numbers)

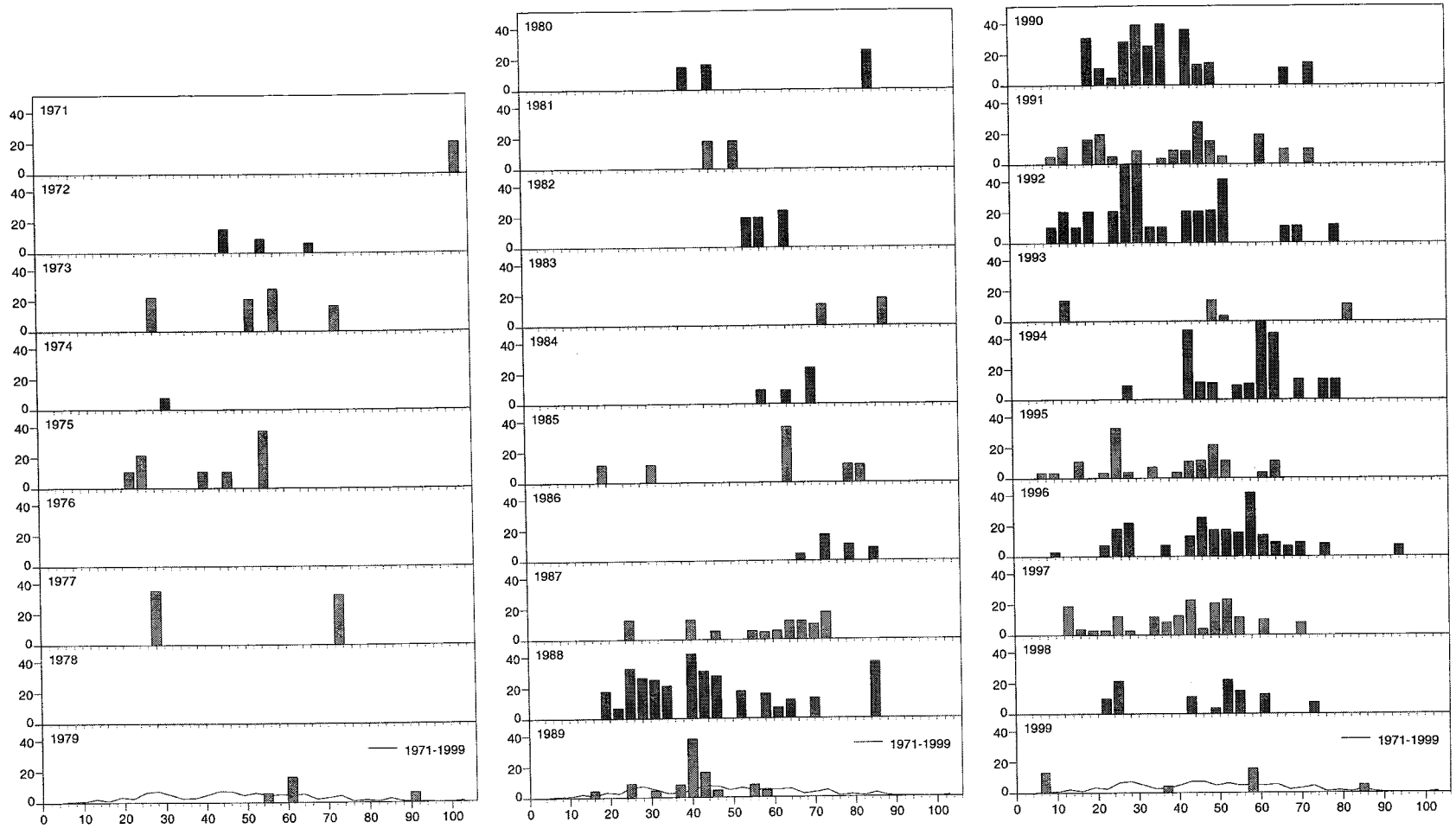

Figure 25 Atlantic Wolffish length freqencies in NAFO divisions 4T from fall RV surveys 1971 to 1999 (stratified numbers)

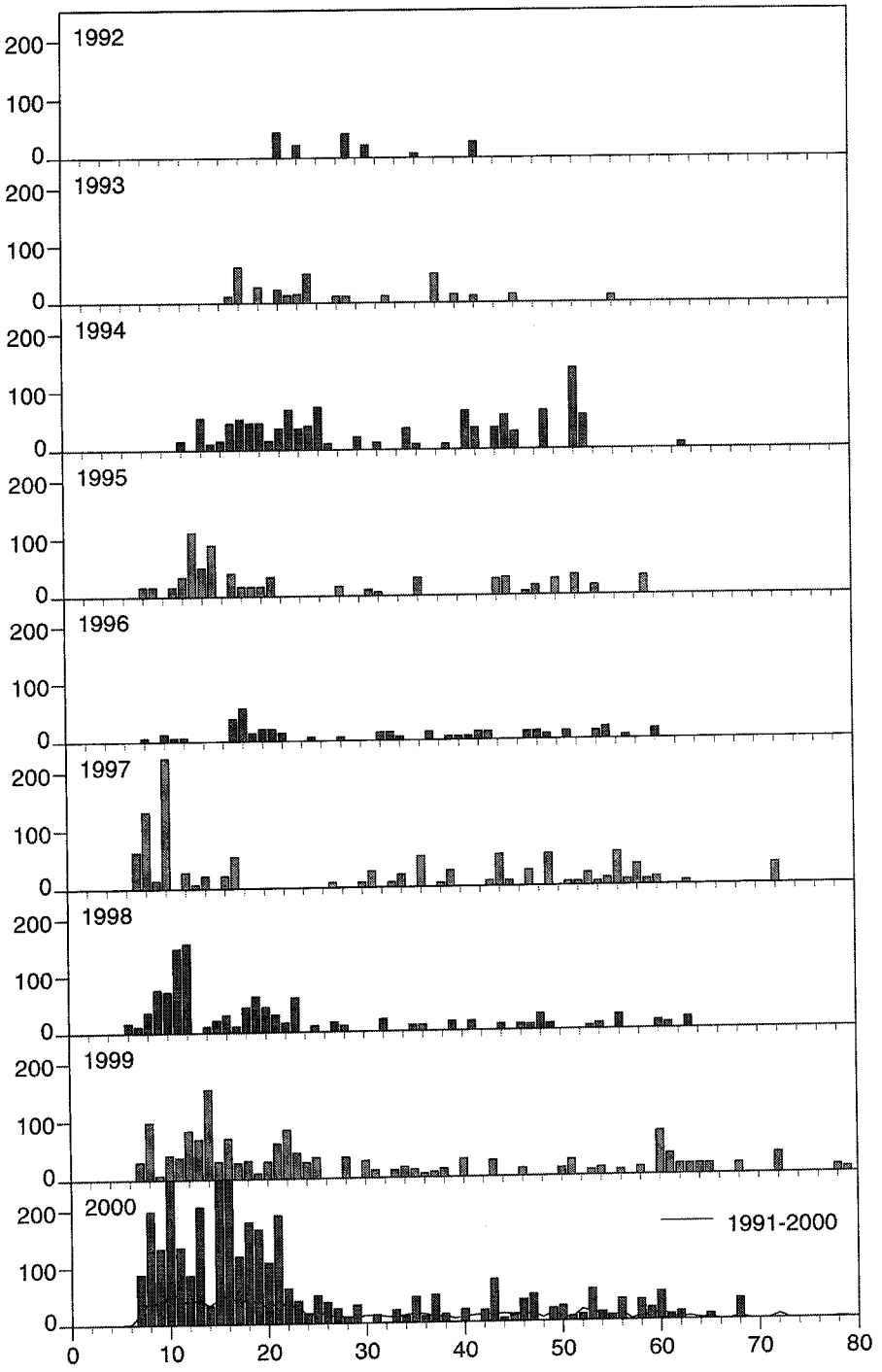

Figure 26 Atlantic Wolffish length frequencies in NAFO division 4RST from summer RV surveys 1992 to 2000 (stratified numbers)

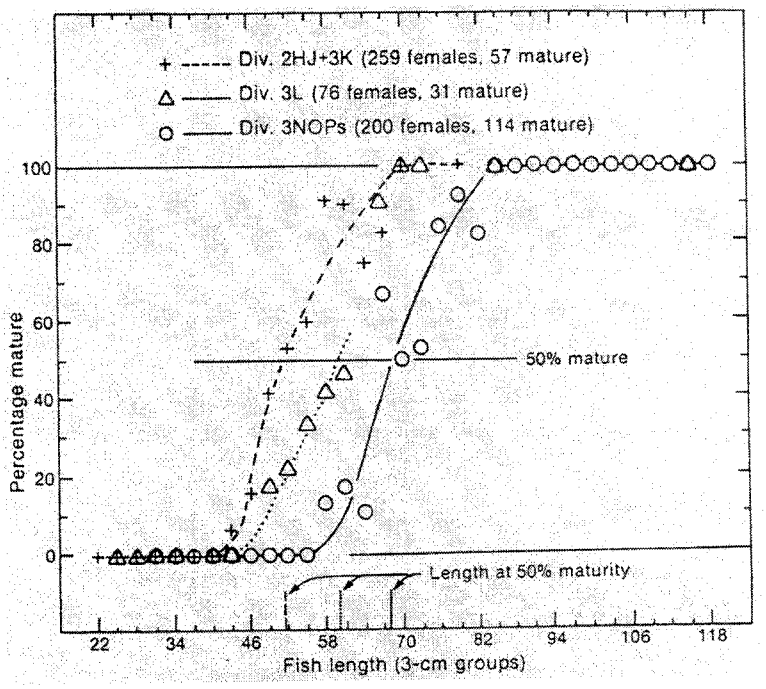

Figure 27 Length-maturity ogives for female Atlantic wolffish from three areas of Labrador-Newfoundland region, 1946-67 (Numbers of fish are indicated) (Templeman (1986)

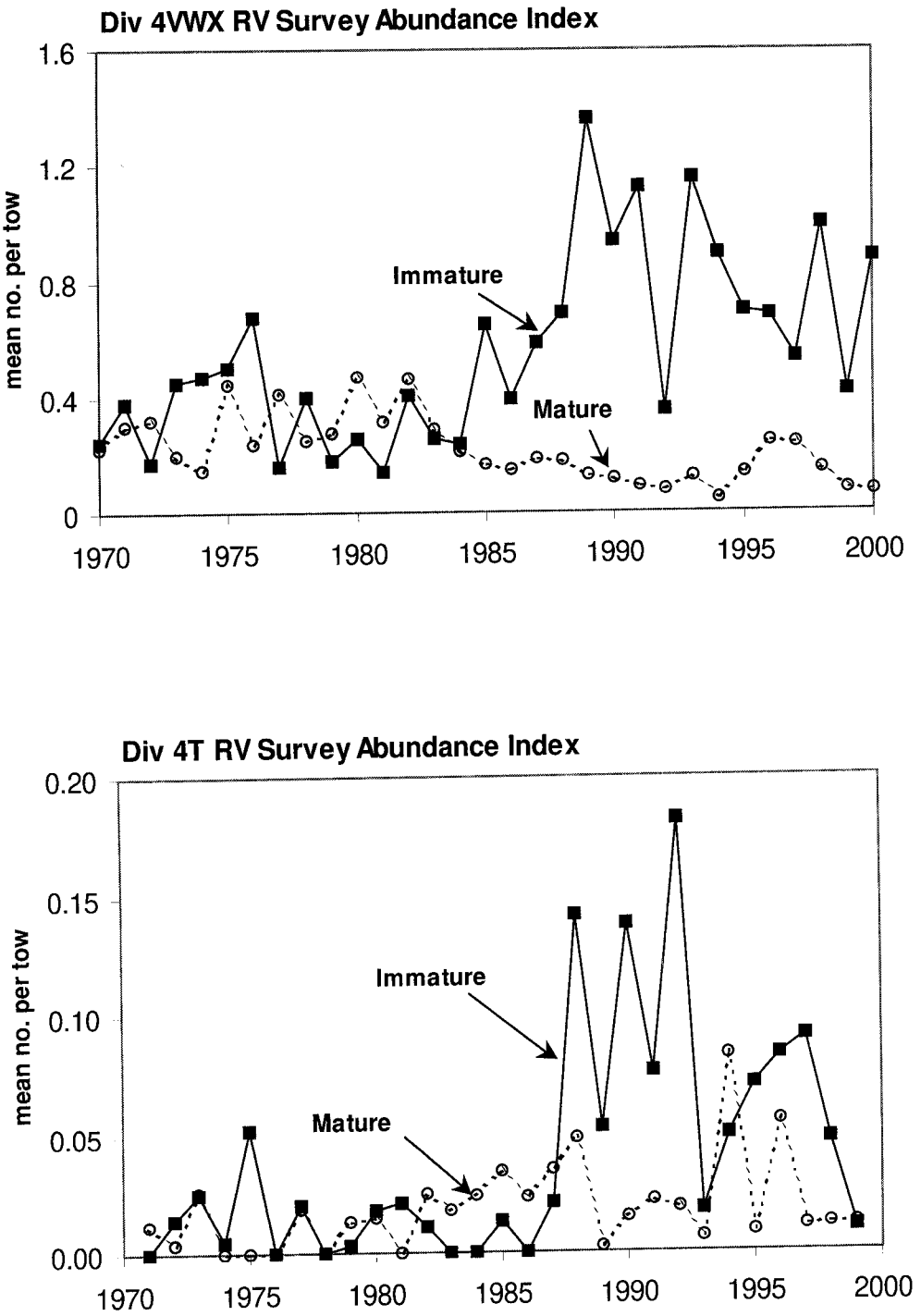

Figure 28 Indices of immature (<=55cm) and mature (>55cm) fish mean numbers per tow in Divisions 4VWX and 4T from RV surveys

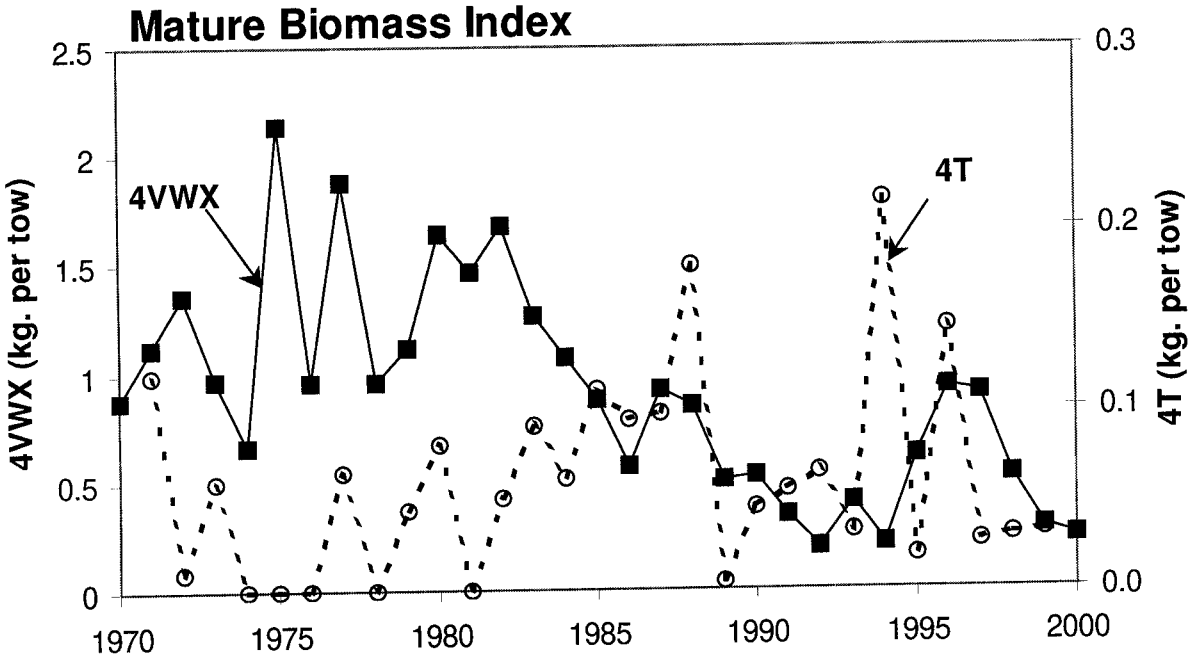

Figure 29 Biomass index for mature Atlantic Wolffish (>55cm) from the 4VWX summer RV survey and the 4T fall RV survey.

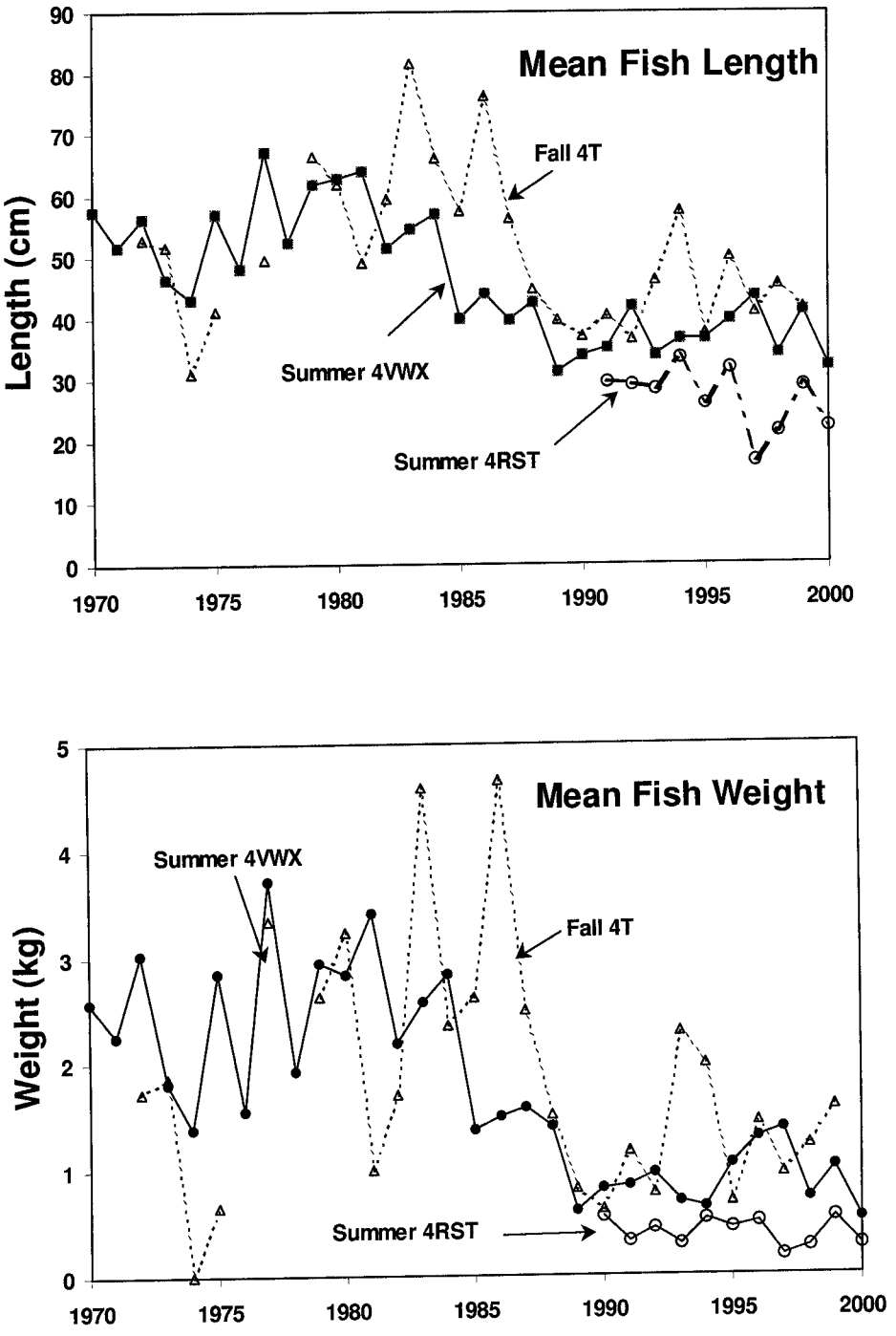

Figure 30 Mean length (cm) and weight (kg) derived from RV Surveys in Sub-area 4, the summer 4VWX survey (solid line, solid sqaures), the summer 4RST RV survey (northern Gulf , dashed line , open circles) and the fall 4T RV survey (southern Gulf, dotted line, solid triangles).

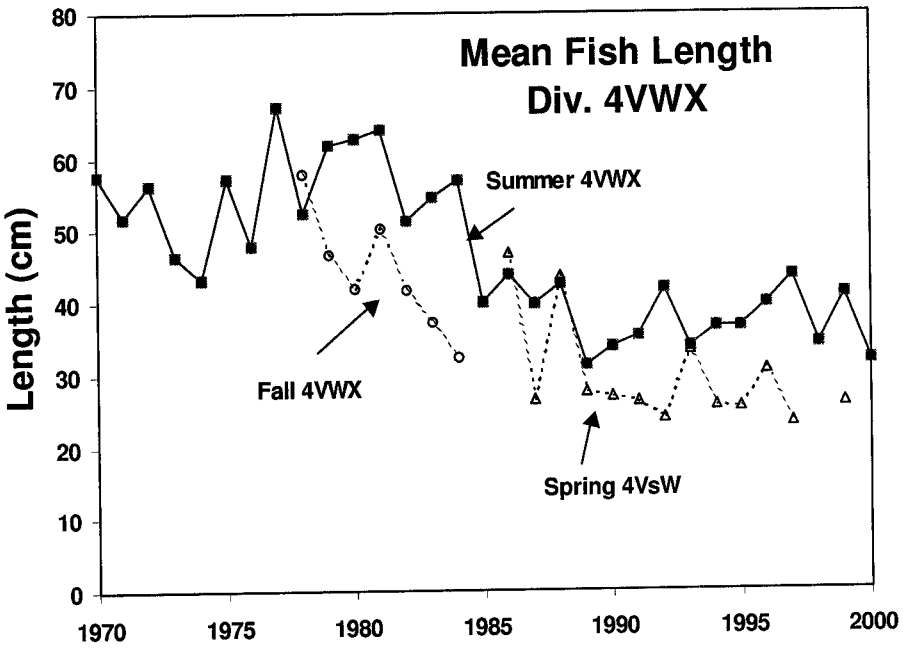

Figure 31 Mean fish length (cm) of Atlantic wolffish from the Summer RV Survey (4VWX), the Fall RV Survey (4VWX) and the Spring RV Survey (4VW).

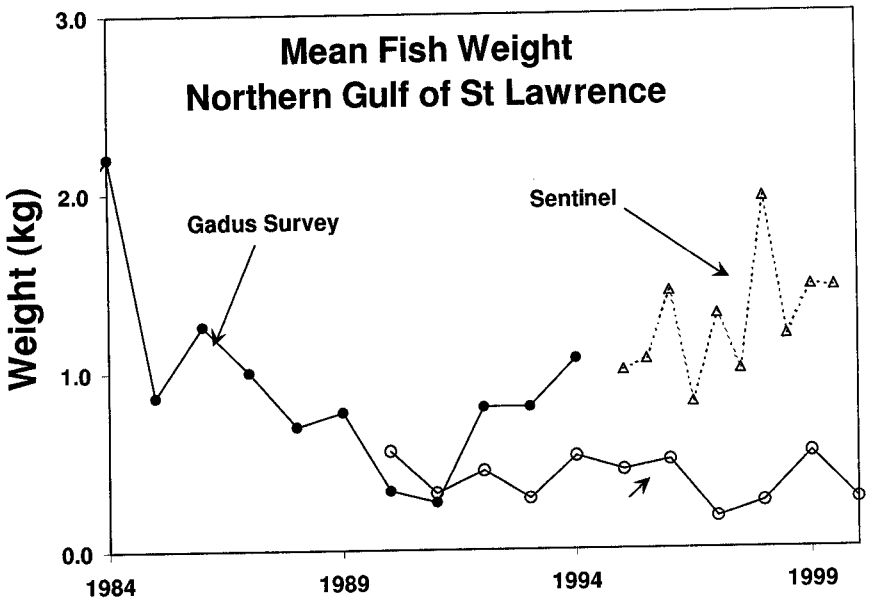

Figure 32 Mean fish weight (kg) of Atlantic wolffish from the Summer RV and Sentinel surveys in the northern Gulf.

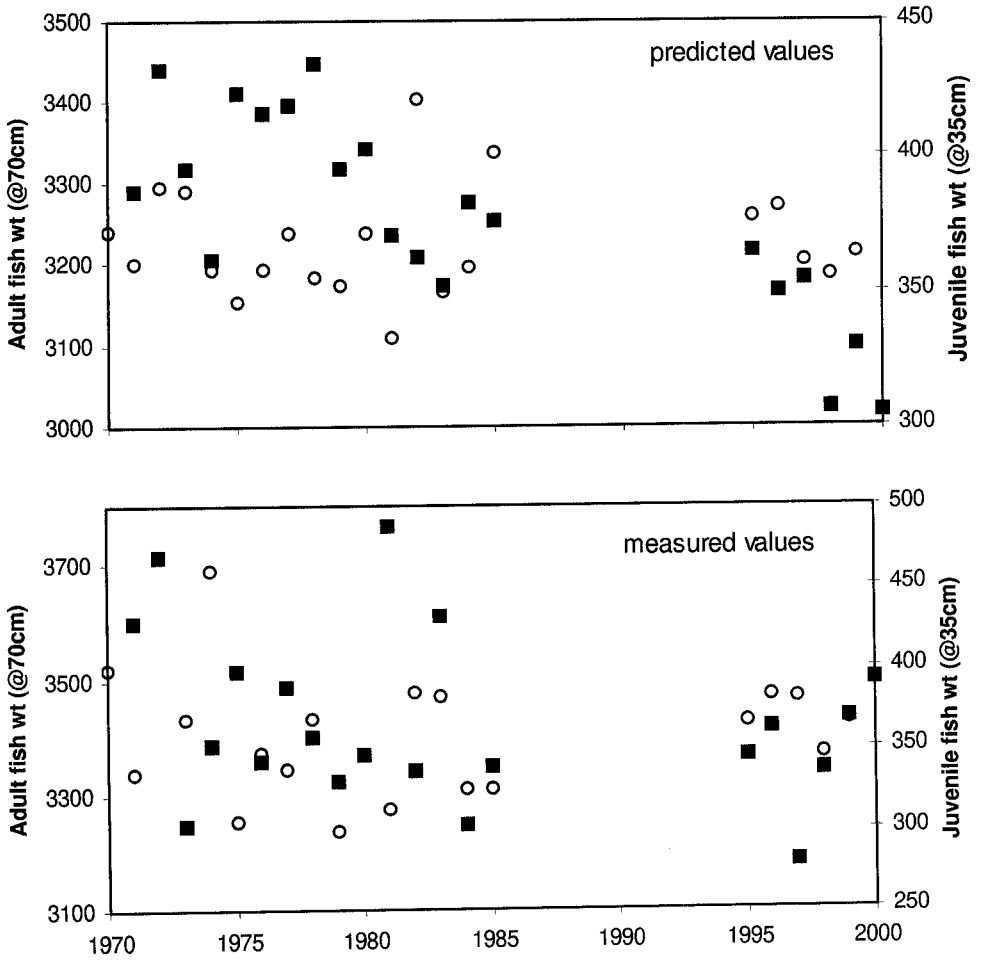

Figure 33 Atlantic wolffish condition using predicted (upper panel) and measured (lower panel) values from 4VWX Summer RV Survey 1970 to 2000. Juvenile fish are open circles and dashed line, Adult fish are solid line and squares. Individual fish weights were not collected between 1986 and 1994.

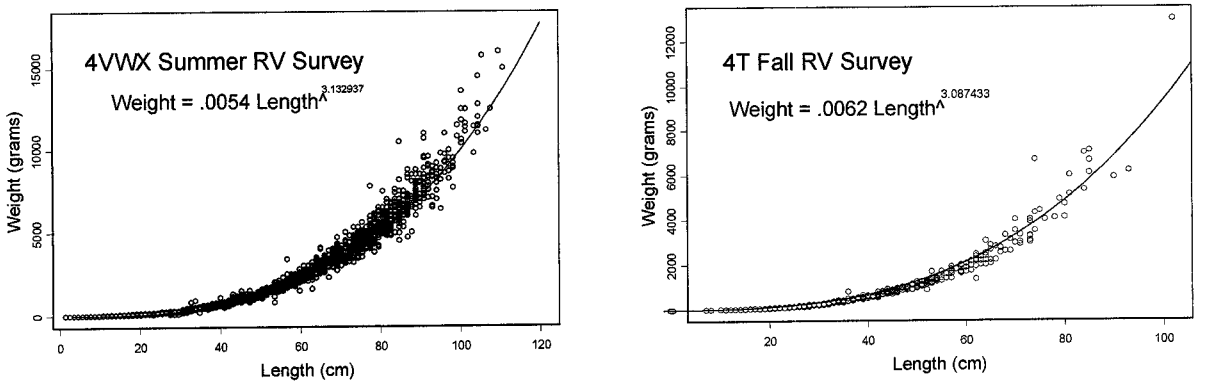

Figure 34 The length and weight of Atlantic wolffish from RV surveys in NAFO Div. 4VWX 1970 to 1999 (left) and Div. 4T 1971 to 1999 (right)

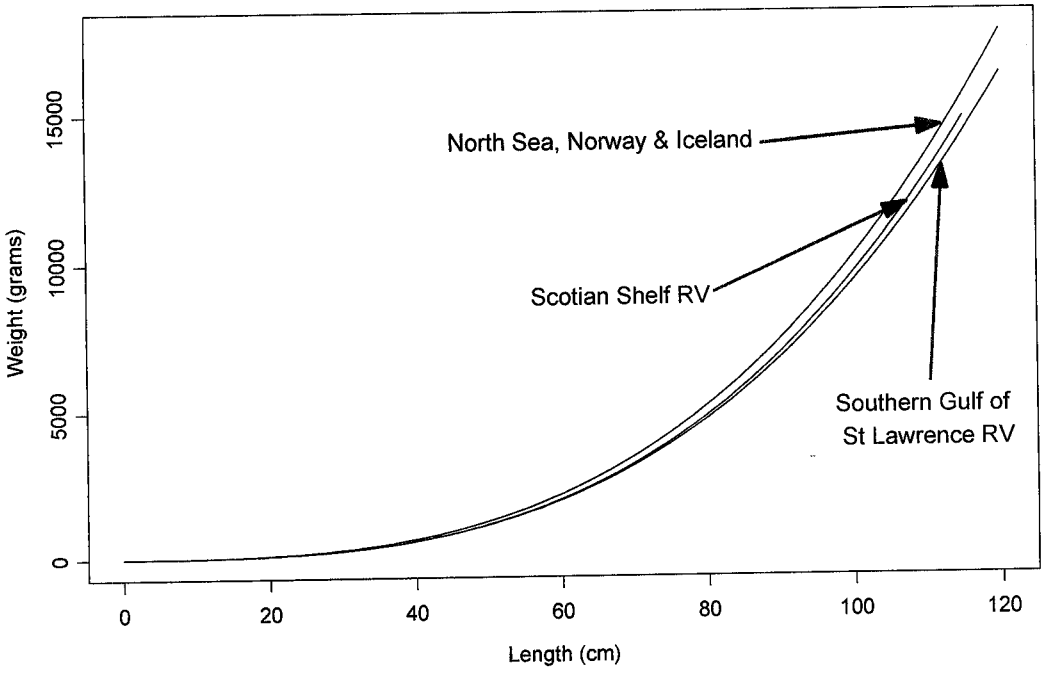

Figure 35 Length weight curves from the North Sea, Norway and Iceland (Beese & Kändler), the Scotian Shelf (Div. 4VWX) and the Southern Gulf of St Lawrence (Div. 4T)

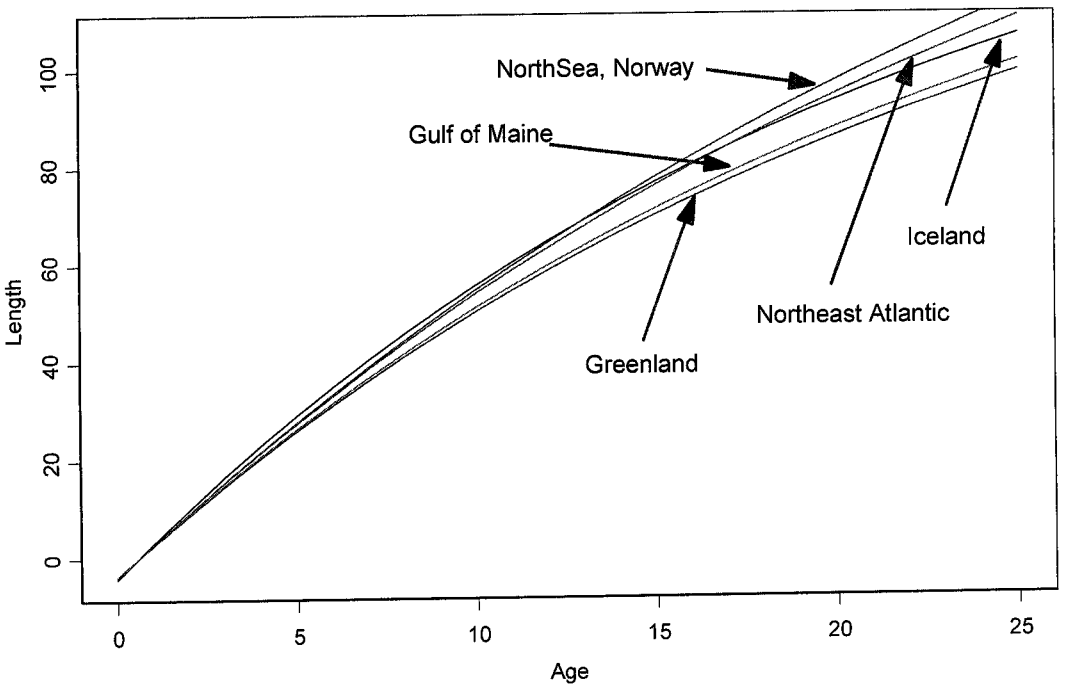

Figure 36 Von Bertalanffy age length curves from the literature for Atlantic wolffish (Table 4).

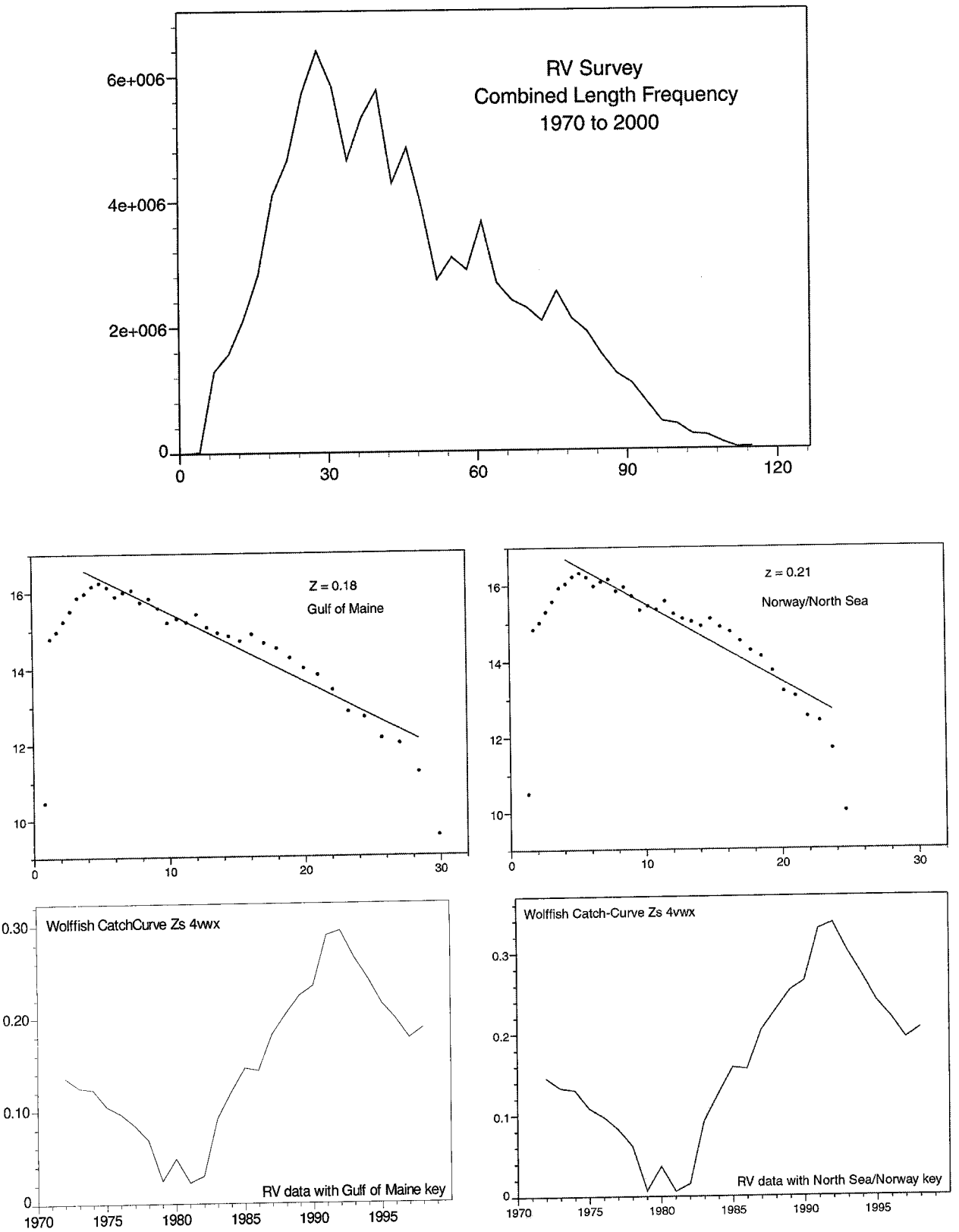

Figure 37 Atlantic wolffish estimates of total mortality from the 4VWX Summer RV Survey using Gulf of Maine and Norway/North Sea age length keys.

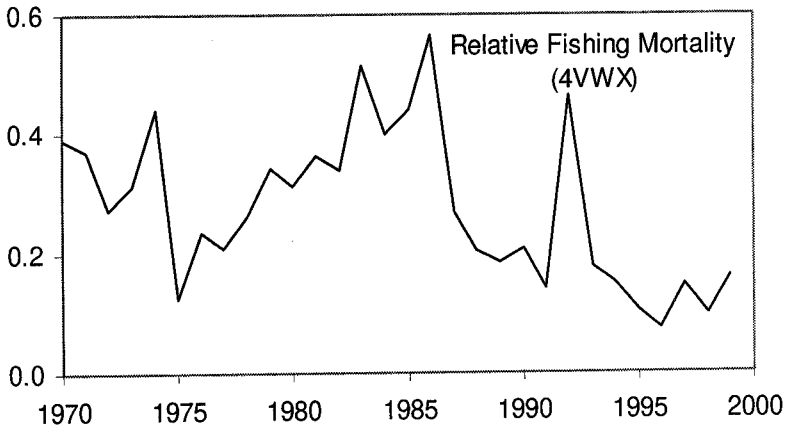

Figure 38 Relative fishing mortality for Div. 4VWX using total landings and biomass estimates from 4VWX summer RV surveys (1970 to 1999)

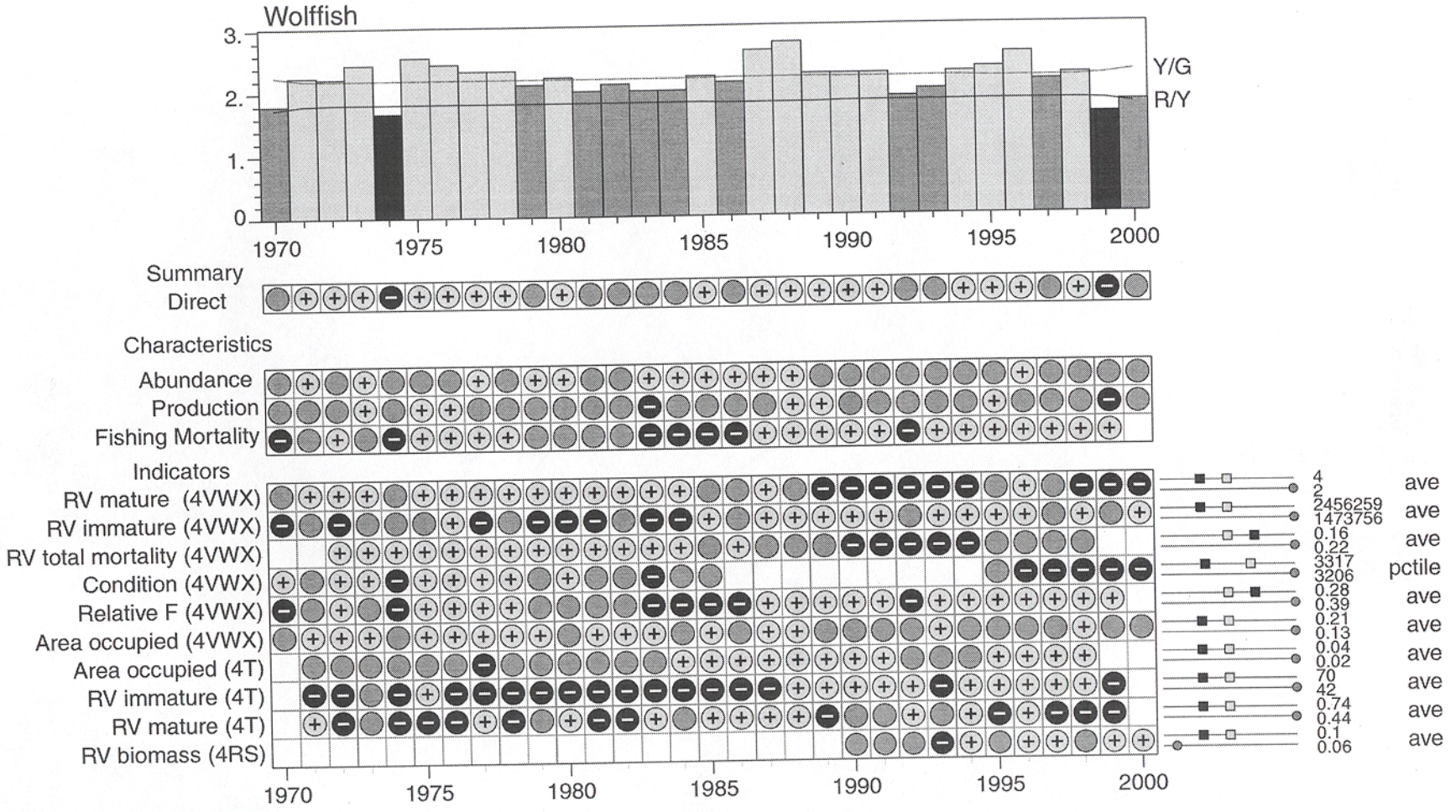

Figure 39 Traffic Light Table for Atlantic Wolffish using indices from NAFO Sub-Area 4. Green values ⊕ are good, Red values ⊖ are bad and Yellow values ◍ require caution. Slide bars (lower right) show Red-Yellow and Yellow-Green levels, index weighting, data range and type.

Figure 39 Traffic Light Table for Atlantic Wolffish using indices from NAFO Sub-Area 4. Green values ⊕ are good, Red values ⊖ are bad and Yellow values ○ require caution. Slide bars (lower right) show Red-Yellow and Yellow-Green levels, index weighting, data range and type.