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Maritimes Region | **Région des Maritimes**

Pre-COSEWIC Review of Atlantic Wolffish (*Anarhichas lupus*), Northern wolffish (*A. denticulatus*), and Spotted Wolffish (*A. minor*) in the Maritimes Region

Examen, préalable à l'évaluation du COSEPAC, du loup atlantique (*Anarhichas lupus*), du loup à tête large (*A. denticulatus*) et du loup tacheté (*A. minor*) dans la Région des Maritimes

James Simon, Sherrylynn Rowe, and Adam Cook

Department of Fisheries and Oceans
Population Ecology Division
Bedford Institute of Oceanography
P.O. Box 1006, 1 Challenger Drive
Dartmouth, Nova Scotia
B2Y 4A2

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ABSTRACT

The *Committee on the Status of Endangered Wildlife in Canada* (COSEWIC) examined the status of Atlantic wolffish in 2000 and recommended that it be listed as a species of special concern; while in 2001, the status of Northern and Spotted wolffish were recommended to be listed as threatened for the Canadian Atlantic. COSEWIC is required to track the status of wildlife species previously designated as endangered, threatened, and special concern by preparing updated status reports. As part of this process COSEWIC has called for a re-evaluation of the three species of wolffish and DFO, as the department responsible for the management of these species, is required to provide up to date information on the status of these species. This paper examines the DFO research vessel (RV) and industry surveys, extending the analysis to include USA RV surveys and examines observer and commercial landings data within the Maritimes Region. Collectively the data suggest that although Atlantic wolffish is found throughout the Maritimes Region, there are two primary areas of concentration on the Scotian Shelf. On the eastern Scotian Shelf (Divs. 4VW), the abundance of mature individuals has declined by 99% since 1970, while the abundance of immature individuals has increased over the same period. On the western Scotian Shelf (Div. 4X), both immature and mature abundance has declined since 1970. Although these two concentrations exhibit differing trends in abundance, there is no evidence to suggest that they are separate designatable units. On the northeast peak of Georges Bank, there is a small aggregation of Atlantic wolffish that appears to be spatially discrete from the remainder of the surveyed area (Div. 5Z) and that has declined dramatically since 1986. Although there are no directed fisheries for wolffish (assumed to be Atlantic wolffish) in the Maritimes Region, the species is caught as bycatch in other fisheries. Fishers have been known to make directed sets for wolffish within a trip, but they are no longer permitted to direct for the species. Annual landings of wolffish by Canada in Div 5Z have generally been below 100 t since 1963, with recent landings near zero. In Divs. 4X5Y, landings peaked in the late 1970s at 1,600 t and subsequently have declined to less than 100 t in recent years. In Divs. 4VW, landings ranged from 400 to 700 t between 1963 and the early 1980s then declined sharply until 1993 when all directed fishing for cod and haddock ended. Since 1993, wolffish landings have been near zero. An examination of wolffish landings in Div. 4X revealed that wolffish were concentrated on the western peak of Browns Bank, west of German Bank, and in three isolated areas inshore of the 50 fathom line. These inshore areas are not surveyed by the DFO RV surveys and should be examined in more detail as they are potentially areas of critical habitat. The 2001 review of the status of Northern wolffish and Spotted wolffish indicated that both species were near the southern limit of their range in the Maritimes Region. This review confirms that conclusion with the composite distribution pattern from all data sources in the Maritimes Region indicating that both species are restricted primarily to the eastern Scotian Shelf, with some fish found along the shelf edge in Divs. 4WX. Abundance in each survey examined has always been very low with both species occurring in less than 0.5% of the sets.

RÉSUMÉ

Le *Comité sur la situation des espèces en péril au Canada* (COSEPAC) a examiné la situation du loup atlantique en 2000 et recommandé que celui-ci soit inscrit sur la liste des espèces en péril comme espèce préoccupante; en 2001, ce fut au tour du loup à tête large et du loup tacheté du Canada atlantique de faire l'objet d'une recommandation d'inscription sur cette même liste en tant qu'espèces menacées. Le COSEPAC est tenu d'effectuer un suivi de la situation des espèces sauvages qui ont été désignées comme étant en voie de disparition, menacées ou préoccupantes, au moyen d'une mise à jour du rapport de situation les concernant. Dans le cadre de ce processus, le COSEPAC a demandé une réévaluation de la situation de ces trois espèces de loup et le MPO, en tant que ministère responsable de la gestion de ces espèces, est tenu de fournir des renseignements à jour sur leur situation. On examine ici les résultats des relevés par navire scientifique (NS) du MPO et des relevés de l'industrie, élargissant aussi l'analyse aux relevés NS des États-Unis, ainsi que les données des observateurs et les statistiques de débarquements commerciaux dans la Région des Maritimes. Globalement, les données semblent indiquer que bien qu'il soit présent dans toutes les eaux de la Région, le loup atlantique se concentre surtout dans deux endroits du plateau néo-écossais. Dans l'est du plateau (div. 4VW), l'abondance des individus matures a diminué de 99 % depuis 1970, alors que celle des individus immatures a augmenté sur la même période. Dans l'ouest du plateau (div. 4X), l'abondance de tous les individus, matures et immatures, a reculé depuis 1970. Quoique les tendances d'abondance de ces deux concentrations diffèrent, rien n'indique que celles-ci constituent des unités désignables distinctes. Dans la pointe nord-est du banc Georges, il y une petite agrégation de loups atlantiques qui semble distincte, sur le plan spatial, de la concentration présente dans le reste de la zone examinée dans les relevés (div. 5Z), et cette agrégation a considérablement diminué depuis 1986. Bien qu'il n'y ait pas de pêche dirigée du loup (tenu pour être du loup atlantique) dans la Région des Maritimes, l'espèce est capturée accessoirement dans d'autres pêches. On sait qu'au cours de sorties de pêche des traits ciblant le loup ont été effectués, mais la pêche dirigée de ce poisson est désormais interdite. Les débarquements canadiens annuels de loup provenant de la division 5Z ont été généralement inférieurs à 100 t depuis 1963 et proches de zéro dernièrement. Dans les divisions 4X5Y, les débarquements ont culminé à 1 600 t à la fin des années 1970, avant de reculer ensuite, pour se chiffrer à moins de 100 t ces dernières années. Dans les divisions 4VW, les débarquements se sont situés entre 400 et 700 t entre 1963 et le début des années 1980, puis ils ont chuté nettement jusqu'en 1993, année où il a été mis fin à toute pêche dirigée de la morue et de l'aiglefin. Depuis lors, les débarquements de loup ont été pratiquement nuls. Il ressort d'un examen des débarquements de loup en provenance de la division 4X qu'ils étaient concentrés dans la pointe ouest du banc de Brown, dans l'ouest du banc German et dans trois secteurs côtiers isolés situés en deçà de l'isobathe de 50 brasses. Ces secteurs ne sont pas compris dans le relevé NS du MPO et il conviendrait de les étudier plus en détail comme zones possibles d'habitat essentiel. D'après l'examen de la situation du loup à tête large et du loup tacheté effectué en 2001, les deux espèces se trouvaient près de la limite sud de leur aire de répartition dans la Région des Maritimes. Le présent examen le confirme et l'image composite de la répartition que donnent toutes les sources de données dans la Région des Maritimes révèle que les deux espèces se limitent surtout à l'est du plateau néo-écossais, certains poissons évoluant sur le bord du plateau dans les divisions 4WX. Dans chaque relevé examiné, l'abondance des loups des deux espèces était faible, ces loups n'étant présents que dans moins de 0,5 % des traits.

INTRODUCTION

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reviewed the status of three species of North Atlantic wolffish in 2000 and 2001 and determined that Atlantic wolffish (*Anarhichas lupus*) should be listed as special concern, while Northern wolffish (*A. denticulatus*) and Spotted wolffish (*A. minor*) were listed as threatened in Canadian waters (COSEWIC, 2001a; 2001b). These listings were based on declines of 87, 98, and 96 percent, respectively, for Atlantic wolffish, Northern wolffish and Spotted wolffish in Canadian waters of the North Atlantic. COSEWIC is required to track the status of wildlife species previously designated as endangered, threatened, and special concern by preparing updated status reports. As part of this process COSEWIC has called for a re-evaluation of the three species of wolffish and the Department of Fisheries and Oceans (DFO), as the Department responsible for marine species, is required to summarize all available information. The COSEWIC review of the three species revealed that Atlantic wolffish were commonly caught within the Maritimes Region, but Northern wolffish (O'Dea and Haedrich, 2001a) and Spotted wolffish (O'Dea and Haedrich, 2001b) were relatively rare and at the southern edge of their distribution.

The status of Atlantic wolffish in the Maritimes (Subarea 4 and 5) had been previously summarized by DFO for COSEWIC in 2000 (McRuer et. al., 2000; DFO 2000). These papers focused on Atlantic wolffish in Divs. 4VWX and 5YZe and were updated in 2002 (DFO, 2002).

This paper represents a re-examination of the DFO research vessel (RV) and industry surveys, extends the analysis to include USA RV surveys, and examines observer and commercial landings information within the Maritimes Region for all three species. Atlantic wolffish were examined in detail with distributional plots, trends in abundance by immature and mature length categories, and area occupied presented where possible. Given that the Maritimes Region represents the southern edge of the distributional range for Northern wolffish and Spotted wolffish, less information was available for these two species. Predator prey information for Atlantic wolffish and Northern wolffish was also presented.

METHODS

Life History Characteristics

McRuer et al. (2000) reviewed the available biological information for Atlantic wolffish. They summarized length, condition, age, growth, and fecundity information from DFO surveys and other North Atlantic wolffish populations. Since 2000 - 2001 when the status of the three species of wolffish was first assessed, the Department of Fisheries and Oceans has taken steps to facilitate their recovery by supporting research on life history, distribution, and habitat associations of all three species upon which to base future conservation measures (Dutil et al., 2010; Kulka et al., 2004). This research has focused on the northern Gulf and Newfoundland/Labrador DFO regions, where the greatest declines in wolffish abundance were observed, and there has been no substantive research program on wolffish in the Maritimes Region over the last twelve years. The DFO Maritimes RV survey database was re-examined and a small number (48) of Atlantic wolffish, with detailed maturity information that had not been examined in 2000, was reviewed. The data was compared with historical Canadian and US information

Overview of Canadian RV, Industry/Science, and USA Survey Information

DFO Research Vessel Surveys

Maritimes Region (Divs. 4VWX, 5Y, 5Ze)

The DFO summer survey has been conducted annually on the Scotian Shelf (Divs. 4VWX) since 1970 using a stratified random design based on depth and geographic area (Table 1, Figure 2). In 1995, coverage was expanded into three deepwater strata (365-732 m) on the edge of the shelf. These strata have been included in the distribution maps but they have not been included in the abundance analyses. From 1970 to 1981, the survey was conducted by the *A.T. Cameron* using a Yankee 36 trawl. In 1982, the *A.T. Cameron* was replaced by the *Lady Hammond* using the Western IIA as the new standard trawl. In 1983, the *Lady Hammond* was replaced by the *Alfred Needler* using the Western IIA trawl. In 2004, the *Alfred Needler* was replaced by the *Teleost* due to a fire on the *Alfred Needler*. The 2005 survey was conducted by both the *Teleost* and the *Alfred Needler* to investigate differences in catchability between the two vessels but this has not been investigated for wolffish. In 2006, the survey was conducted by the *Alfred Needler*. In 2007, the survey reverted back to the *Teleost* and in 2008, the sister ship of the *Alfred Needler*, the *Wilfred Templeman,* conducted the survey. In 2009 and 2010, the survey was again conducted by the *Alfred Needler*.

The Spring 4VsW Survey (4VWCOD) has been conducted since 1986 on the eastern half of the Scotian Shelf (Table 1). This survey uses a stratification scheme that was meant to optimize the abundance estimates of cod (Figure 2). No surveys were conducted in 1998 or 2004 and the 2009 survey was incomplete. The *Alfred Needler* has conducted the survey using the Western IIA trawl during 1986-2003, 2005-2006, and 2010. The *Wilfred Templeman,* using the same gear, conducted the 2007 survey and in 2008, the *Teleost* was the survey vessel. Deep-water strata (365-549 m) in the Laurentian Channel were added to this survey in 1993 and although not included in abundance trend analysis, the data from in these strata are included in the distribution maps.

The February/March RV survey on Georges Bank (Div. 5Ze) commenced in 1986 using Western IIA trawl gear and a stratified random design (Table 1, Figure 3). The *Alfred Needler* has been the survey vessel, except in 1993 and 2004 when its sister ship the *Wilfred Templeman* was used. The survey concentrates on the Canadian side of the bank (Subdiv. 5Zc) with additional sets on the USA side of Canada's Exclusive Economic Zone (EEZ) that cover the remainder of the bank as well as some stations north of the bank.

Other surveys examined for the presence of Northern wolffish and Spotted wolffish include the Spring (1979-1984) and Fall (1978-1984) RV surveys of the Scotian Shelf that were conducted by the *Lady Hammond* and the *Alfred Needler* (Table 1). These surveys used the same stratification scheme as the summer RV survey.

A dedicated Redfish RV survey was conducted in the fall from 1982 to 1988 primarily on the edges of the Scotian Shelf. These surveys also used a stratified random design based on depth and geographic area. They utilized the regular survey strata and included deepwater strata that extended down to 900 m.

USA Research Vessel Surveys (Div. 4X, Subarea 56)

Research surveys of the east coast of the USA and the southern half of the Scotian Shelf have been conducted by the National Marine Fisheries Service (NMFS) each fall since 1963 and

each spring since 1968 (Table 1). Both surveys use a stratified random design similar to the Canadian DFO summer RV survey (Figure 3). Two research vessels, the *Albatross IV* and the *Delaware II,* have been the primary survey vessels with the *Atlantic Twin* surveying the inshore areas from autumn 1972 to spring 1975. Generally, a Yankee 36 has been the standard survey gear except a modified Yankee 41 was used during the spring survey from 1973 to 1981. In addition, there was a change in the trawl doors in 1985. In 2008, the *Henry B. Bigelow* using a more efficient 400x12 four-seam rockhopper trawl replaced the *Albatross IV*. Tow distance, duration, and towing speed were modified from those used previously. Although conversion factors between the two vessels have been calculated these have not been applied in this section.

Canadian Industry/Science Surveys

Four industry/science surveys based in the Maritimes Region and conducted since the mid 1990s were also evaluated (Table 1). These surveys each have standard sampling designs. The industry participants have undergone training for sampling methods and species identification and, in addition, trained observers have been deployed on a majority of the participating vessels.

The Individual Transferable Quota (ITQ) Fixed Station Industry Survey in Div. 4X began in the summer of 1995. This survey is conducted by four otter trawlers using a balloon trawl that has smaller diameter footgear than the RV survey gear and, therefore, potentially higher catchability of wolffish. The area sampled is similar to the RV survey except an area inshore of the 50 fm line is also surveyed.

The 4VsW Sentinel Survey is a stratified random longline survey conducted by industry participants. The series began in fall 1995 and includes all areas surveyed by the RV survey in Divs. 4VsW as well as three additional inshore strata. In 2005, the survey was reduced to the two western inshore strata as well as four core offshore strata that were thought to be the centre of distribution for haddock.

The Halibut Industry Survey began in 1998 using longline gear primarily on the Scotian Shelf with sets extending into the southern portion of the Grand Banks. An index fishery conducted by the same participants fished in waters deeper than the regular survey, primarily in the slope waters of the Scotian Shelf and the Grand Banks. Details on location, gear type, time of year, duration, and sampling effort are described by Armsworthy et al. (2006).

The Snow Crab Industry survey began in 1997 using a Bigouden *Nephrops* trawl that was originally designed for Norway lobsters. This survey uses a systematic random design that initially occupied 150 stations each within a 10^{o} latitude by 10^{o} longitude grid. The number of stations has expanded spatially and the density of station has increased so that over 400 stations are sampled annually in Div. 4Vn, 4Vs, 4W, and the nearshore area of Div. 4X. Unfortunately, bycatch species have not been consistently sampled and therefore only the distributional data is presented for the three wolffish species since 2004.

Population Sizes and Trends

Estimates of minimum trawlable abundance were calculated for Atlantic wolffish by extrapolating RV survey catch per tow to the total number of trawlable units in a survey area. These estimates should be considered minimum estimates given that catchability of the survey gear is much less than one. Wolffish are usually thought to be associated with ‘hard’ bottom, which tends to be avoided by survey sets (Kulka et. al., 2004). Minimum total population estimates were

calculated from the research vessel surveys for Div. 5Zc and Divs. 4VWX from the Canadian and USA surveys. Minimum trawlable estimates are provided for immature and mature individuals where possible. Minimum trawlable estimates of abundance from the industry surveys were not calculated. Given the low numbers of Northern wolffish and Spotted wolffish in this region, minimum trawlable estimates or trends in the data were not calculated.

Trends in population levels for mature Atlantic wolffish, as well as all lengths of Atlantic wolffish, were estimated using linear regression after log transformation. Concern has been expressed on the use of this method when the data series in question is complex and non-linear but in general; this has been less of a problem for Atlantic wolffish. These trends are provided where possible for each survey series and for a period of three generations. A generation was estimated to be age at 50% maturity (6 years old) (Nelson and Ross 1992; Templeman 1986) plus 1/M where M (natural mortality) was assumed to be 0.2. This results in a period of 33 years for three generations.

Area Occupied

This section provides information on the trends in design weighted area occupancy (DWAO) within the Maritimes Region (Divs. 4VWX and 5Z) based on the DFO annual bottom-trawl surveys in those areas.

Area of occupancy (A_t) was calculated for year *t* as follows:

$$A_t = \sum_{i=1}^{n} a_i I \quad \text{where } I = \begin{cases} 1 \text{ if } Y_i > 0 \\ 0 \text{ otherwise} \end{cases}$$

where *n* is the number of tows in the survey in year *t*, Y_i is the number of Atlantic wolffish caught in tow *i*, and a_i is the area of the stratum fished by tow *i* divided by the number of sites fished in that stratum (Smedbol et al., 2002). Given that relatively few sets in an annual survey captured Atlantic wolffish, the DWAO index was not calculated for the DFO and industry surveys where abundance was too low to calculate meaningful estimates of occupancy.

Habitat Associations

Ecosystem Considerations

Essential Habitat

In 2009, a preliminary essential fish habitat document for Atlantic wolffish was prepared for the New England Fishery Management Council. This memorandum summarized the known information on geographic range, habitats, reproduction, food habits, size, age and growth, and maturity for the species. Although the document focused on the species in US waters, information was also reported for the remainder of its range (Anon., 2009).

Habitat preferences for all three species of wolffish on the Scotian Shelf were generated by comparing cumulative stratified estimates of abundance to cumulative stratified estimates of depth, temperature and salinity from the summer RV survey. These preferences for Atlantic wolffish will be compared with those reported in the 2009 essential fish habitat memorandum for that species.

Threats

Observer records within the Maritimes Region, from 1978 to 2009, were used to examine the distribution of wolffish in the Canadian Atlantic. Given the bias in only examining data that recorded wolffish and not those sets that did not record the three species may result in possible artificial gaps in distribution. Another factor in using these data is the possibility of either misidentifying or not speciating the three species of wolffish.

Landings of wolffish (or catfish) are summarized using data from the Northwest Atlantic Fisheries Organization (NAFO) and DFO landings statistics since 1963. Wolffish landings are not separated by species in the Maritimes Region but based on the RV surveys within this area these landings are assumed to be Atlantic wolffish. This species is generally a bycatch in other groundfish fisheries but directed sets have been made to reach bycatch limits permitted within a trip.

ATLANTIC WOLFFISH RESULTS

Life History Characteristics

An examination of the Canadian RV database revealed that only 48 individuals of Atlantic wolffish had maturity stages on the Scotian Shelf. Of these, 21 fish were from Divs. 4VW, while 27 were from Div. 4X. All fish less than 24 cm were determined to be immature, while all fish greater than 38 cm were determined to be mature based on a visual inspection of the reproductive organs. There were only five fish between 31 and 37 cm making length at 50% maturity imprecise. Maturity staging was likely based on gadoid maturity keys available at the time. A 2009 preliminary study on essential fish habitat of Atlantic wolffish for the New England Fishery Management Council (unpublished manuscript) reviewed some of the difficulties in visually determining the maturity of wolffish. Second generation eggs may be visible in young immature fish but they may not be able to spawn for several more years (Gunnarson et al. 2006; Templeman, 1986). A logistic maturity ogive was developed for female Atlantic wolffish based on the spring and fall NEFSC surveys using maturity staging similar to the Maritimes Region. L_{50} was estimated from the US NMFS surveys at approximately 35 cm, which is similar to the Scotian Shelf estimates reported above. McRuer et al. (2000) and Simpson and Kulka (2002) used 55 cm as the length of 50% maturity in their review of the status of Atlantic wolffish, based on work by Templeman (1986). Given the uncertainty in estimating maturity of wolffish, it was decided to use the same length of 50% maturity in this document as McRuer et al. (2000) and Simpson and Kulka (2002). The research vessel and commercial length data is binned in 3 cm groupings and so for this analysis the length of 50% maturity was 53 cm. Potential changes in growth and maturity during the series were not considered.

Overview of Canadian RV Surveys

Maritimes Region

Summer Survey of the Scotian Shelf (Divs. 4VWX)

The Summer RV Survey is the longest running survey series in the Maritimes Region having been conducted annually in July since 1970. Out of the 7,200 sets completed during 1970–2010, 1,379 sets or 19.2% captured Atlantic wolffish (Table 2).

The composite distribution pattern revealed two primary areas of concentration: the eastern Scotian Shelf including Div. 4Vn and on the western Scotian Shelf (Div. 4X), primarily Brown's Bank (Figure 4). The distributional data was then separated into immature (1-53 cm) and mature (> 53 cm) individuals. The distribution of immature individuals was similar to the overall distribution pattern, while the abundance of mature individuals appeared to be higher in Div. 4X (Figure 5).

The annual mean number per tow from the survey was adjusted using areal expansion into total abundance of immature and mature individuals for Divs. 4VW and Div. 4X and then for the entire survey area (Divs. 4VWX) (Figure 6). Note that in all cases the deep-water strata that have been sampled since 1995 were not been included in the abundance estimates although they have been included in the distribution maps. In Div 4X, total number of immature individuals generally increased during the 1970s, declined during the 1980s, increased to a second peak in the late 1990s, and have subsequently fallen to very low estimates. Mature abundance was highest in the 1970s and has declined since the mid 1990s to low values. In Divs. 4VW, abundance of immature fish has been generally much higher than in Div. 4X. Abundance has generally increased over the series, peaking in the early 2000s although with high interannual variability. The 2009 and 2010 estimates are similar to those seen in the 1970s. The overall abundance trends for immature and mature individuals for the Scotian Shelf (Divs. 4VWX) are similar to the trends observed in Divs. 4VW alone. The trend in immature individuals was lowest prior to 1985, peaked in the early 1990s, and has subsequently exhibited a slight decline. Mature abundance was highest in the 1970s and has generally declined since then to the lowest estimates in the series (Figure 6). The number of immature and mature individuals as estimated by the survey has averaged 2.6 and 0.3 million, respectively since 2000.

The log transformed catch rates of Atlantic wolffish are presented for the entire survey period as well as for three generations. For the entire survey period (1970-2010, 41 years), figures are presented for all sizes classes combined and for mature fish only in Div. 4X, Divs. 4VW and Divs. 4VWX (Table 3). These data suggest that the eastern and western Scotian Shelf exhibited different responses during the survey series. In Div. 4X, the decline when all length groups were considered was 69%, while there was a decline in the mature length group of 81%. In Divs. 4VW, there was an overall increase in the total numbers at length of 70%, but the decline in the mature abundance was 98%. When the Scotian Shelf is considered as a whole (Divs. 4VWX), there was no significant trend in the total numbers at length (4% increase) but the abundance of mature fish declined by 90% (Table 3, Figure 7).

Similar changes in abundance for the summer survey were calculated for a period of three generations (1978-2010, 33 years). In Div. 4X, the decline in the total and mature abundance was 65 and 82 % respectively. In Divs. 4VW, the total number increased by 28% over the period, while the mature abundance declined by 99%. When the Scotian Shelf is considered as a whole, the decline in total abundance and mature abundance was 9 and 91%, respectively (Table 3, Figure 8).

Given the differences in the abundance trends by length groups observed in the summer survey series in Divs. 4VW, the cumulative length frequencies between 1970-1984 and 1985-2010 were compared (Figure 9). Although the range of lengths caught by the survey has not changed significantly, Atlantic wolffish caught between 1985 and 2010 tended to be much smaller than those caught from 1970 to 1984.

4VWCOD Survey of the Eastern Scotian Shelf (Divs. 4VsW)

A total of 2,022 sets have been completed since 1986 with 219 records of Atlantic wolffish or an occurrence rate of 10.8% (Table 2). The species is distributed throughout Div. 4Vs, except on the shallowest part of Banquereau Bank and the eastern portion of Div. 4W (Figure 10). The catch rate of immature individuals has varied without trend since the beginning of the series while the number of mature individuals declined to near zero in 1990 and has subsequently remained low (Figure 11). The decline rate for the total number at length from this survey series was 58% from 1986-2010 (Figure 12). The overall length frequency for the survey series was similar to that observed in the summer RV series for Divs. 4VW, peaking at less than 30 cm (Figure 13).

Winter Survey of Georges Bank (Div. 5Ze)

A total of 2,092 sets have been completed since 1986 with 133 or 6.4% containing Atlantic wolffish (Table 2). Atlantic wolffish are primarily distributed north of the Great Southwest Channel, especially close to Cape Cod and on the northern half of the Northeast peak of Georges Bank (Figure 14). There is a break in distribution between the Canadian and USA sides of the bank.

An examination of the stratified total number at length of immature and mature individuals from the Canadian side of the bank revealed that immature Atlantic wolffish (1-53 cm) were only occasionally caught by the survey. Since the beginning of the survey, they have only been caught in significant amount in four of the 25 years and since 1996, abundance has been near zero. The total abundance of mature (>53 cm) Atlantic wolffish averaged approximately 40,000 individuals until 2000 and has been near zero since 2006 (Figure 15). No Atlantic wolffish were caught by this survey in 2009 or 2010. The decline rate for all size classes is 99.9% over the survey period (Table 3, Figure 16).

Although the length range of Atlantic wolffish caught during this survey was similar to that observed during the Scotian Shelf surveys, the pattern observed was completely different. The length frequency increased from near 10 cm, peaked near 94 cm, and subsequently declined to zero at 121 cm. The maximum reported length of a fish was 133 cm (Figure 17).

Spring Survey of the Scotian Shelf (Divs. 4VWX)
Fall Survey of the Scotian Shelf (Divs. 4VWX)

These two surveys series were examined for the presence of Atlantic wolffish. In both surveys, the distribution of the species was similar to that observed in the summer RV survey (Figure 18). A total of 741 and 941 sets were completed during the spring and fall surveys, respectively with 175 or 23.6%, and 146 or 15.5% sets containing Atlantic wolffish (Table 2).

Redfish Survey of the Scotian Shelf (Divs. 4VWX)

A total of 546 sets were completed between 1982-1988 with 60 or 11.0% containing Atlantic wolffish (Table 2). Atlantic wolffish were primarily distributed in the Gully and the southern slopes of Banquereau Bank (Figure 19). Very few Atlantic wolffish were caught south of the Gully in Div. 4W or Div. 4X. Although one Atlantic wolffish was caught at a depth greater than 500 fm most of the fish were encountered between 50 and 150 fm in Div. 4Vs (Figure 20).

Overview of USA RV Surveys, Subarea 56

The Spring RV Survey has been conducted annually since 1968. A total of 8,220 sets have been completed with 583 (7.1%) records of Atlantic wolffish (Table 2). The Fall RV Survey began in 1963 and out of 9,427 sets, there have been 402 (4.3%) records of Atlantic wolffish. A comparison of the seasonal surveys conducted by the USA revealed few differences between the spring and fall surveys. Atlantic wolffish were distributed primarily on Brown's Bank, north towards the Bay of Fundy, the near shore area off Massachusetts and the northeast Peak of Georges Bank (Figures 21 and 22). The distribution as indicated by both US surveys was similar to the distribution indicated by the Canadian 5Z survey where the three surveys overlap. It is important to note that only one fish was caught in either survey southwest of Southwest Channel indicating that this is near the southern extent of the species range (Figures 21 and 22).

The Spring RV Survey abundance was grouped into the same length groups of 1 – 53 cm and > 53 cm for comparison with Canadian surveys (Figure 23). Both trends in abundance indicate a near continuous decline since the early 1970s. No Atlantic wolffish greater than 53 cm were caught in either 2007 or 2008. In 2009, the number of Atlantic wolffish less than 54 cm was the highest observed since 1994 but as stated before, the *Henry B Bigelow* conducted the surveys in 2008 and 2009, and may not be comparable to the remainder of the series. The decline in the total number at length and the mature portion of the population was 95% and >99% respectively for 1968 to 2007 (42 years) (Figures 24). If only the three generation period is considered (1975-2007, 33 years) the decline was 96% and >99 % for the total abundance and mature abundance, respectively (Figure 25).

The Fall RV Survey abundance trends were grouped into the same length groups as the spring RV survey (Figure 26). These trends in abundance were similar to those observed in the spring survey (Figure 26). The high abundance observed in 2008 and 2009, were conducted by the *Henry B Bigelow* and may not be comparable to the remainder of the series. The decline for the total and mature abundance is 97% and greater than 99%, respectively (Figure 27) when the entire survey series is considered (1963-2007, 47 years). If only the three generation period is considered (1975-2007, 33 years), the decline in total number and mature abundance was 98% and greater than 99%, respectively (Figure 28).

Canadian Industry/Science Surveys

Sentinel Survey of the Eastern Scotian Shelf (Div. 4VsW Longline)

The distribution of Atlantic wolffish as indicated by the 4VsW Sentinel Survey was concentrated north of Banquereau and Middle Banks, as well as in the inshore strata less than 50 fm (Figure 29). In these inshore strata, Atlantic wolffish were distributed as far west as the Divs. 4WX boundary. Due to changes in the area surveyed, no trends in abundance were calculated. Total number of survey sets was 2,248 with 214 reporting Atlantic wolffish (9.5%) (Table 2). The length frequencies from this survey ranged from 37-61 cm peaking at 46 cm (Figure 30).

Halibut Survey of the Scotian Shelf and Southern Grand Banks (Divs. 3MNOP4VWX)

The distribution of Atlantic wolffish as indicated by the fixed station portion of the halibut longline survey revealed that Atlantic wolffish were found throughout the survey area (Figure 31). Total number of sets in the fixed station surveys was 2,378 with 309 reporting Atlantic wolffish (13.0%) (Table 2). The index fishery portion of the survey fished in waters that were often

deeper than the fixed station phase of the survey and Atlantic wolffish were broadly distributed throughout the surveyed area (Figure 31).

Stratified mean catch (kg) per tow from the fixed station portion of the survey for the entire survey area was generally less than 2 kg per tow and decreased slightly over the series (Figure 32). Length frequencies are not available from this survey.

Snow Crab Survey of the Scotian Shelf (Div. 4VWX, Otter Trawl)

Since 2004, a total of 2,331 sets have been surveyed during the Snow Crab Survey with Atlantic wolffish occurring in 220 or 9.4% of the sets (Table 2). Atlantic wolffish were broadly distributed throughout Div. 4Vn and the northern half of Div. 4Vs. They were scattered throughout the remainder of the surveyed area (Figure 33).

ITQ Survey of the Southwestern Scotian Shelf (Div. 4X Otter Trawl)

This survey has been conducted each July since 1995 using four industry trawlers equipped with rockhopper footgear. A total of 2,704 sets have been completed with Atlantic wolffish occurring in 246 or 9% of the sets (Table 2). Atlantic wolffish were distributed throughout Div. 4X with their highest concentration between Lobster Bay and the northwest peak of Browns Bank. They were also found north of this area generally along the 50 fm contour into the Bay of Fundy (Figure 34). The concentration south of Lobster Bay and inshore of the 50 fm contour is not surveyed by the summer RV survey. The mean catch per tow from 1996-2002 was stable near 1.5 kg per tow but abundance has steadily decline to near zero in 2009 (Figure 35). No length frequencies are available from this survey.

Area of Occupancy

The area of occupancy based on the summer RV survey from 1970 to 2010 was examined separately for the western Scotian Shelf (Div. 4X), the eastern Scotian Shelf (Divs. 4VW) and the entire survey area (Divs. 4VWX) (Figure 32). In Div. 4X, the area occupied declined steadily from the late 1970s where it averaged close to 20,000 km^2 to an average less than 7,000 km^2 since 2000. On the eastern Scotian Shelf, the area occupied has not shown any significant trend over the survey series, averaging close to 20,000 km^2. When the entire survey is considered, area occupied has declined from an average of approximately 45,000 km^2 in the 1970s to an average of approximately 25,000 km^2 in the last ten years (Figure 36).

The area of occupancy, based on the March RV survey has declined steadily from an average of 14,000 km^2 in the late 1980s to an average of 6,000 km^2 during the last four survey years (Figure 33).

On the Canadian portion of Georges Bank (Subdiv. 5Zc), the area of occupancy has declined from approximately 6,000 km^2 in the late 1980s to zero the last two years of the survey (Figure 34).

Because area of occupancy was not available for the Halibut or ITQ surveys, the percentage of sets in which Atlantic wolffish occurred in those surveys was used. In the Halibut Fixed Station Survey, wolffish occurred in approximately 20% of the sets in Div. 4X and slightly less than 10% in Div. 4VW (Figure 35). No trends in area of occupancy were evident in either area (Figure 35). The percentage of sets occupied during the ITQ Survey has declined from approximately 15% to less than 5% in the last 4 years (Figure 36).

Habitat Associations

Temperature and Depth Preferences

Cumulative stratified estimates of abundance of Atlantic wolffish were compared to cumulative stratified estimates of depth, temperature, and salinity from the summer RV survey (Figure 41). Atlantic wolffish were found in colder, less saline water than normally occurs in the summer RV survey. The temperature range where the species occurs is 1-9 ^{o} C (Figure 41).

Predator Prey Preferences

Atlantic wolffish were observed in the stomach contents of 30 out of 156,000 fish predators that were examined primarily from the Scotian Shelf. They were most commonly observed in sea raven (1.1% of stomachs, n=13) and Atlantic halibut (0.5% of stomachs, n=6), while spiny dogfish, longhorn sculpin, Atlantic cod, white hake, and haddock were also observed to have consumed them. The main prey items of Atlantic wolffish (n=370) were echinoderms, crabs, and mollusks. Fish were a negligible part of Atlantic wolffish diet.

Threats

The Observer Program in the Maritimes Region has been in place since 1977. Initially, the program only placed observers on non-Canadian vessels within the region but in subsequent years, observers were also placed on Canadian vessels. No attempt has been made to address any possible species identification problems within this data set. Atlantic wolffish have been reported from all NAFO divisions in the Canadian Atlantic (Figure 42). When the same data was examined at a finer scale, Atlantic wolffish were found to be broadly distributed throughout the Maritimes Region (Figure 42 cont.). The concentration observed within what is known as the Haddock Box within Div. 4W occurs where there have been few reports of this species from either the RV or the industry surveys.

The distribution of wolffish from Canadian commercial landings were summarized into two time periods (1986-2001 and 2002-2009) to allow for a comparison of periods with low and high abundance (Figures 43 and 44). Wolffish were broadly distributed throughout Divs. 4X5 and Divs. 4Vn4Vs with very few fish recorded from Div. 4W (Figure 43). In 1994, the directed fishery for cod and haddock was closed in Divs. 4VW. This closure is reflected in the distribution of landings of wolffish in Figure 44. The scattered reports of wolffish in Divs. 4VW are from bycatch in the few remaining fisheries in this area. The distribution of wolffish in Div. 4X, has not changed significantly between the two periods. When the data from 2002 to 2009 were examined at a finer scale, the data revealed that wolffish were not as broadly distributed in Div 4X as suggested in Figure 44. Figure 45 indicates that wolffish were concentrated on the western peak of Browns Bank, west of German Bank, and within three confined areas that are not surveyed by the DFO RV surveys. The largest of these, slightly south southwest of Cape Sable Island, is called the Catfish Hole and fishers have been known to ‘top’ up a trip on the way into port. The lead author has observed the removal of very large Atlantic wolffish from this isolated location in the 1980s.

Annual landings of wolffish by Canada are presented in Figure 46. In Div. 5Z, landings have been generally below 100 t since 1963. Recently landings have been near zero in this area. In Divs. 4X5Y, landings increased from 400 t in the early 1960s to a peak of 1,600 t in the late 1970s. Landings fell subsequently to an average of 400 t in the 1990s, and have continued to decline to less than 100 t in recent years. In Divs. 4VW, landings peaked at close to 700 t in the early 1970s, declined to less than 400t in the late 1970s, and rebounded to 700 t in the early

1980s. Landings declined sharply until 1993 when all directed fishing for cod and haddock ended. Since 1993 landings, have been near zero.

Commercial samples of wolffish were collected from 1996 to 2005 (Figure 47). Sampling effort was inconsistent so that making comparisons between years and areas is difficult. Most of the effort was in Div. 4X except in 1998, 1999, and 2001 where samples were available from Divs. 4VW. In these years, the length frequency was either bimodal or the length range was lower than in years where all the samples were from Divs. 4X5. In Div. 4X, the length range observed in most years was from 55 to 100 cm with a peak near 80 cm. In Divs. 4VW, the length range was from 40 to 70 cm with a peak near 49 cm (Figure 47).

NORTHERN WOLFFISH AND SPOTTED WOLFFISH RESULTS

Overview of Canadian RV Surveys

Maritimes Region

Summer Survey of the Scotian Shelf (Divs. 4VWX)

The composite distribution pattern revealed that Northern wolffish were restricted primarily to the eastern Scotian Shelf including Div. 4V (Figure 48). There were also records of this species on the outer edge of the Scotian Shelf in Divs. 4WX (Figure 48). Spotted wolffish were restricted to Div. 4Vn and Div. 4Vs with a couple of records on the eastern edge of Div. 4W. As well, there was one record in the Bay of Fundy (Figure 48). Of the 7,200 sets completed during this survey, there were only 30 sets (0.4%) containing Northern wolffish and only 22 (0.3%) sets contained Spotted wolffish (Table 2).

Spring Survey of the Eastern Scotian Shelf (Divs. 4VsW)

Northern wolffish were restricted to the deeper waters of the Laurentian Channel while Spotted wolffish were found on the edges of Banquereau Bank (Figure 49). A total of 2,022 sets have been completed since 1986 with only six sets containing Northern wolffish (0.4%) and Spotted wolffish occurred in only 3 or 0.1% of the sets (Table 2).

Winter Survey of Georges Bank (Div. 5Ze)

There has been only one Northern wolffish recorded from this survey and it was found on the northern portion of the northeast peak of Georges Bank (Figure 50). There have been no Spotted wolffish recorded from this survey.

Spring Survey of the Scotian Shelf (Divs. 4VWX)
Fall Survey of the Scotian Shelf (Divs. 4VWX)

These two survey series were examined for the presence of Northern wolffish and Spotted wolffish. During the spring survey series, a single Northern wolffish was caught in Div. 4Vn while there were only five records of Spotted wolffish caught out of 741 sets (Table 2), generally near Banquereau Bank (Figure 51).

During the fall survey both Northern wolffish and Spotted wolffish were again restricted to Div. 4V (Figure 52). Only seven sets contained Northern wolffish and only two sets contained Spotted wolffish of the 941 sets sampled (Table 2).

Redfish Survey of the Scotian Shelf (Divs. 4VWX)

A total of 546 sets were completed between 1982 and 1988 with 30 or 5.5% of sets contained Northern wolffish and 8 or 1.5% of sets contained Spotted wolffish (Table 2). Northern wolffish were broadly distributed within the survey area occurring from Div. 4X to Div. 4Vn. Spotted wolffish were primarily distributed on the southern slopes of Banquereau Bank (Figure 53).

Overview of USA RV Surveys, Subarea 56

Neither Northern wolffish or Spotted wolffish were reported from the spring or the fall RV surveys (Table 2).

Canadian Industry/Science Surveys

Sentinel Survey of the Eastern Scotian Shelf (Divs. 4VsW Longline)

Northern wolffish were reported from two locations in the offshore area of the survey as well as five records within two inshore strata in Div. 4W. Spotted wolffish were more widespread occurring in a number of locations in Div. 4Vs and the inshore strata of Divs. 4VW (Figure 54). The total number of survey sets was 2,248 with seven reporting Northern wolffish (0.3%) and 31 reporting Spotted wolffish (1.4%) (Table 2). The data for this survey was collected by a combination of observers and fishers and only weight per tow was consistently recorded for these two species. Although we have attempted to verify this information, we have not been able to do so at this time.

Halibut Survey of the Scotian Shelf and Southern Grand Banks (Divs. 3MNOP4VWX)

Distribution (kg/tow) from the fixed station portion of the halibut longline survey revealed that Northern wolffish were caught primarily on the edges of the Scotian Shelf and the Grand Banks (Figure 55). Total number of sets in the fixed station surveys was 2,378 with 174 sets with Northern wolffish (7.3%) (Table 2). The index fishery portion of the survey fished in waters that were often deeper than the fixed phase and Northern wolffish were in the same general areas. The report of a Northern wolffish on the southern edge of Georges Bank is the most southerly record of this species in our database (Figure 55).

An examination of the fixed portion of the halibut longline survey revealed that the distribution (kg/tow) of Spotted wolffish was similar to that of Northern wolffish except they did not occur as far south along the Scotian Shelf and were more widely distributed within the eastern Scotian Shelf (Figure 56). Total number of sets in the fixed station surveys was 2,378 with 109 sets with Spotted wolffish (4.6%) (Table 2). In these surveys, numbers of fish caught in a set were not consistently recorded and weight per tow was used.

ITQ Survey of the Southwestern Scotian Shelf (Div. 4X Otter trawl)

A total of 2,704 sets have been completed with Northern wolffish occurring in 3 or 0.1% of the sets (Table 2) (Figure 57). In these surveys, numbers of fish caught in a set were not consistently recorded and weight per tow was used. No Spotted wolffish were reported from this survey.

Snow Crab Survey of the Scotian Shelf (Divs. 4VWX , Otter Trawl)

A total of 2,331 sets have been completed since 2004 with Spotted wolffish occurring in 12 or 0.5% of the sets (Table 2, Figure 58). These fish were found primarily in Div. 4Vn or just south of this subdivision. Northern wolffish were reported from five of the 2,331 sets in the survey (0.2%). Three of the five fish were caught off the northern part of Cape Breton (Figure 58).

Habitat Associations

Temperature and Depth Preferences

Cumulative stratified estimates of abundance of Northern wolffish and Spotted wolffish were compared to cumulative stratified estimates of depth, temperature and salinity from the summer RV survey (Figures 59 and 60). Northern wolffish were found in much deeper and more saline water than normally occurs in the summer RV survey. Northern wolffish were found in a very narrow temperature range with almost all the fish in 3-5 ^{o} C (Figure 59). Spotted wolffish were found in slightly deeper, cooler waters than the average sampled by the survey. The temperature range was 2-8 ^{o} C (Figure 60).

Predator and Prey Preferences

There have been only four records of Northern wolffish in the stomach contents of the 156,000 fish predators that were examined primarily from the Scotian Shelf. These were observed in cod (3) and haddock (1). Diet information on Northern wolffish is limited to the 22 fish examined prior to 1970. The main prey items observed were clams, mollusks and echinoderms. There are no records of Spotted wolffish in the diet of any fish predator and there are no records of Spotted wolffish stomach contents from the Maritimes database.

Threats

Observer reports of Northern wolffish and Spotted wolffish were summarized from 1978 to 2009 (Figures 61 and 62). These reports indicate that both species are distributed in all NAFO divisions in the Canadian Atlantic. In the Maritimes Region, both species are distributed primarily off the Scotian Shelf in the deeper waters near the shelf break. These reports are substantiated by observations during the research vessel survey in Divs. 4VW, but the reports that both species are widely distributed in Div. 4X and Div. 5Zc must be considered suspect.

DISCUSSION AND CONCLUSIONS

In 2000, COSEWIC recommended that Atlantic wolffish be listed as a species of special concern while Northern wolffish and Spotted wolffish should be listed as threatened for the Canadian Atlantic. COSEWIC has called for a re-evaluation of the three species of wolffish and DFO, as the department responsible for the management of these species, is required to provide up to date information on their status. This paper examined the DFO RV and industry surveys, extending the analysis to include USA RV surveys, and examined observer and commercial landings data within the Maritimes Region. Collectively, these data suggest that although Atlantic wolffish are found throughout the Maritimes Region, there are two primary areas of concentration: the Scotian Shelf in Div. 4VW and on Brown's Bank within Div. 4X. The eastern and western portions of the Scotian Shelf exhibit differing trends in abundance when examined separately for mature and immature length groups. In Divs. 4VW the abundance of mature individuals has declined by 99% since 1970 while the abundance of immature

individuals has increased over the same time period. In Div. 4X, mature abundance has declined 81% since 1970, while immature abundance has declined a similar amount over the same time period. The number of immature and mature individuals in the entire survey area has averaged 2.6 and 0.3 million respectively since 2000. On the northeast peak of Georges Bank, there was a small aggregation of Atlantic wolffish that appeared spatially discrete from the remainder of the surveyed area (Div. 5Z). The decline rate since 1986 for all size classes is 99.9%. US seasonal RV surveys, which extend from Browns Bank to Cape Hatteras exhibit similar distributional patterns and trends in abundance to the Canadian surveys in the same areas. Only one Atlantic wolffish was caught in the US surveys southwest of Southwest Channel suggesting that this is near the southern extent of the species range.

Although there are no directed fisheries for wolffish in the Maritime Region, the species is landed as a bycatch in other fisheries. Fishers have been known to make directed sets for wolffish within a trip, but they are no longer permitted to direct for the species. Annual landings of wolffish by Canada in Div. 5Z have generally been below 100 t since 1963 with recent landings near zero. In Divs. 4X5Y, landings peaked in the late 1970s at 1,600 t and subsequently have declined to less than 100 t in recent years. In Divs. 4VW, landings ranged from 400 to 700 t between 1963 and the early 1980s then declined sharply until 1993 when all directed fishing for cod and haddock ended. Since 1993, landings have been near zero.

Finer scale examination of wolffish landings in Div. 4X revealed that wolffish were concentrated on the western peak of Browns Bank, west of German Bank, and within three isolated areas that are not surveyed by the DFO RV surveys. These areas should be examined in more detail as they may reflect areas of critical habitat.

The composite distribution pattern from all sources on the Scotian Shelf revealed that Northern wolffish and Spotted wolffish are restricted primarily to the eastern Scotian Shelf including Div. 4Vn and Div. 4Vs, with some fish found along the shelf edge in Divs. 4WX. In all surveys, abundance was very low with both species occurring in less than 0.5% of sets.

McRuer et al. (2000) reported that Atlantic wolffish were commonly caught within the Maritimes Region, but Northern wolffish and Spotted wolffish were relatively rare and at the southern edge of their distribution. Since 2000, Atlantic wolffish abundance has continued to decline while abundance of northern and Spotted wolffish remains very low in this region.

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Table 1. Temporal and spatial extent of data used in examining the distribution, abundance, and threats of wolffish in the Maritimes Region.

	Canadian RV Surveys						Canadian Industry Surveys				
Identifier NAFO AREA	Georges Bank 5Z	4VWCOD 4VsW	Summer 4VWX5Y	Spring 4VWX	Fall 4VWX	Redfish 4VWX	Sentinel (LL) 4VsW	Halibut (LL) 3NOP4VWX5	Snow crab 4VWX	ITQ (OT) 4X	Observer Subarea 02345
1963											
1964											
1965											
1966											
1967											
1968											
1969											
1970			x								
1971			x								
1972			x								
1973			x								
1974			x								
1975			x								
1976			x								
1977			x								
1978			x		x						x
1979			x	x	x						x
1980			x	x	x						x
1981			x	x	x						x
1982			x	x	x	x					x
1983			x	x	x	x					x
1984			x	x	x	x					x
1985			x			x					x
1986	x	x	x			x					x
1987	x	x	x			x					x
1988	x	x	x			x					x
1989	x	x	x								x
1990	x	x	x								x
1991	x	x	x								x
1992	x	x	x								x
1993	x	x	x								x
1994	x	x	x								x
1995	x	x	x							x	x
1996	x	x	x				x			x	x
1997	x	x	x				x			x	x
1998	x		x				x	x		x	x
1999	x	x	x				x	x		x	x
2000	x	x	x				x	x		x	x
2001	x	x	x				x	x		x	x
2002	x	x	x				x	x		x	x
2003	x	x	x				x	x		x	x
2004	x		x				x	x	x	x	x
2005	x	x	x				x	x	x	x	x
2006	x	x	x				x	x	x	x	x
2007	x	x	x				x	x	x	x	x
2008	x	x	x				x	x	x	x	x
2009	x	x	x				x	x	x	x	x
2010	x	x	x								

Table 2. Details of the individual survey series examined in this document showing gear, sampling effort, and percent occurrence of the three wolffish species.

	Identifier	NAFO AREA	Years	Gear	Total Number of sets examined	Number of Sets with Atlantic Wolffish	Percent Occurrence
Canadian RV Surveys	Georges Bank	5Z	1987-2010	OT	2092	133	6.4
	4VWCOD	4VsW	1986-2010	OT	2022	219	10.8
	Summer	4VWX5Y	1970-2010	OT	7200	1379	19.2
	Spring	4VWX	1979-1984	OT	741	175	23.6
	Fall	4VWX	1978-1984	OT	941	146	15.5
	Redfish	4VWX	1982-1988	OT	546	60	11
Canadian Industry Surveys	Sentinel	4VsW	1996-2009	LL	2248	214	9.5
	Halibut	3NOP4VWX5	1998-2009	LL	2378	309	13
	Snow crab	4VWX	2004-2009	OT	2331	220	9.4
	ITQ	4X	1995-2009	OT	2704	246	9.1
US RV Survey	Spring	4X5	1968-2009	OT	8220	583	7.1
	Fall	4X5	1963-2009	OT	9427	402	4.3

	Identifier	NAFO AREA	Years	Gear	Total Number of sets examined	Number of Sets with Northern. Wolffish	Percent Occurrence
Canadian RV Surveys	Georges Bank	5Z	1986-2010	OT	2092	1	0.05
	4VWCOD	4VsW	1986-2010	OT	2022	6	0.3
	Summer	4VWX5Y	1970-2010	OT	7200	30	0.4
	Spring	4VWX	1979-1984	OT	741	1	0.1
	Fall	4VWX	1978-1984	OT	941	7	0.7
	Redfish	4VWX	1982-1988	OT	546	30	5.5
Canadian Industry Surveys	Sentinel	4VsW	1996-2009	LL	2248	7	0.3
	Halibut (Fixed)	3NOP4VWX5	1998-2009	LL	2378	174	7.3
	Snow crab	4VWX	2004-2009	OT	2331	5	0.2
	ITQ	4X	1995-2009	OT	2704	3	0.1
US RV Survey	Spring	4X5	1968-2009	OT	8220	0	0
	Fall	4X5	1963-2009	OT	9427	0	0

	Identifier	NAFO AREA	Years	Gear	Total Number of sets examined	Number of Sets with Spotted. Wolffish	Percent Occurrence
Canadian RV Surveys	Georges Bank	5Z	1986-2010	OT	2092	0	0
	4VWCOD	4VsW	1986-2010	OT	2022	3	0.1
	Summer	4VWX5Y	1970-2010	OT	7200	22	0.3
	Spring	4VWX	1979-1984	OT	741	5	0.7
	Fall	4VWX	1978-1984	OT	941	2	0.2
	Redfish	4VWX	1982-1988	OT	546	8	1.5
Canadian Industry Surveys	Sentinel	4VsW	1996-2009	LL	2248	31	1.4
	Halibut (Fixed)	3NOP4VWX5	1998-2009	LL	2378	104	4.4
	Snow crab	4VWX	2004-2009	OT	2331	12	0.5
	ITQ	4X	1995-2009	OT	2704	0	0
US RV Survey	Spring	4X5	1968-2009	OT	8220	0	0
	Fall	4X5	1963-2009	OT	9427	0	0

Table 3. Summary of percent change in abundance of Atlantic wolffish from all length groups and mature lengths from the research surveys conducted within the Maritimes Region. Note that abundance was too low or sporadic for some surveys or for some mature length groupings to estimate a decline rate.

Survey	Years	Area	Abundance Trend	
			All lengths	Mature
Summer RV	1970-2010	4X	-69	-81
	41 years	4VW	+70	-98
		4VWX	+4	-90
Summer RV	1978-2010	4X	-65	-82
	33 years	4VW	+28	-99
		4VWX	-9	-91
4VWCOD	1986-2010	4VsW	-58	NA
	25 years			
Georges Bank	1986-2010	5Z, Cdn	-99	NA
	25 years			
US Fall	1963-2007	4X5YZ	-97	-99
	47 years			
US Fall	1975-2007	4X5YZ	-98	-99
	33 years			
US Spring	1968-2007	4X5YZ	-95	-99
	42 years			
	1975-2007	4X5YZ	-96	-99
	33 years			

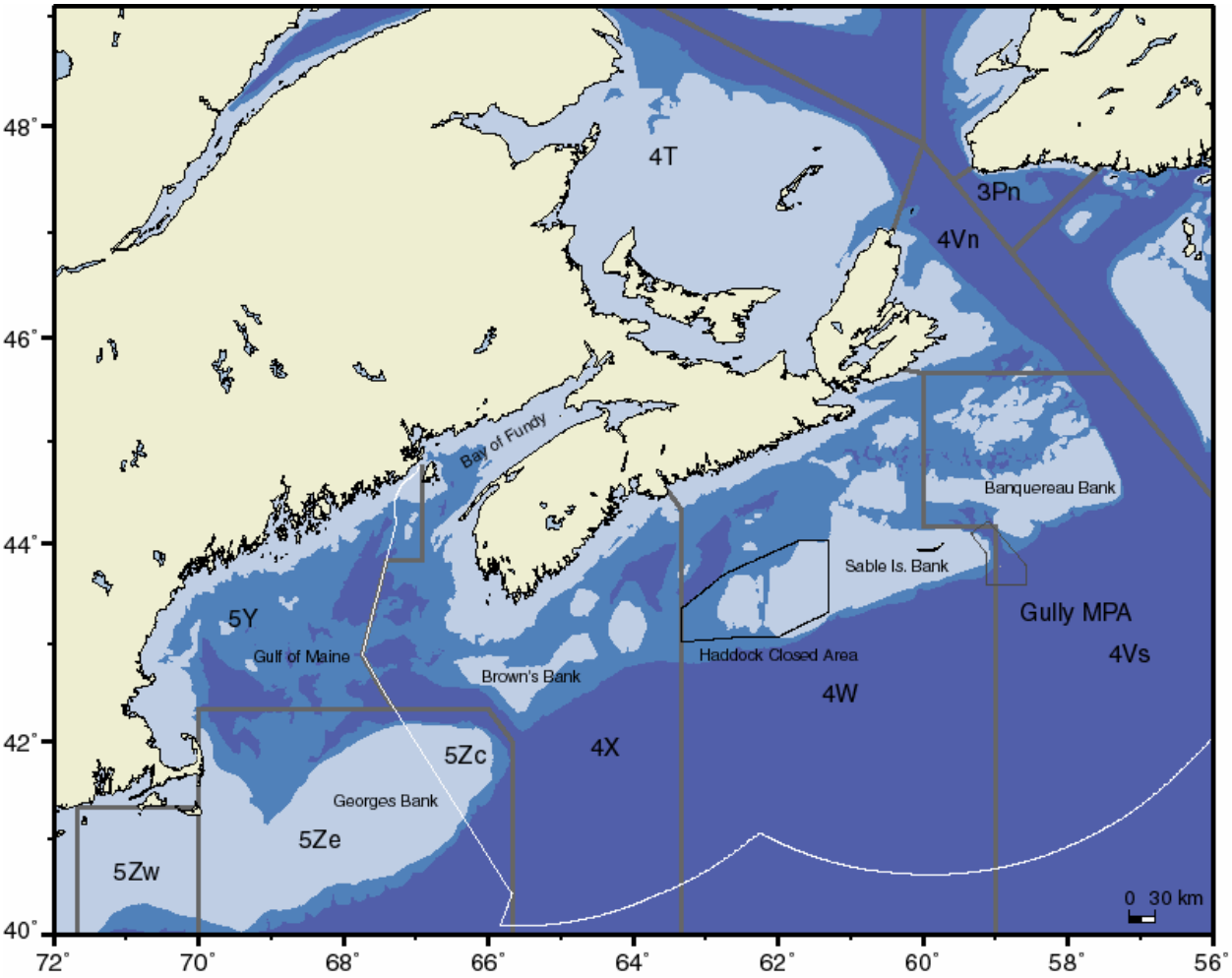


Figure 1. NAFO Divisions and principle areas mentioned in this document.

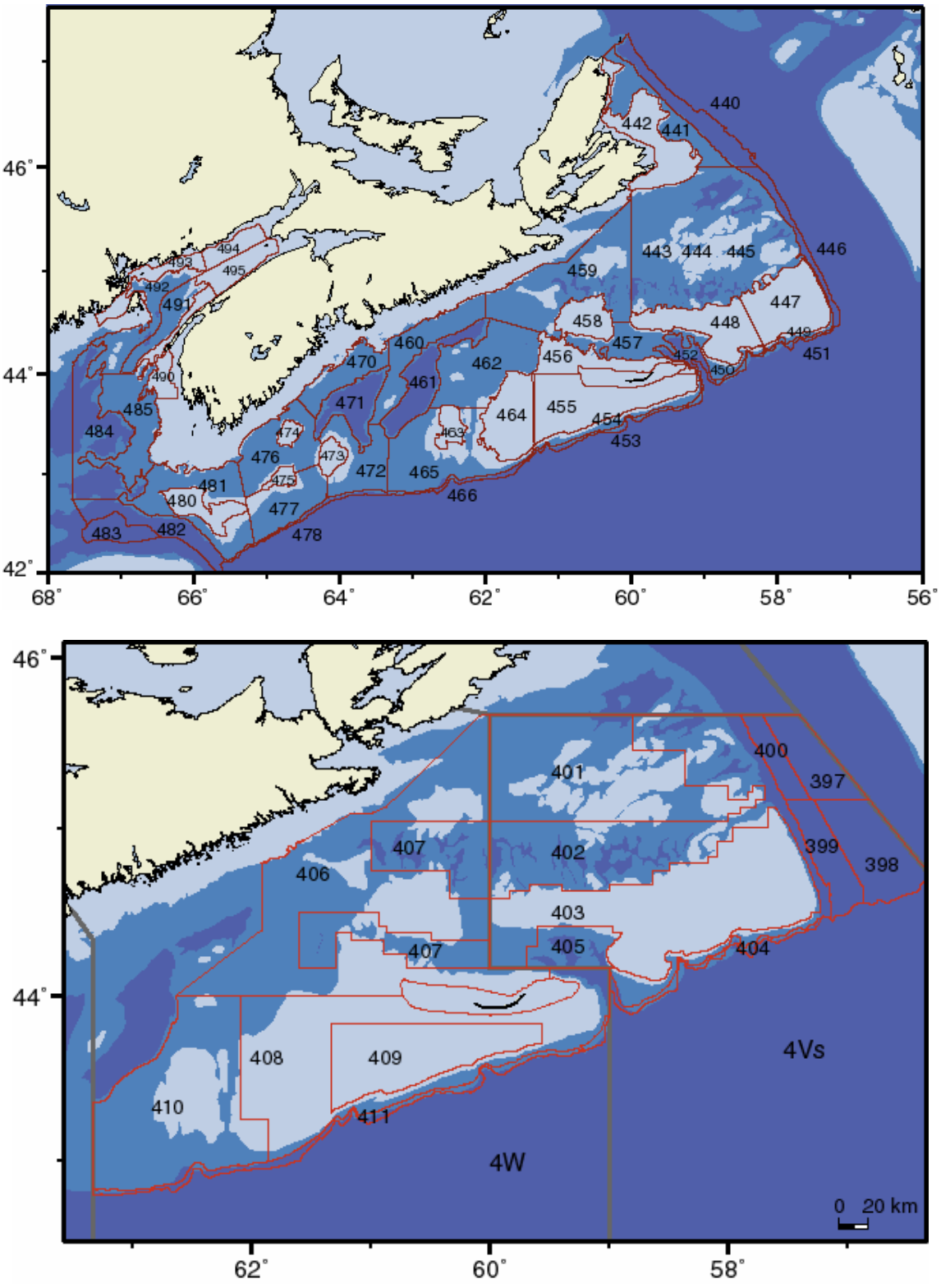


Figure 2. Survey strata used during the summer RV survey (top panel) and the 4VWCOD (spring) RV survey (bottom panel). The deepwater strata added in 1995 to the summer RV survey are not displayed.

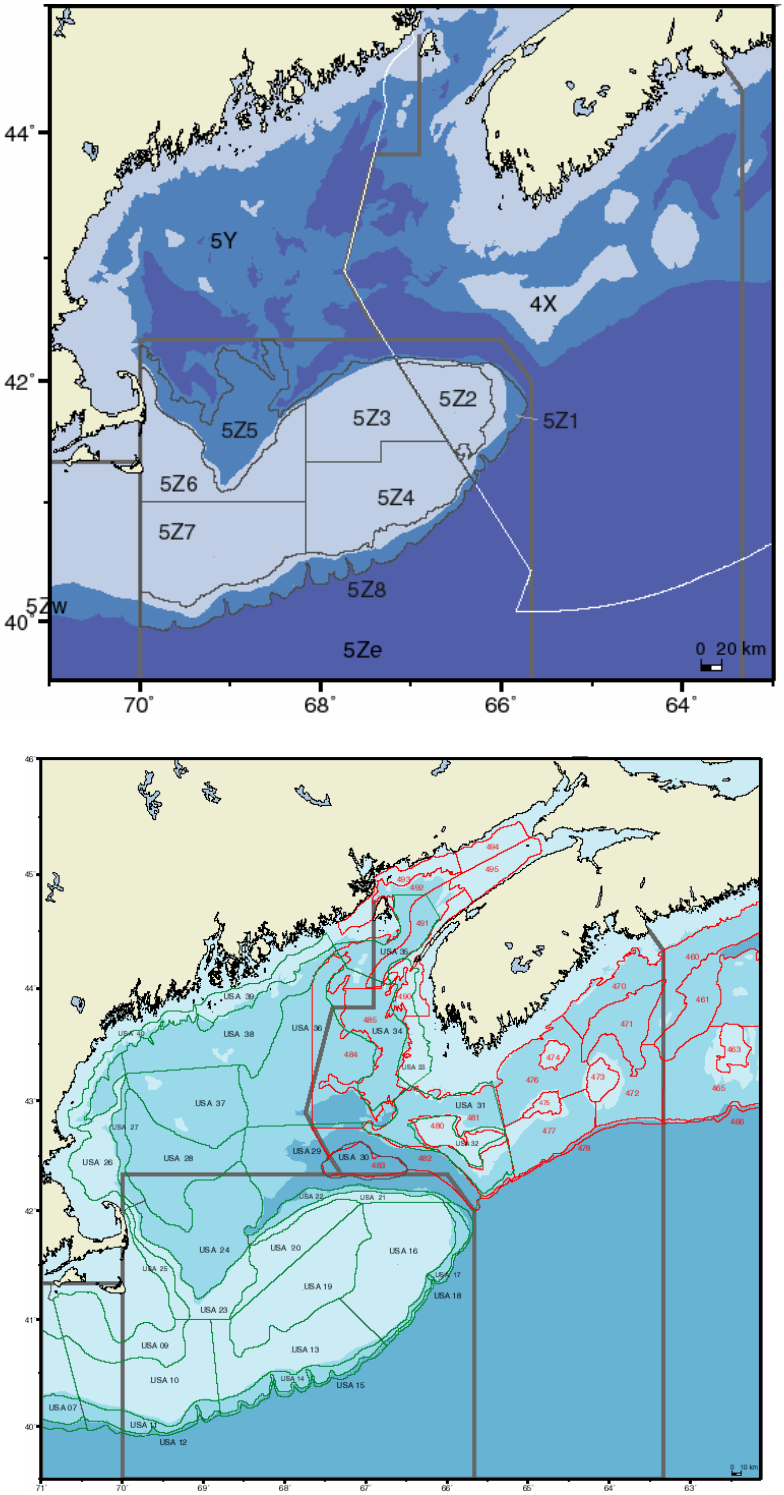


Figure 3. Survey strata used during the Canadian RV survey on Georges Bank (top panel) as well as survey strata used during the US spring and fall RV surveys of Georges Banks and the Gulf of Maine (bottom panel). The Canada/USA border is indicated in the top panel

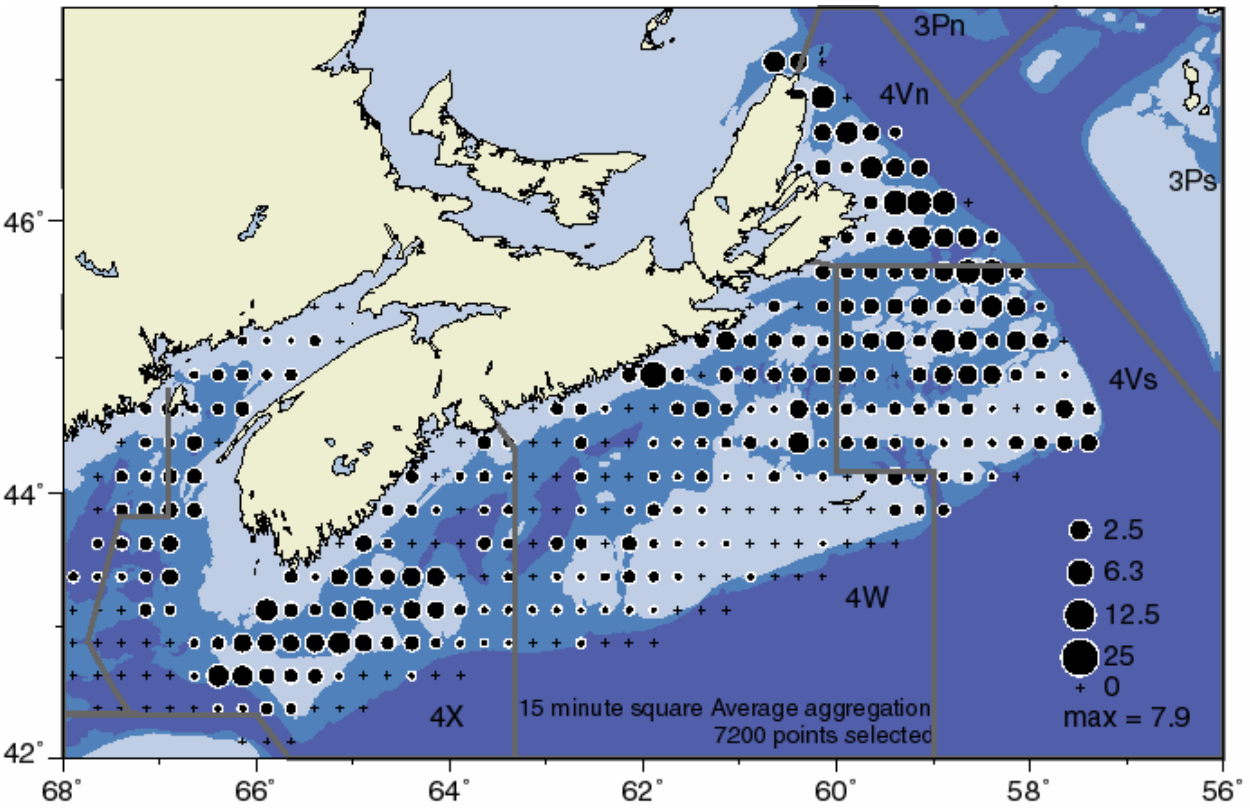


Figure 4. Distribution of Atlantic wolffish as indicated by the Summer RV survey on the Scotian Shelf, 1970-2010.

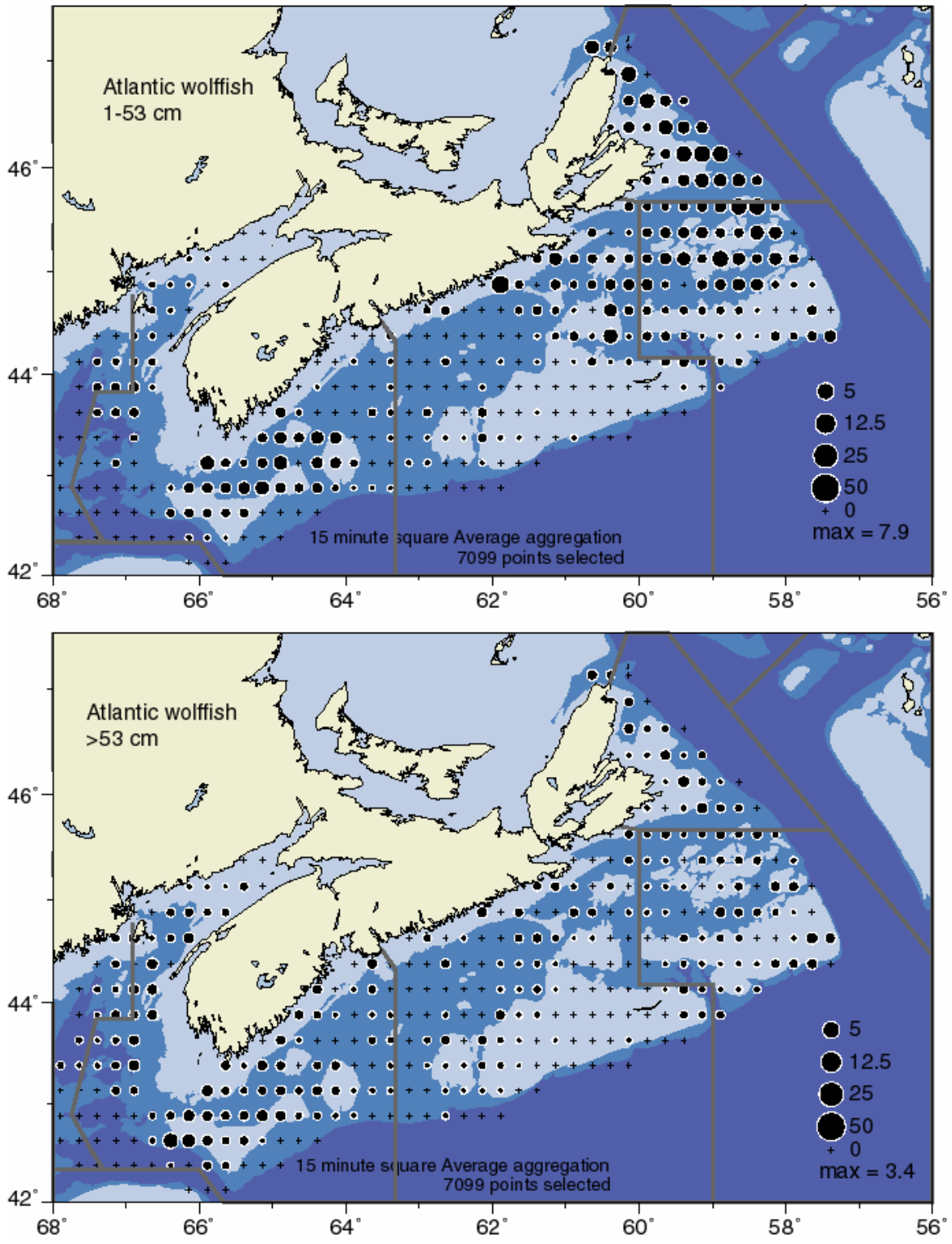


Figure 5. Distribution of immature (1-53 cm) and mature (>53 cm) Atlantic wolffish as indicated by the summer RV survey. This figure does not include the deep water sets on the edge of the Scotian Shelf.

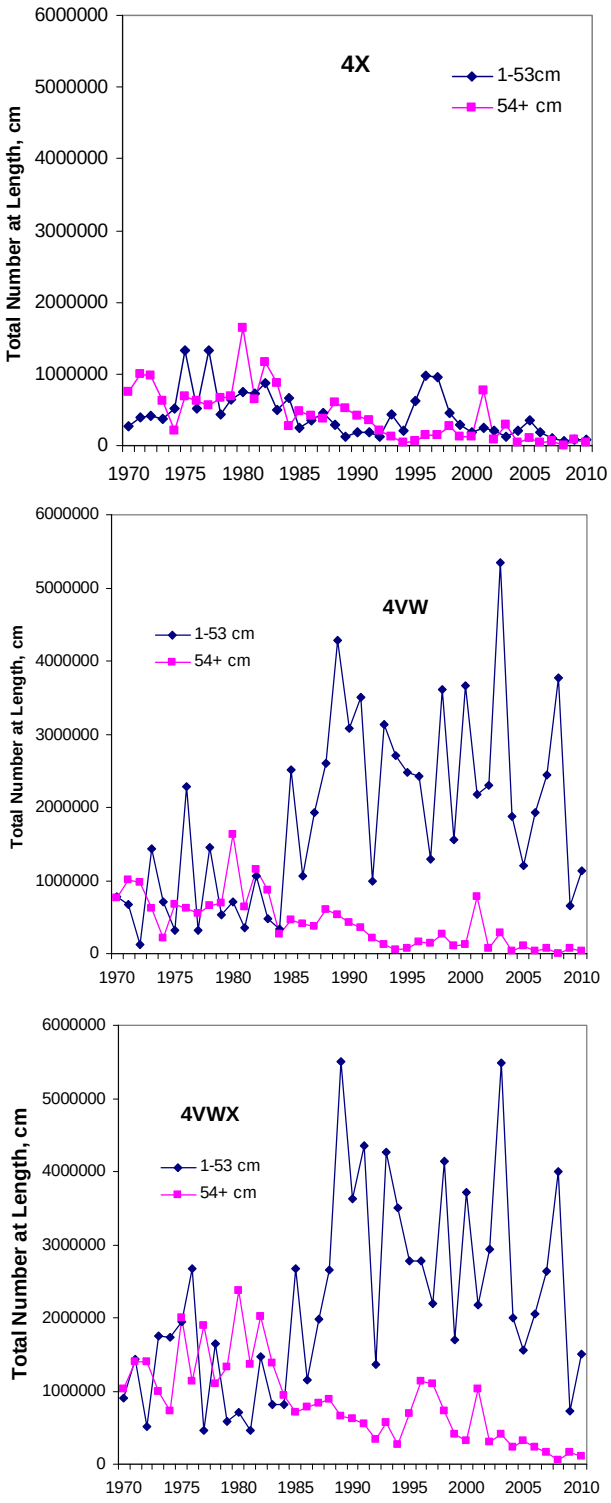
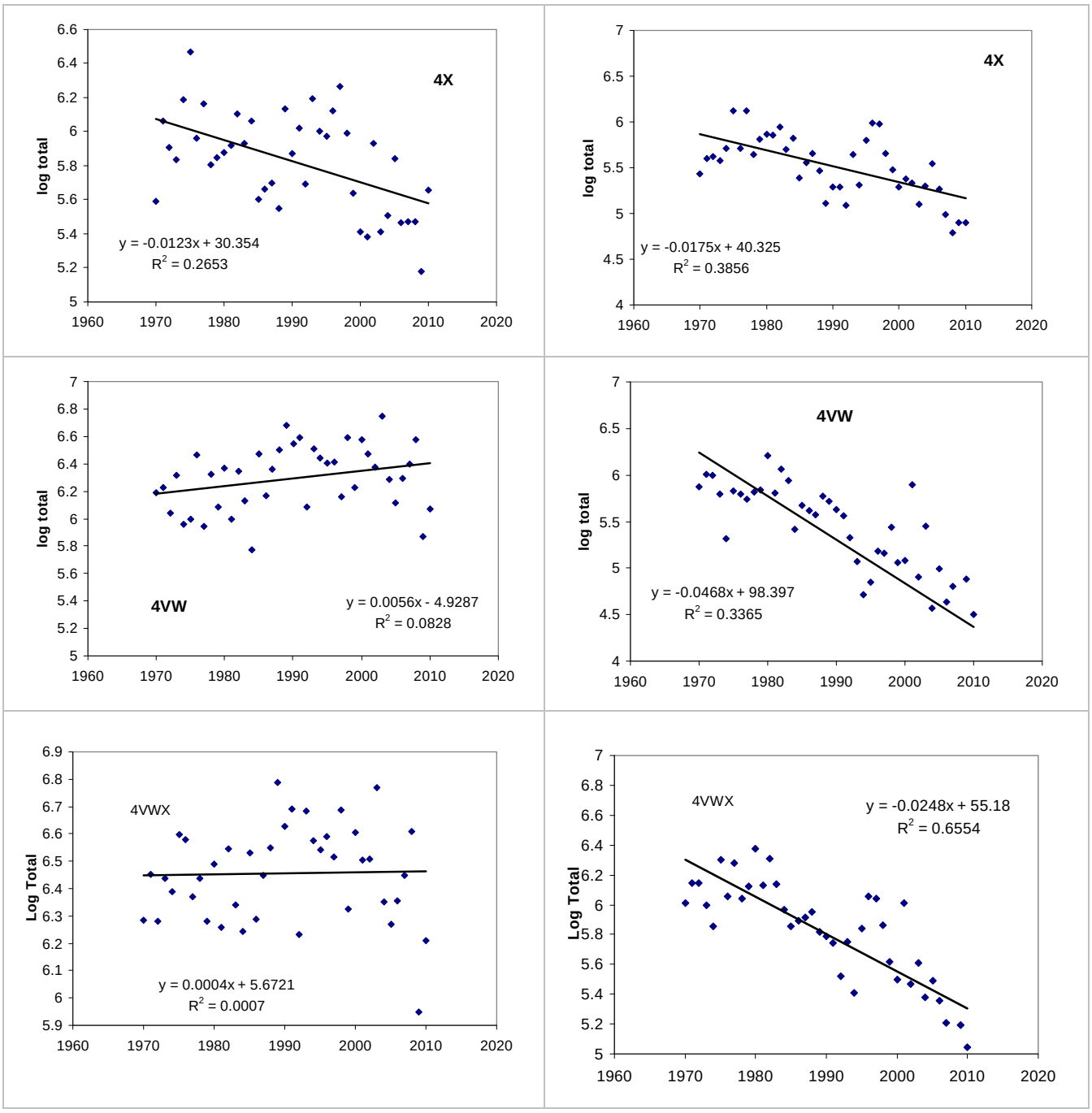
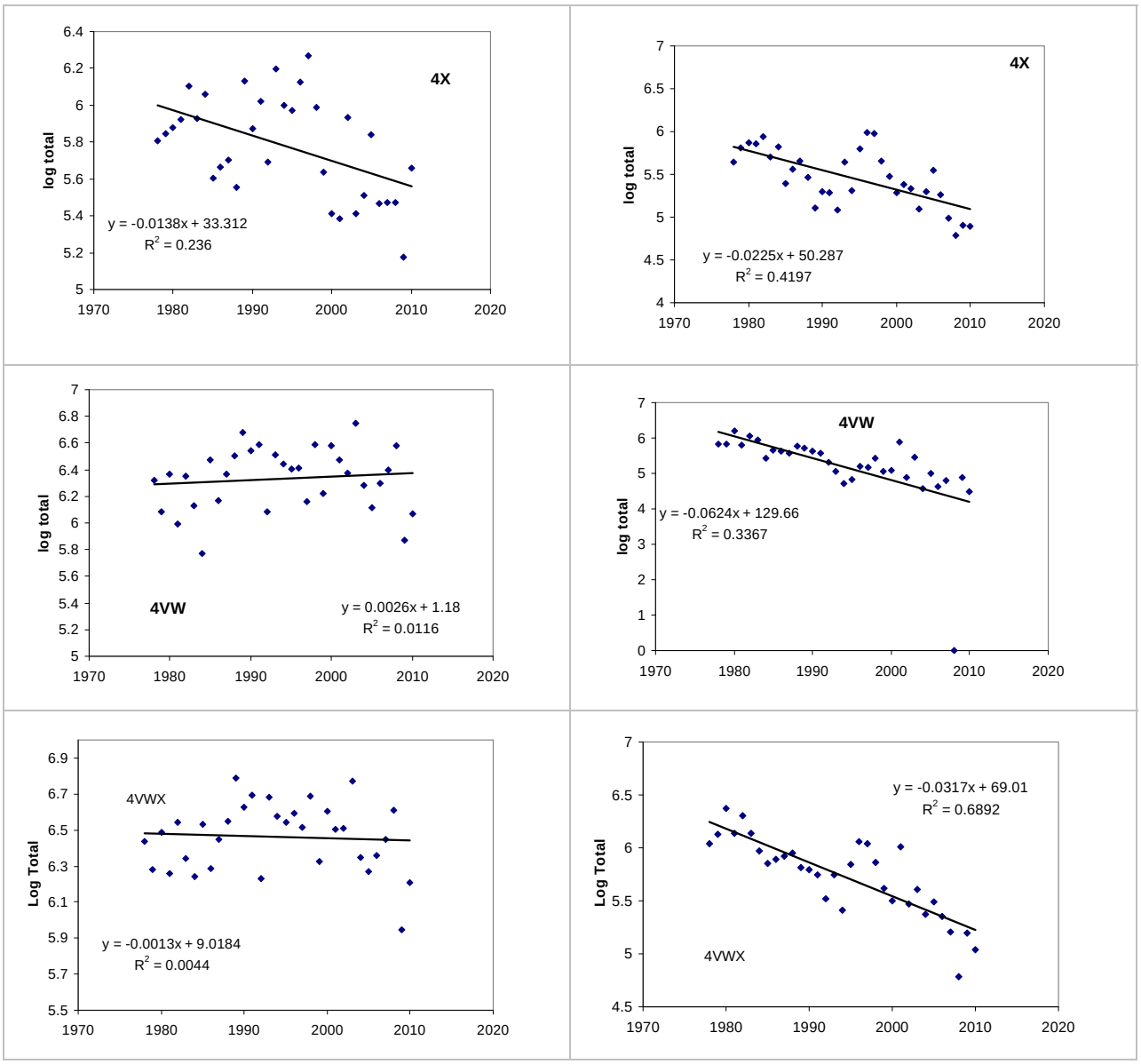


Figure 6. Abundance of immature (1-53 cm) and mature (>53 cm) of Atlantic wolffish caught during the summer RV survey, 1970-2010 from NAFO Div. 4X, 4VW, and 4VWX.



All length groups | Mature length (>53 cm) groups

Figure 7. Log transformed catch rate (number per tow) of all length groups and mature length (>53 cm) groups of Atlantic wolffish during the summer RV survey, 1970-2010 from NAFO Div. 4X, 4VW, and 4VWX.



All length groups

Mature length (>53 cm) groups

Figure 8. Log transformed catch rate (number per tow) of all length groups and mature length (>53 cm) groups of Atlantic wolffish during the summer RV survey during a three generation period, 1978-2010 (33 years), from NAFO Div. 4X, 4VW, and 4VWX.

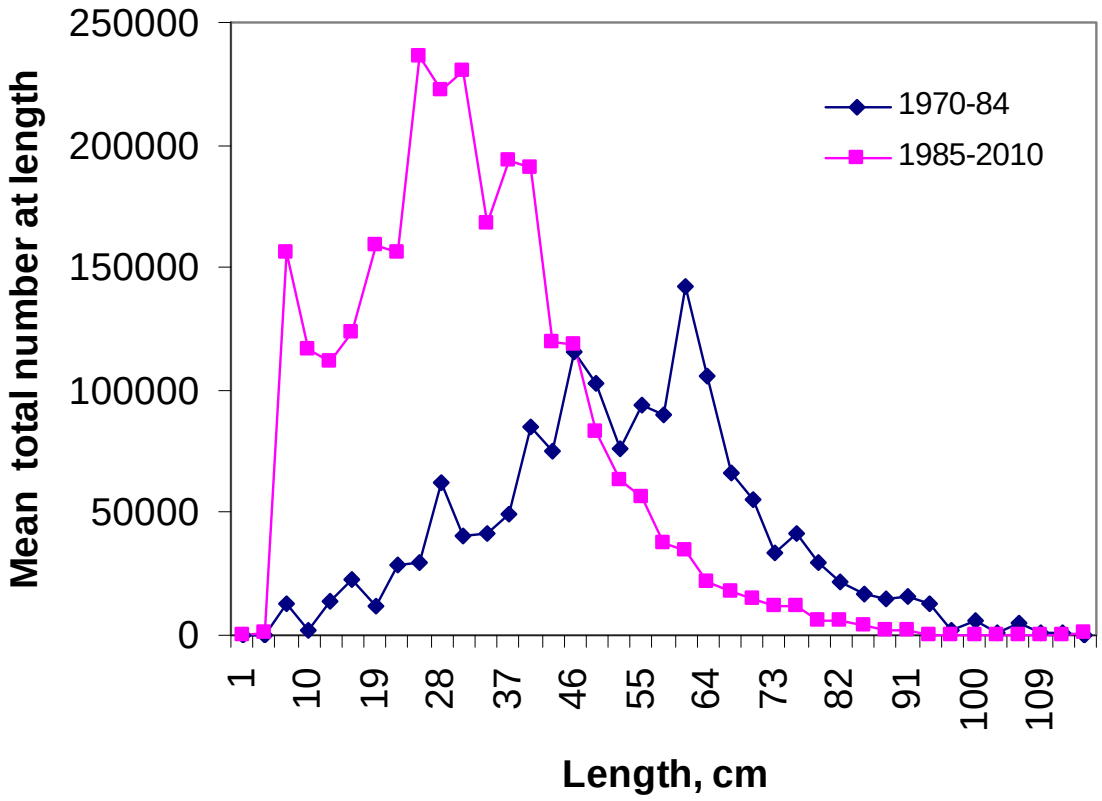


Figure 9. Mean total number at length from the summer RV survey in Divs. 4VW. These times periods were based on the changes in abundance trends observed in Figure 6.

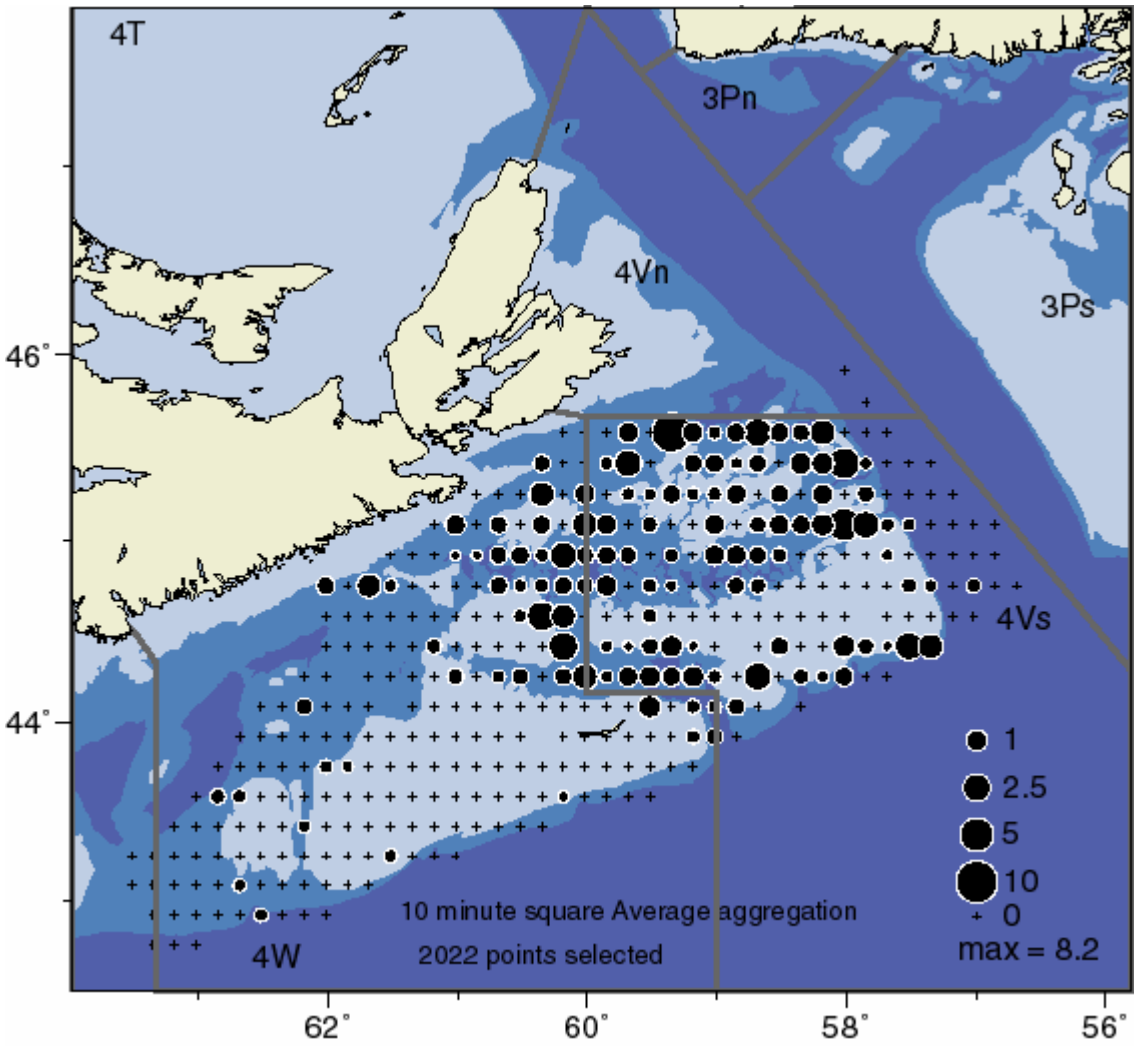


Figure 10. Distribution of Atlantic wolffish from the 4VWCOD RV survey on the eastern Scotian Shelf, 1986-2010. Note that during some of the years coverage was incomplete and the years 1998 and 2004 are missing.

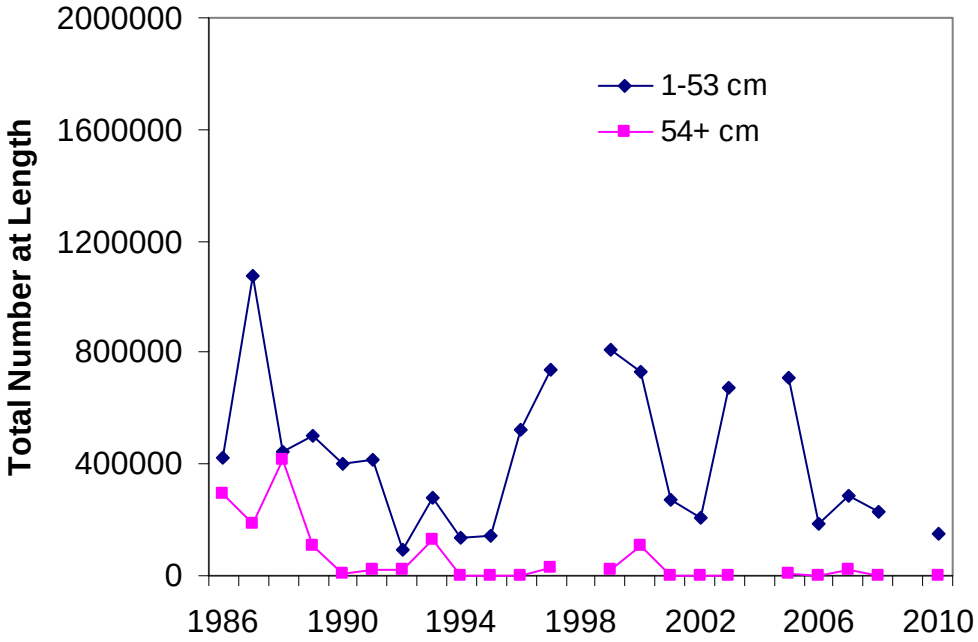


Figure 11. Abundance of immature (1-53 cm) and mature (>53 cm) Atlantic wolffish during the 4VWCOD RV survey, 1986-2010. Note that the 1998, 2004, and 2009 surveys are missing or incomplete.

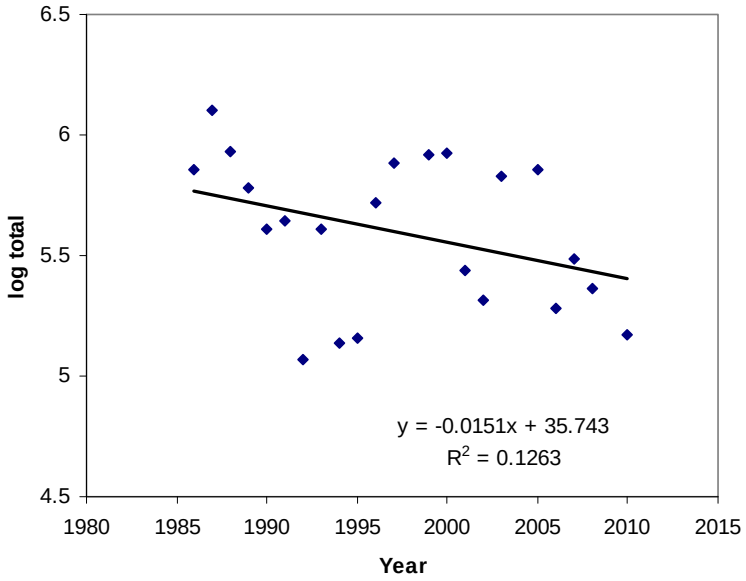


Figure 12. Log transformed catch rate (number per tow) of Atlantic wolffish (all sizes) during the 4VWCOD RV survey, 1986-2010. Note that the 1998, 2004, and 2009 surveys are missing or incomplete.

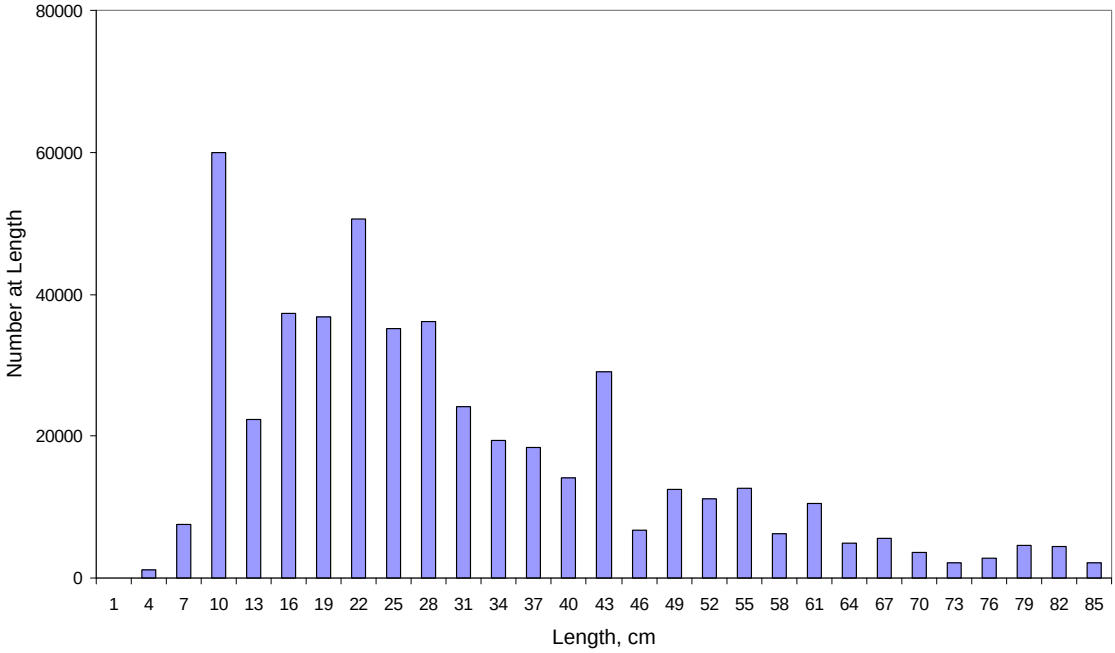


Figure 13. Total number at length (cm) of Atlantic wolffish from the 4VWCOD RV survey, 1986-2010.

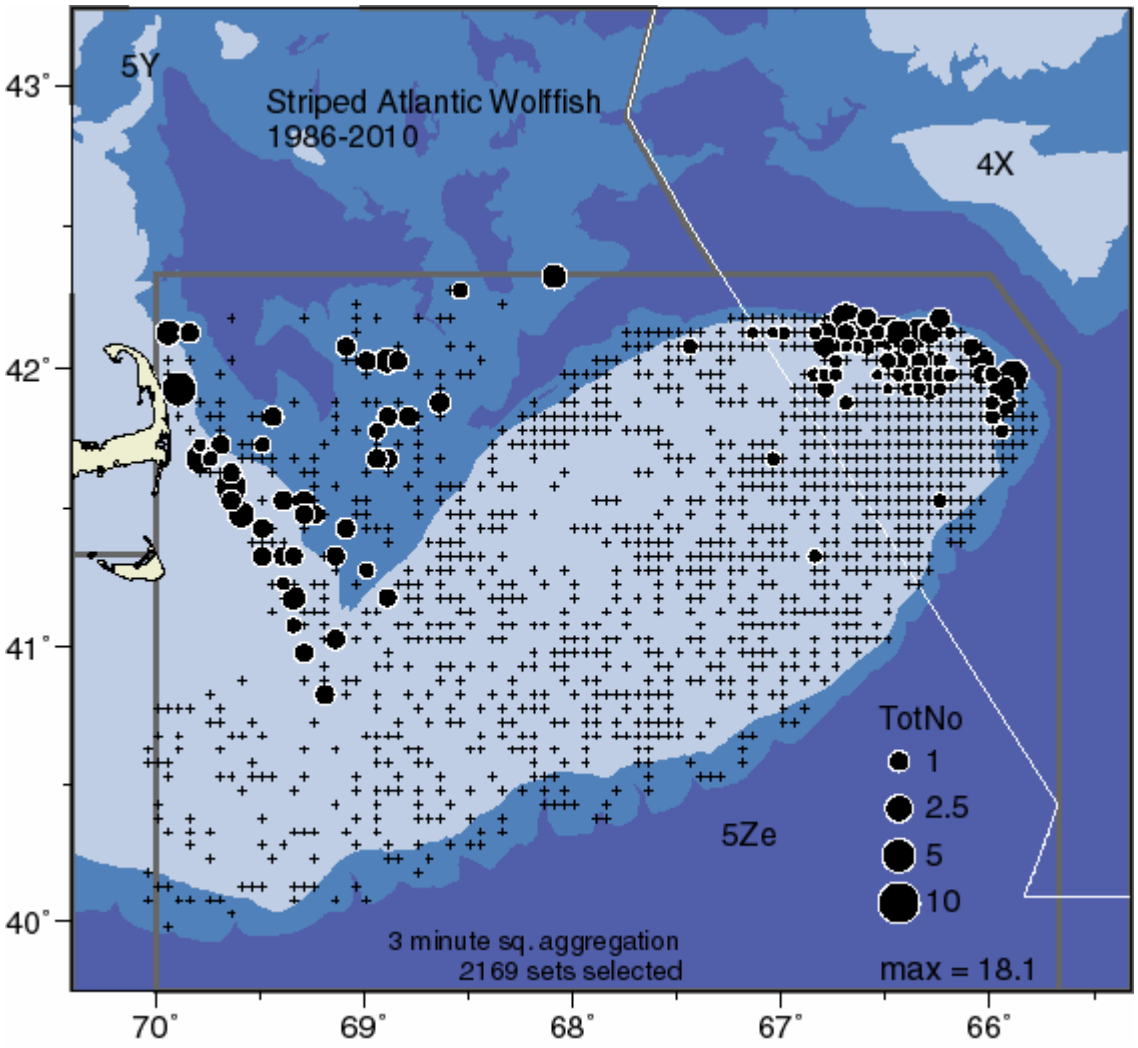


Figure 14. Distribution of Atlantic wolffish as indicated by the Georges Bank RV Survey, 1986-2010.

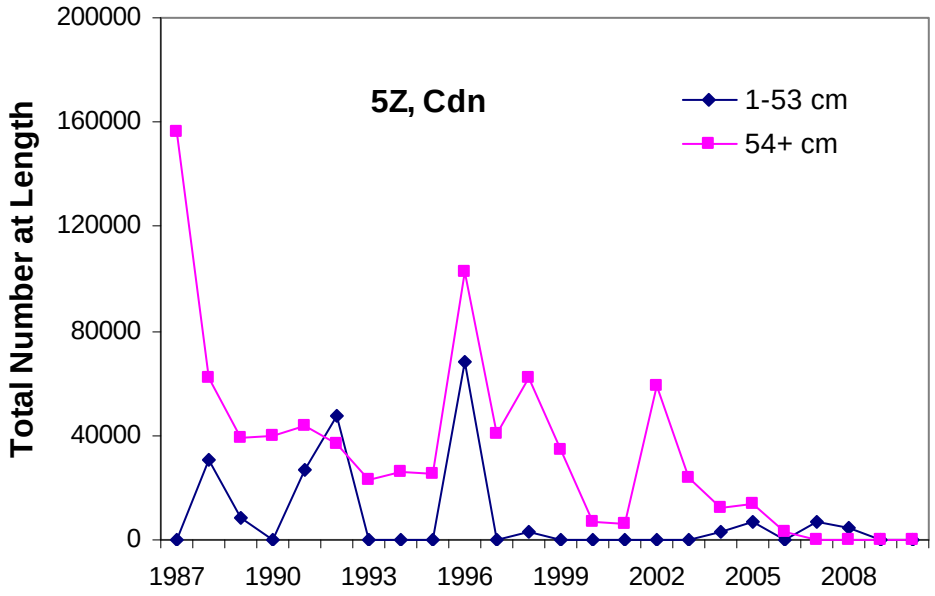


Figure 15. Abundance of immature (1-53 cm) and mature (>53 cm) Atlantic wolffish from the Canadian strata of the Georges Bank RV survey in Div. 5Z.

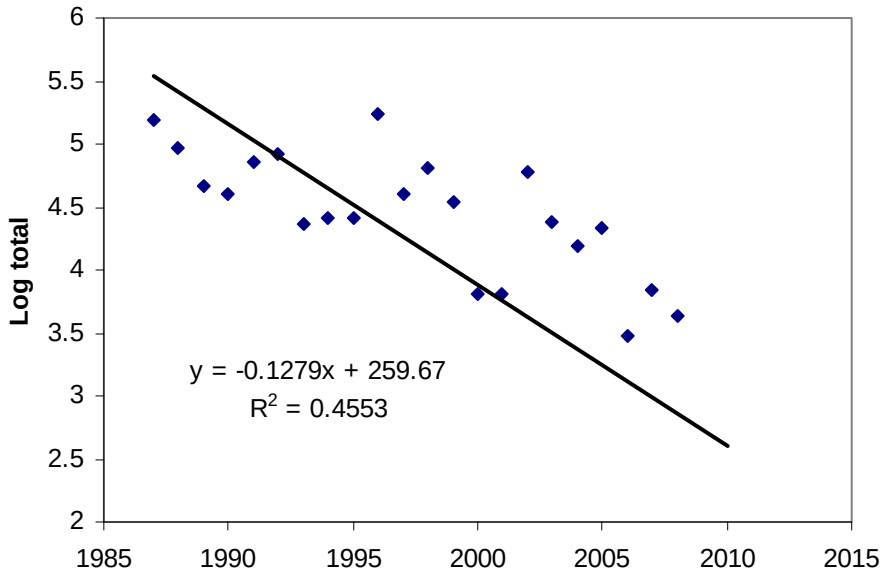


Figure 16. Log transformed catch rate (total number per tow) of all length groups of Atlantic wolffish from the Georges Bank RV survey, Canadian strata only.

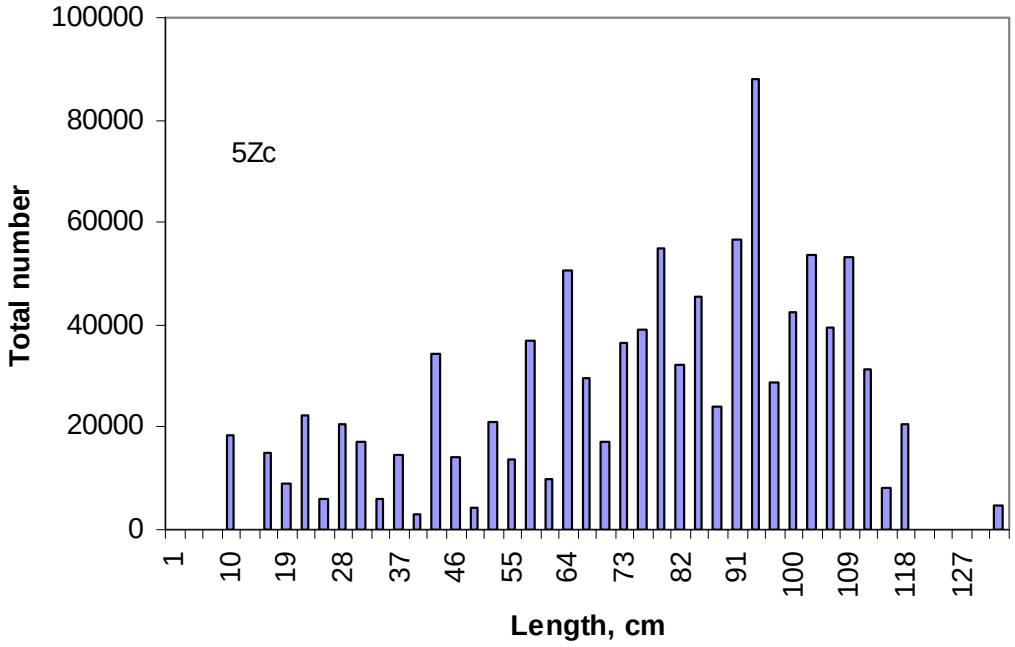


Figure 17. Total number at length of Atlantic wolffish from the Georges Bank RV survey in Divs. 4VsW, 1986-2010.

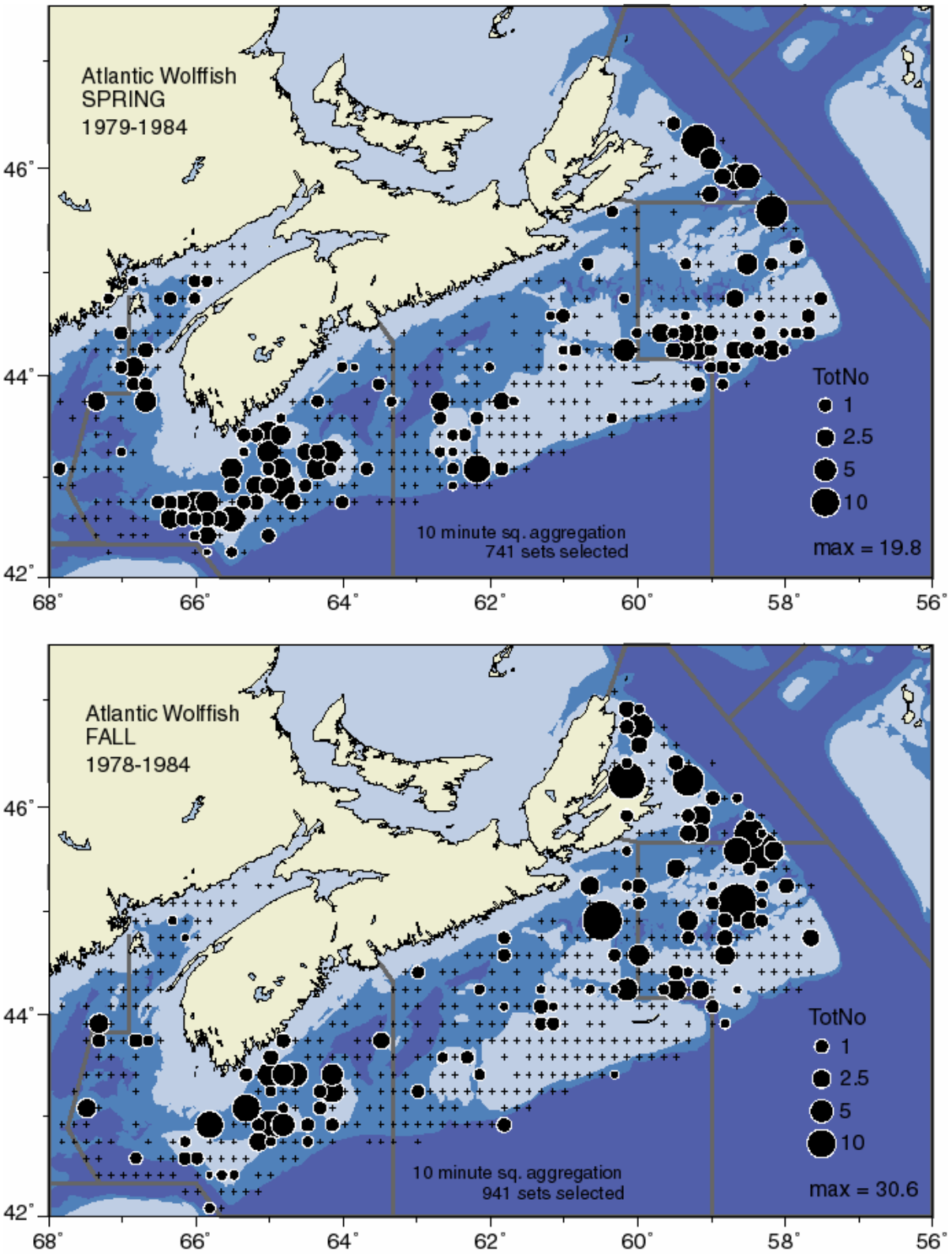


Figure 18. Distribution of Atlantic wolffish as indicated by the Spring (top panel) and Fall (bottom panel) RV Surveys of the Scotian Shelf.

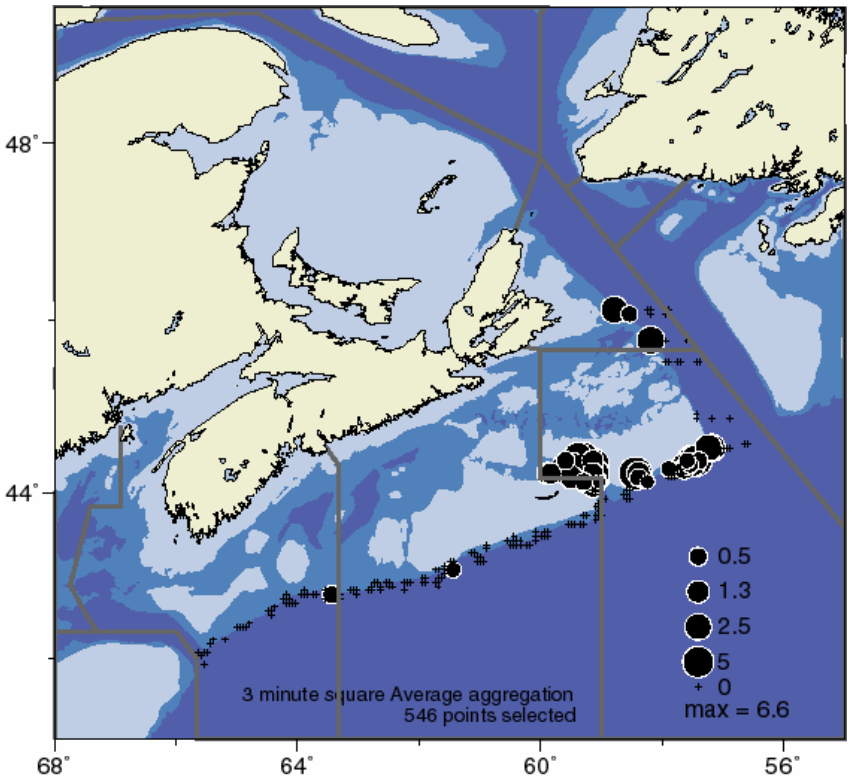


Figure 19. Distribution of Atlantic wolffish from the DFO Redfish RV Survey, 1982-88.

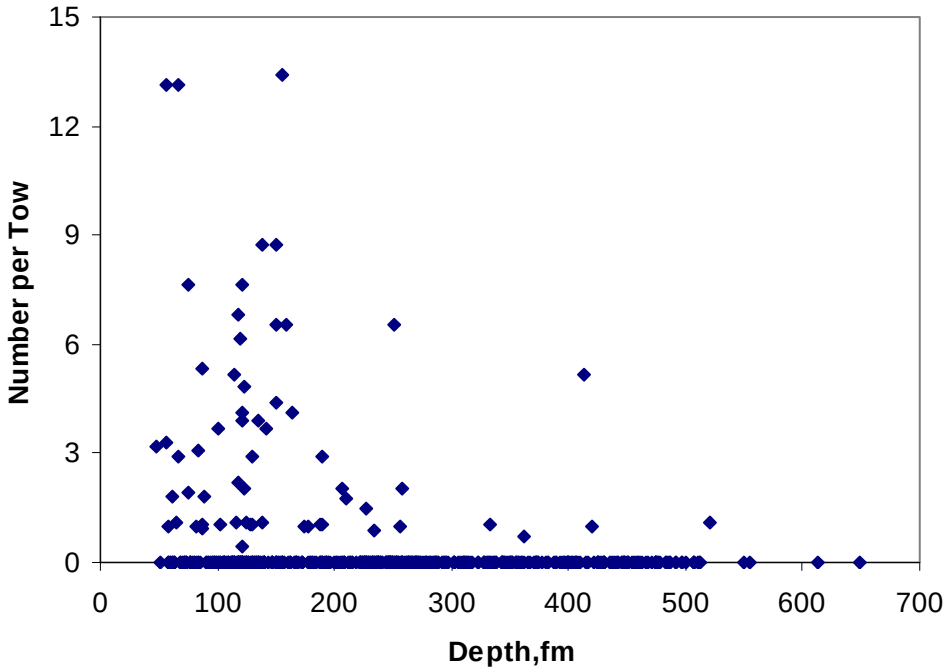


Figure 20. Depth (fathom) distribution of Atlantic wolffish from the DFO Redfish RV Surveys, 1982-1988 in Divs. 4VWX.

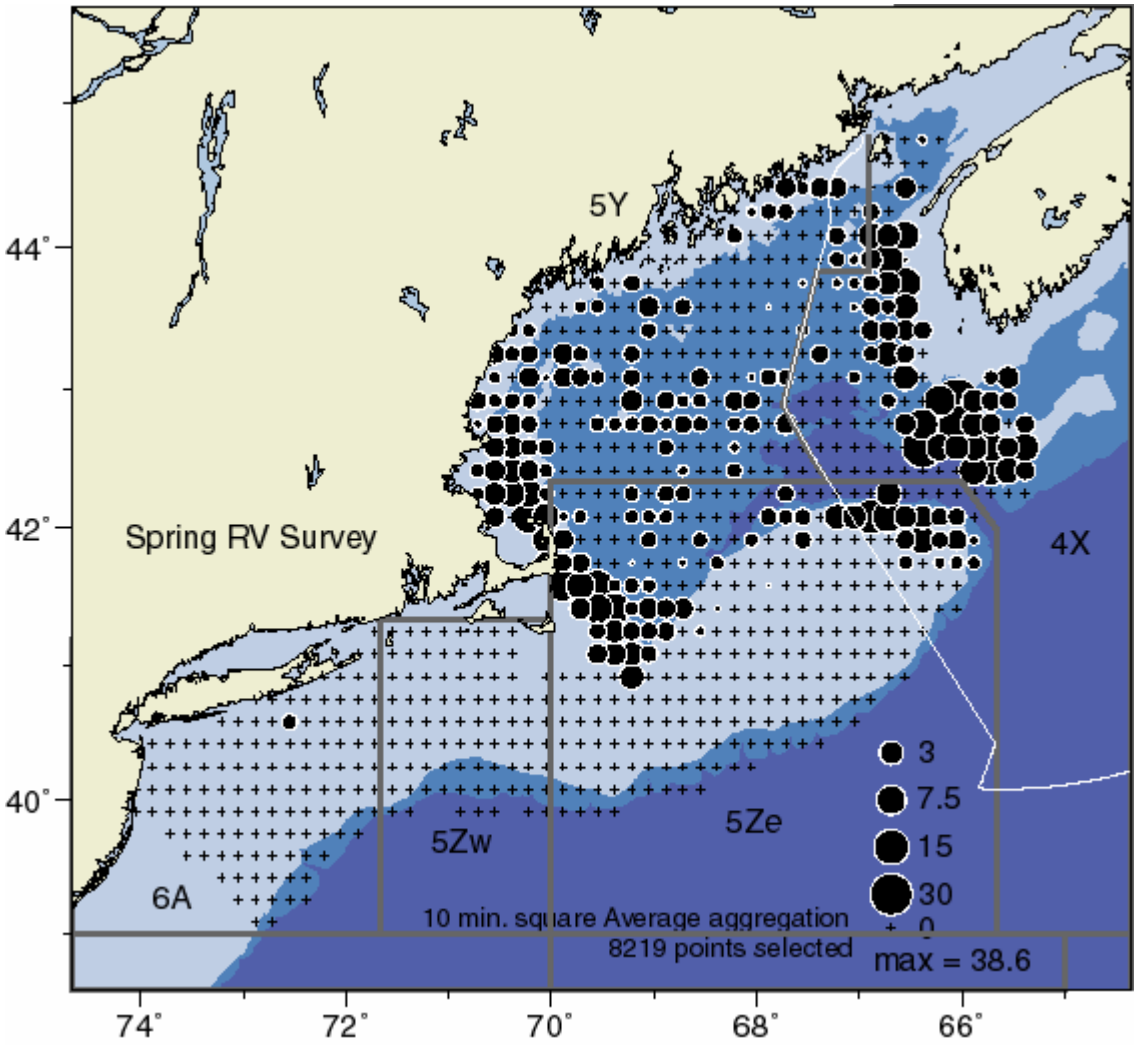


Figure 21. Distribution of Atlantic wolffish as indicated by the US Spring RV Survey, 1968-2009.

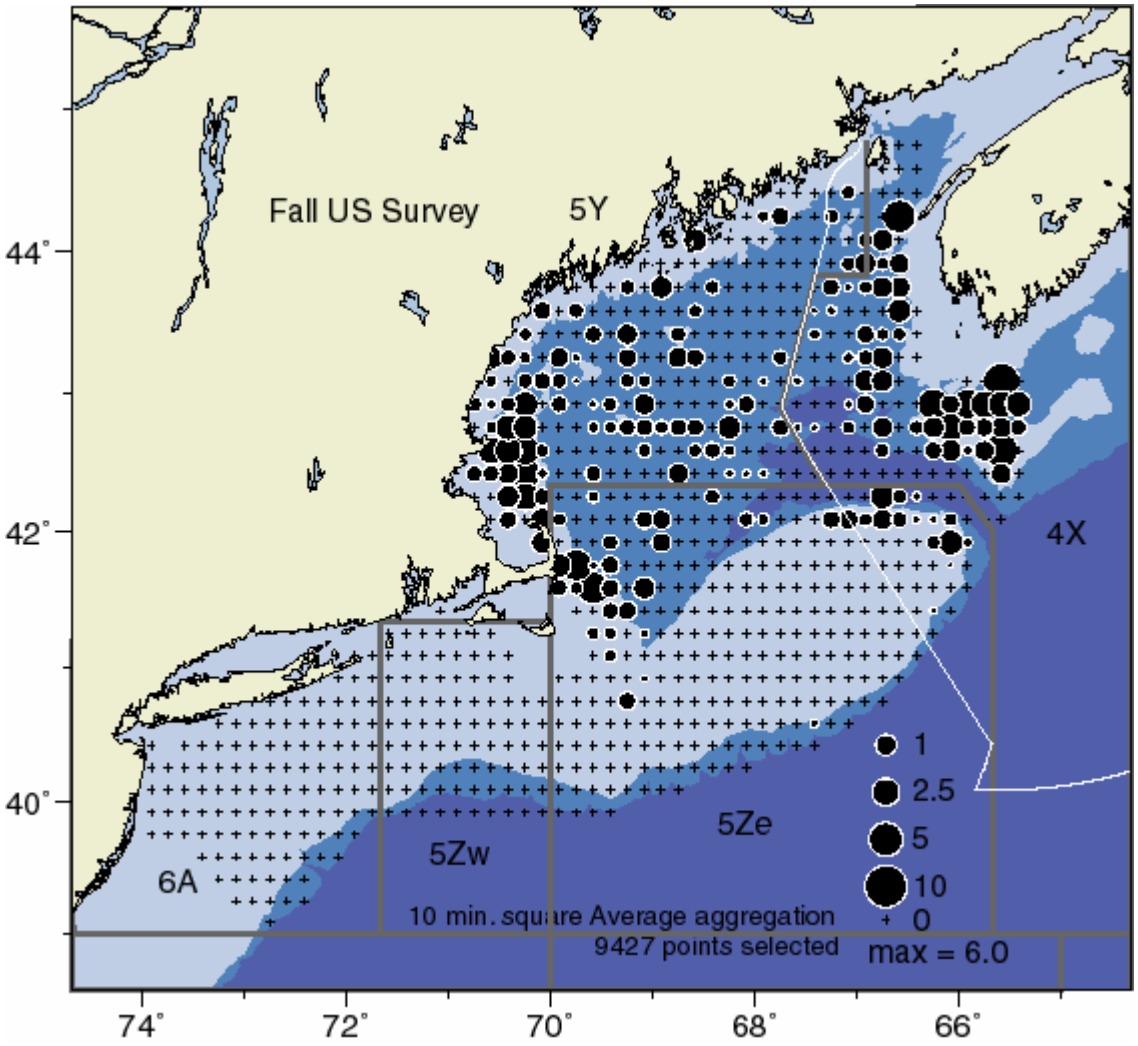


Figure 22. Distribution of Atlantic wolffish as indicated by the US Fall RV Survey, 1963-2009.

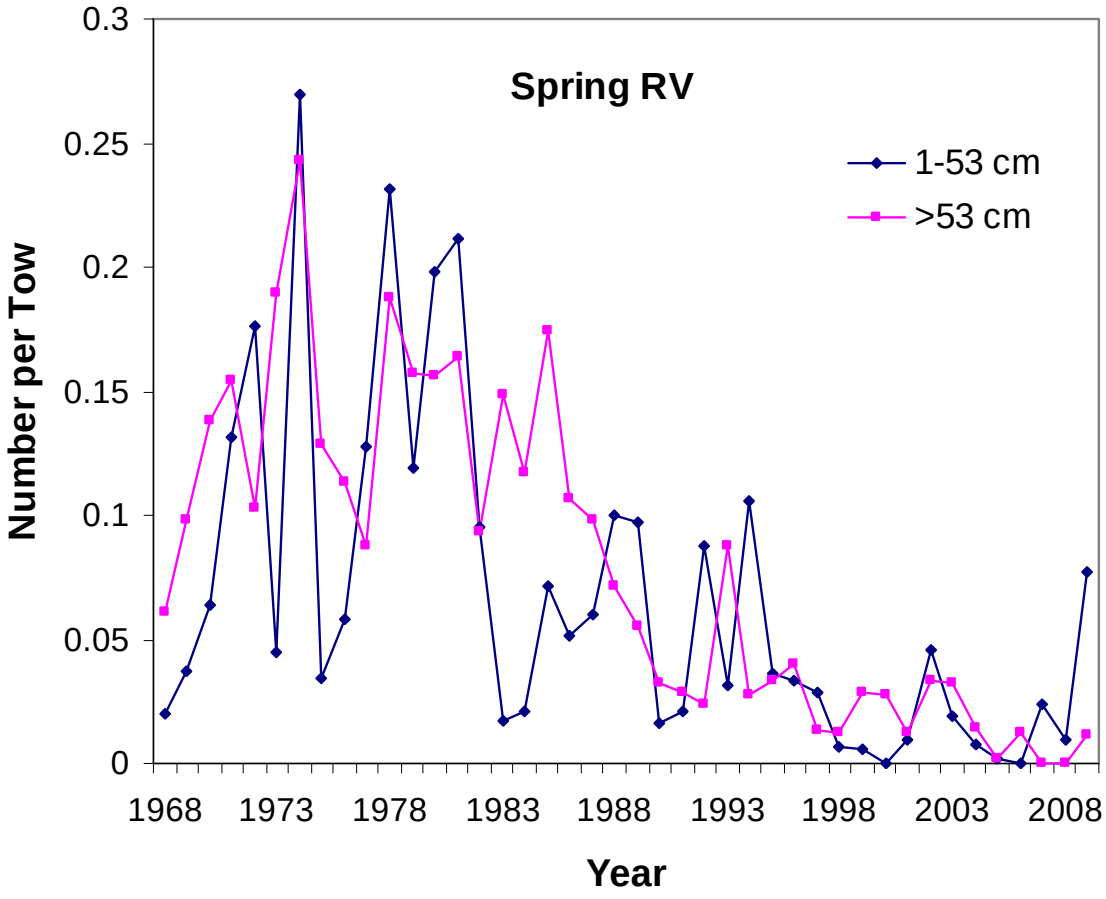


Figure 23. Stratified mean number per tow of immature (1-53 cm) and mature (>53 cm) Atlantic wolffish as indicated by the US Spring RV Survey.

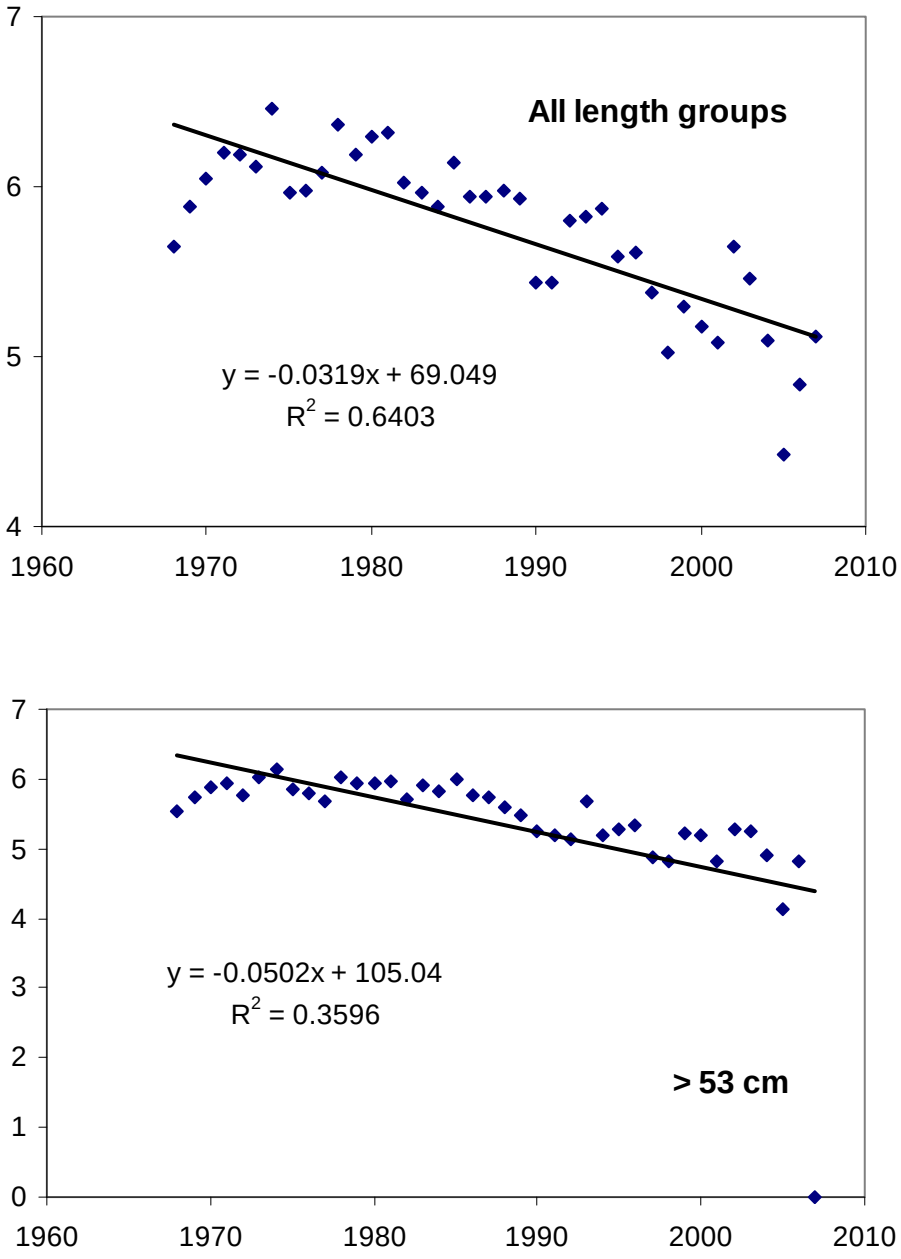


Figure 24. Log transformed catch rate (total number at length) of Atlantic wolffish (all length groups and mature length groups only (>54 cm)) from the all strata of the US spring RV survey, 1963-2007. Note that the 2008 and 2009 surveys were conducted using different tow protocols, gears, and vessels and were not included.

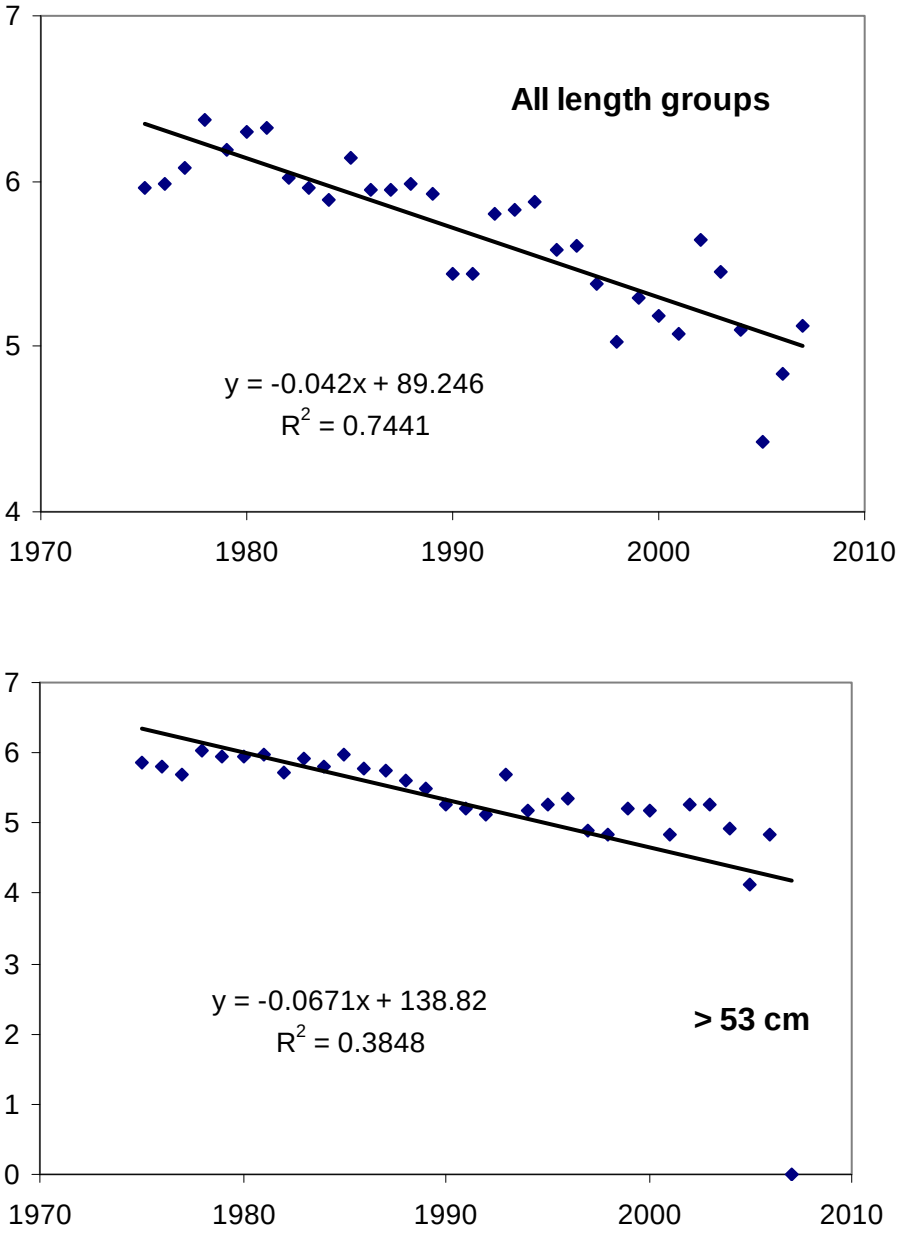


Figure 25. Log transformed catch rate (total number at length) of Atlantic wolffish (all length groups and mature length groups only (>53 cm)) from the all strata of the US spring RV survey for three generations, 1975-2007. The 2008 and 2009 surveys were conducted using different tow protocols, gears, and vessels and are not included.

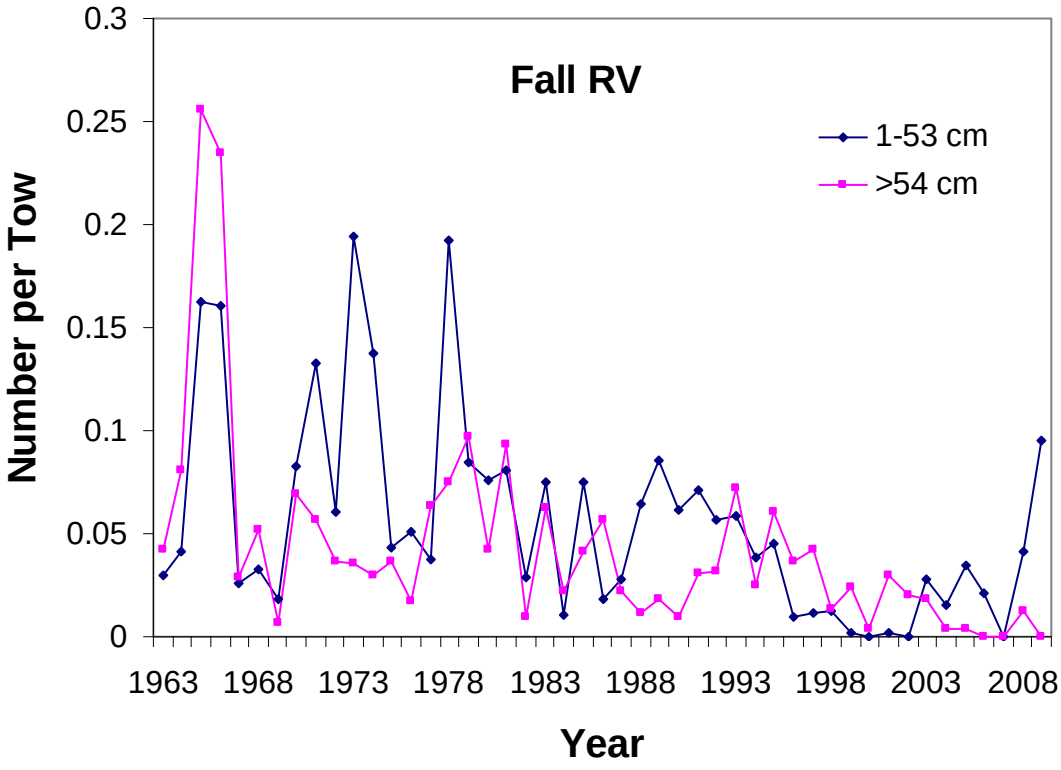
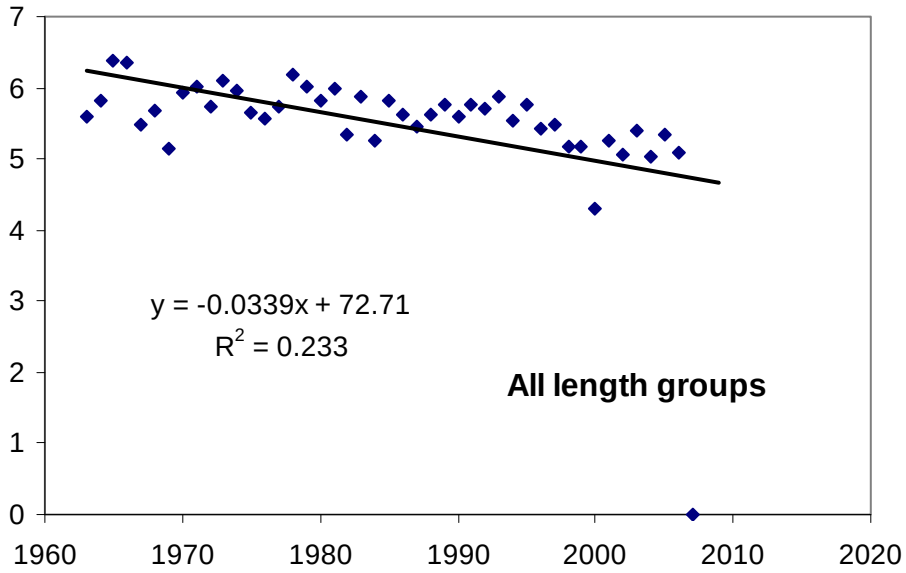


Figure 26. Stratified mean number per tow of immature (1-53 cm) and mature (> 53 cm) Atlantic wolffish as indicated by the US Fall RV Survey.



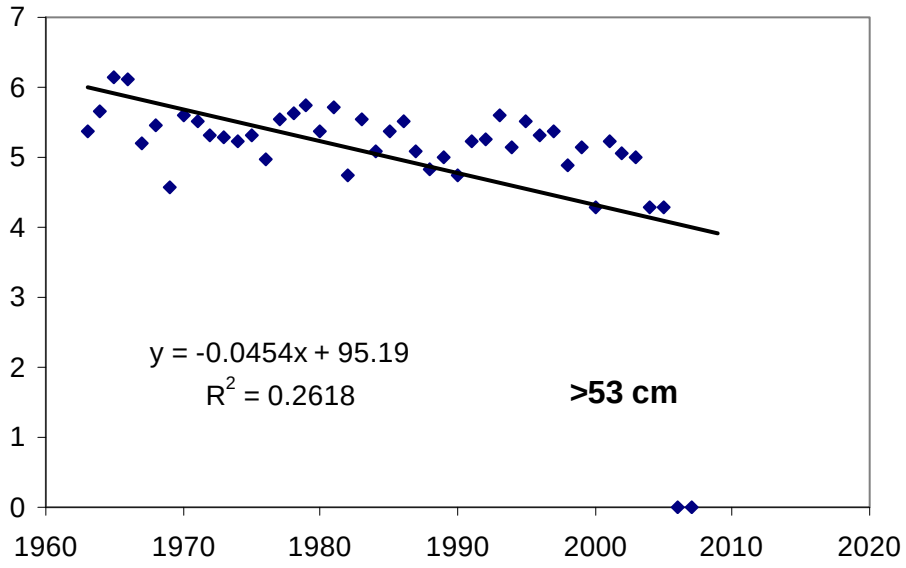


Figure 27. Log transformed catch rate (total number at length) of Atlantic wolffish (all length groups and mature length groups only (>53cm)) from the all strata of the US Fall RV Survey, 1963-2007. The 2008 and 2009 surveys were conducted using different tow protocols, gears, and vessels and are not included.

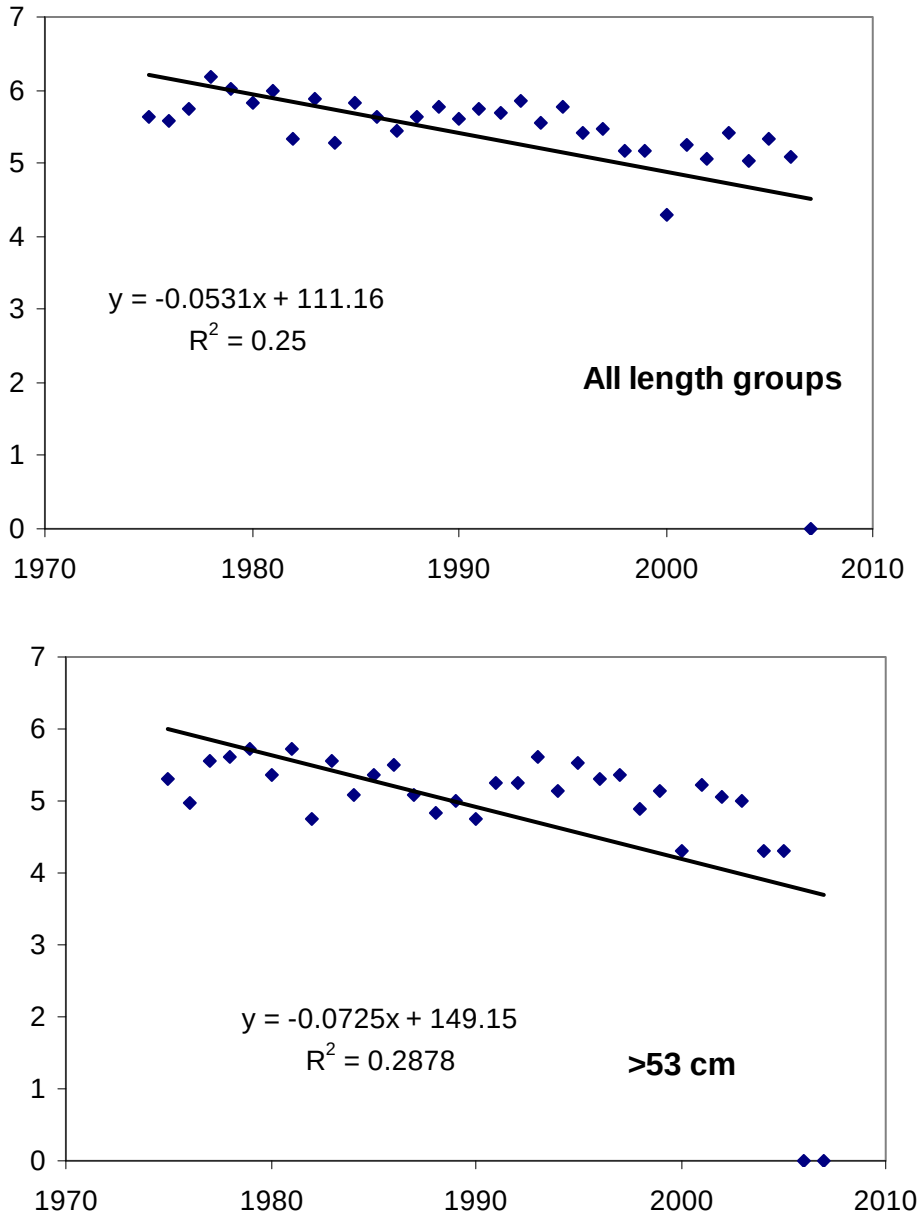


Figure 28. Log transformed catch rate (total number at length) of Atlantic wolffish (all length groups and mature length groups only (>53 cm)) from the all strata of the US fall RV survey during a three generation period, 1975-2007. Note that the 2008 and 2009 surveys were conducted using different tow protocols, gears, and vessels and were not included.

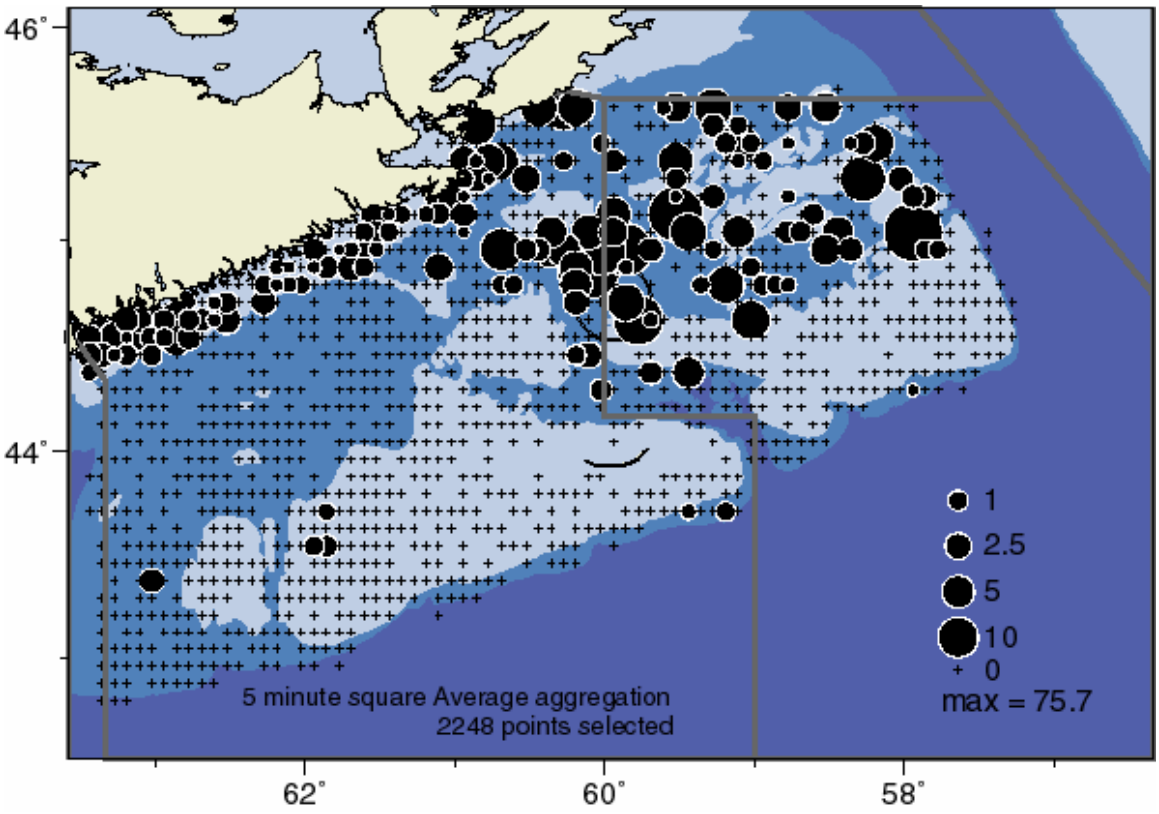


Figure 29. Distribution of Atlantic wolffish as indicated by the 4VsW Sentinel Industry Longline Survey, 1996-2009.

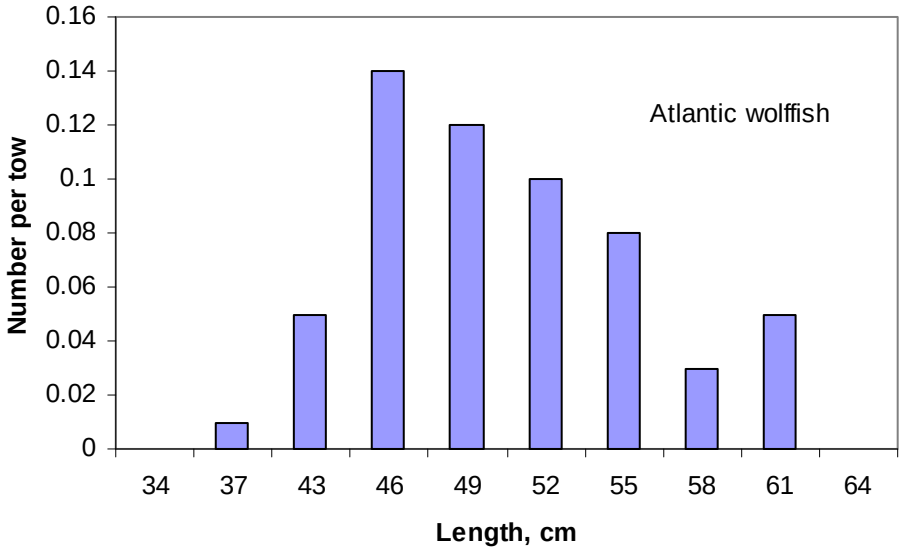


Figure 30. Number per tow at length (3 cm groupings) of Atlantic wolffish from the 4VsW Sentinel Industry Longline Survey, 1996-2009.

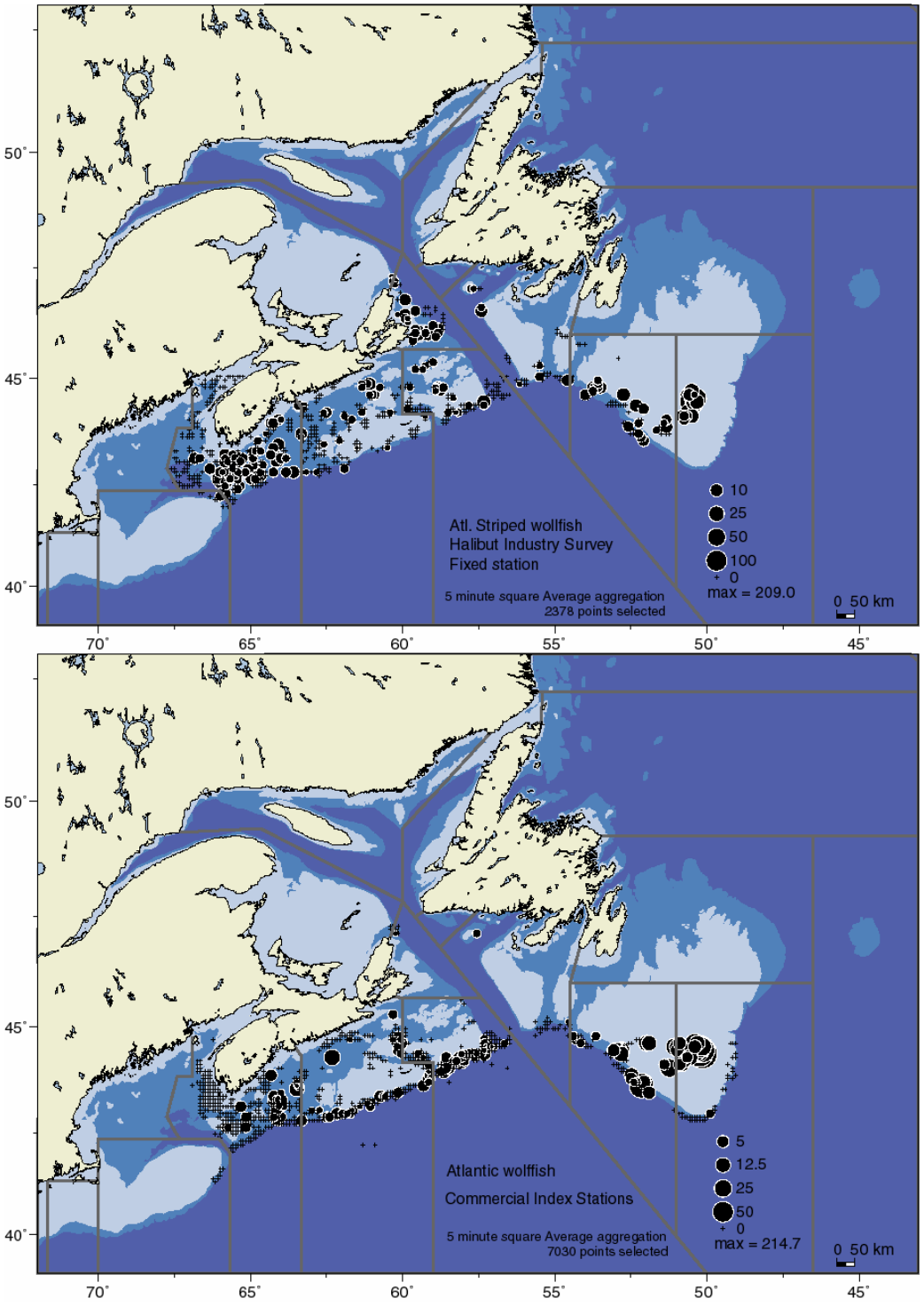


Figure 31. Distribution of Atlantic wolffish as indicated by the fixed station (upper panel) and commercial index stations (lower panel) of the halibut industry longline survey, 1998-2009.

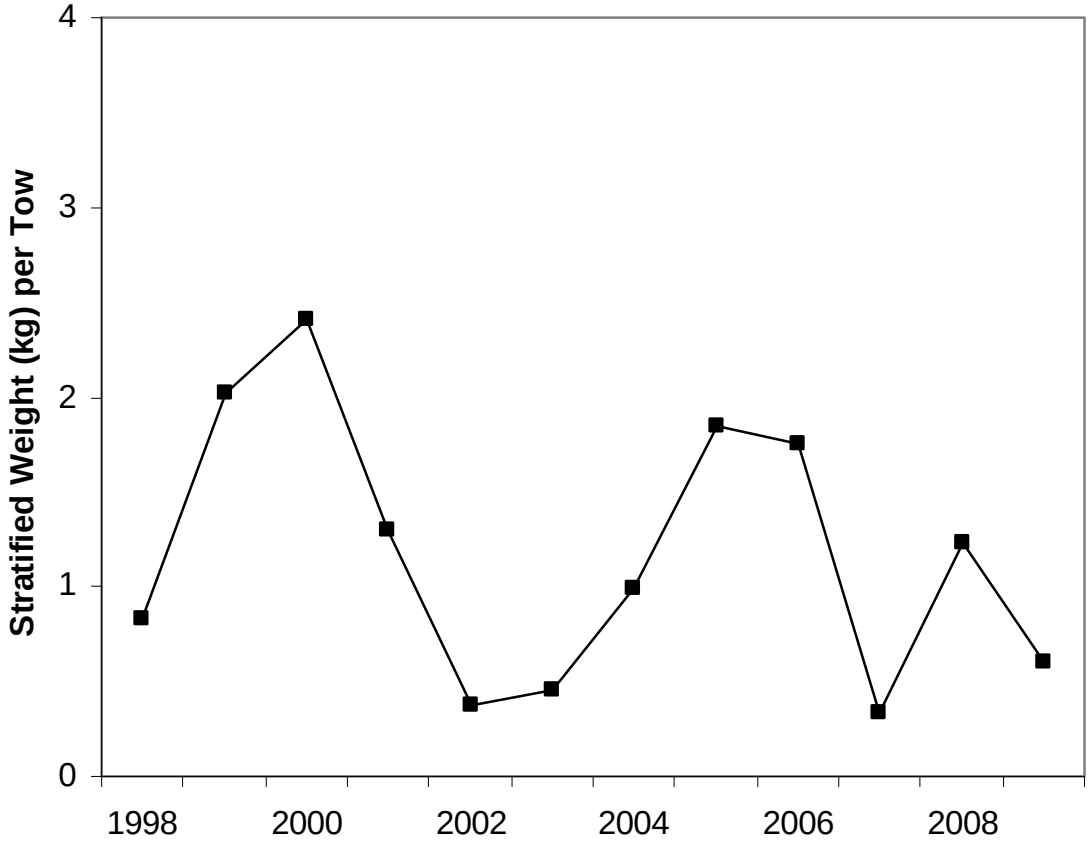


Figure 32. Stratified mean weight (kg) per tow of Atlantic wolffish from all strata of the fixed station portion of the halibut industry longline survey.

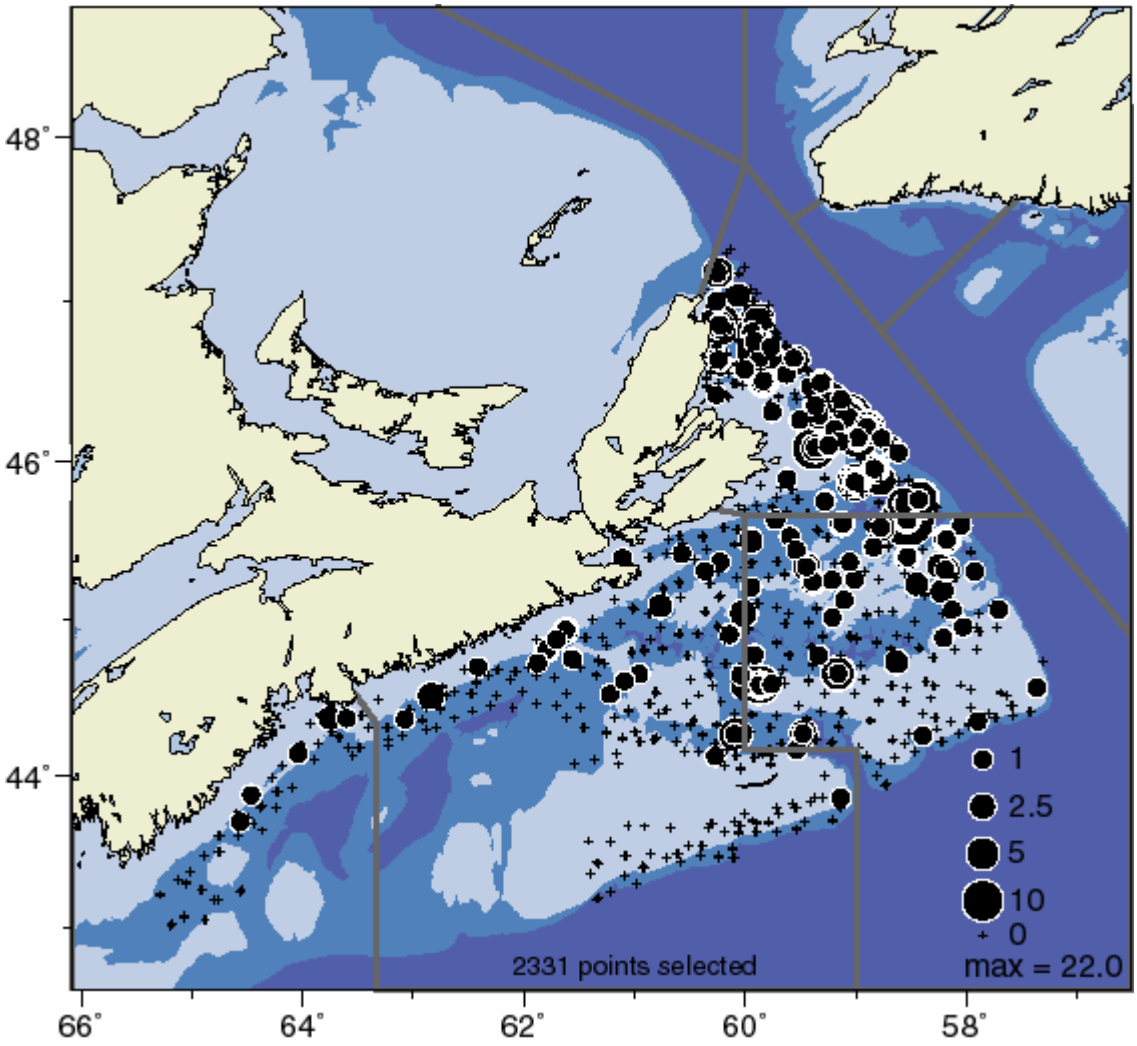


Figure 33. Distribution of Atlantic wolffish as indicated by the Snow Crab Industry Survey, 2004-2009.

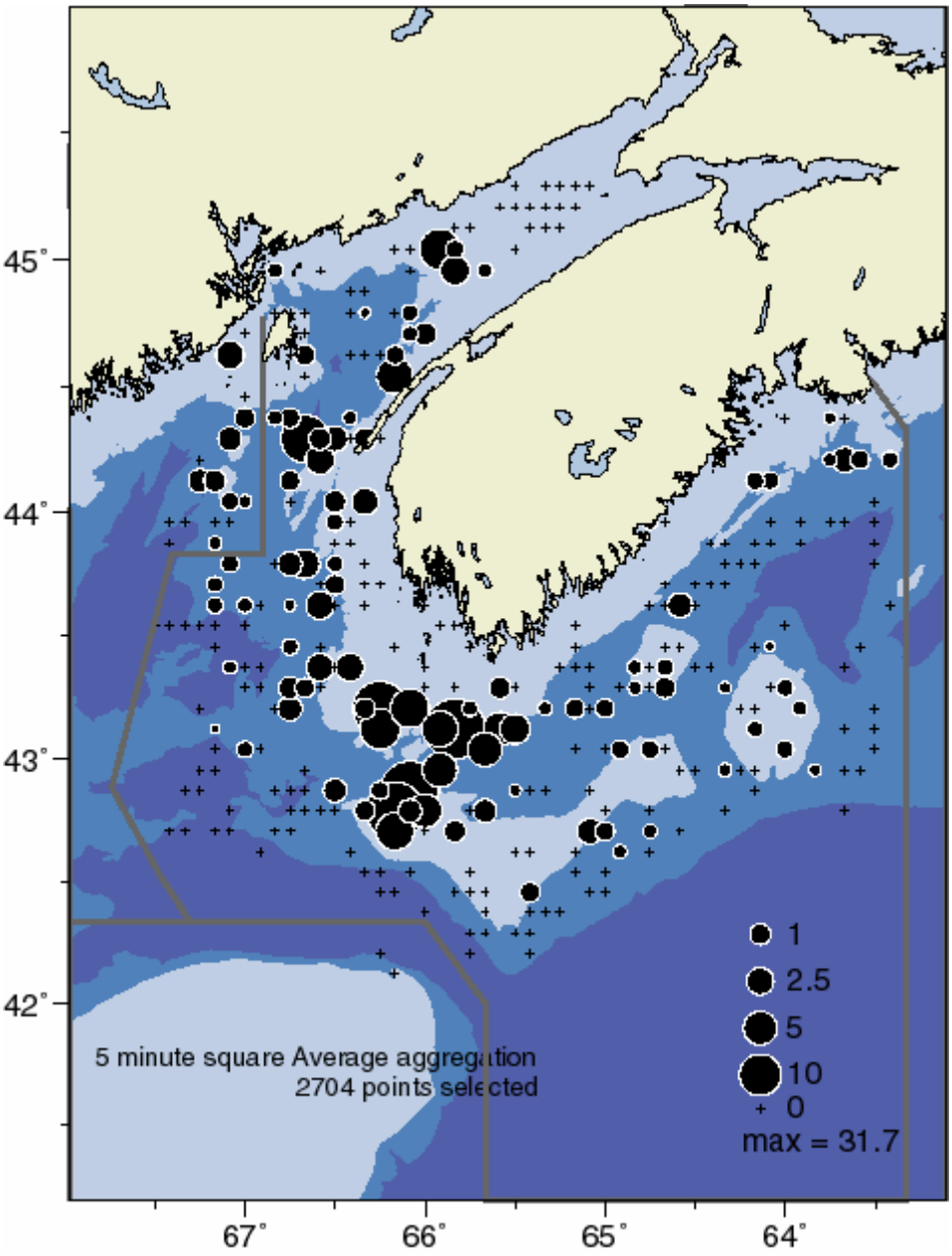


Figure 34. Distribution of Atlantic wolffish as indicated by the ITQ industry OT survey, 1995-2009.

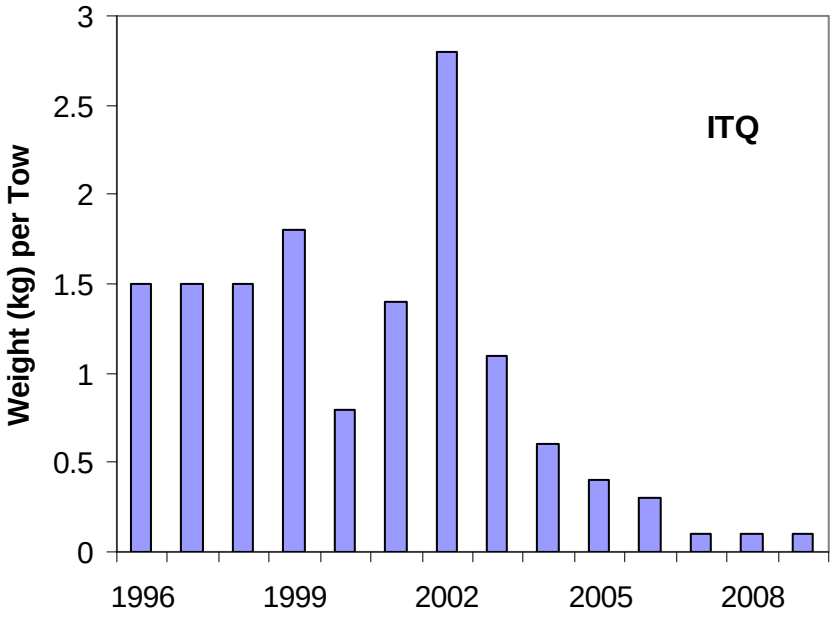


Figure 35. Abundance (kg/tow) of Atlantic wolffish as indicated by the ITQ industry survey, 1996-2009.

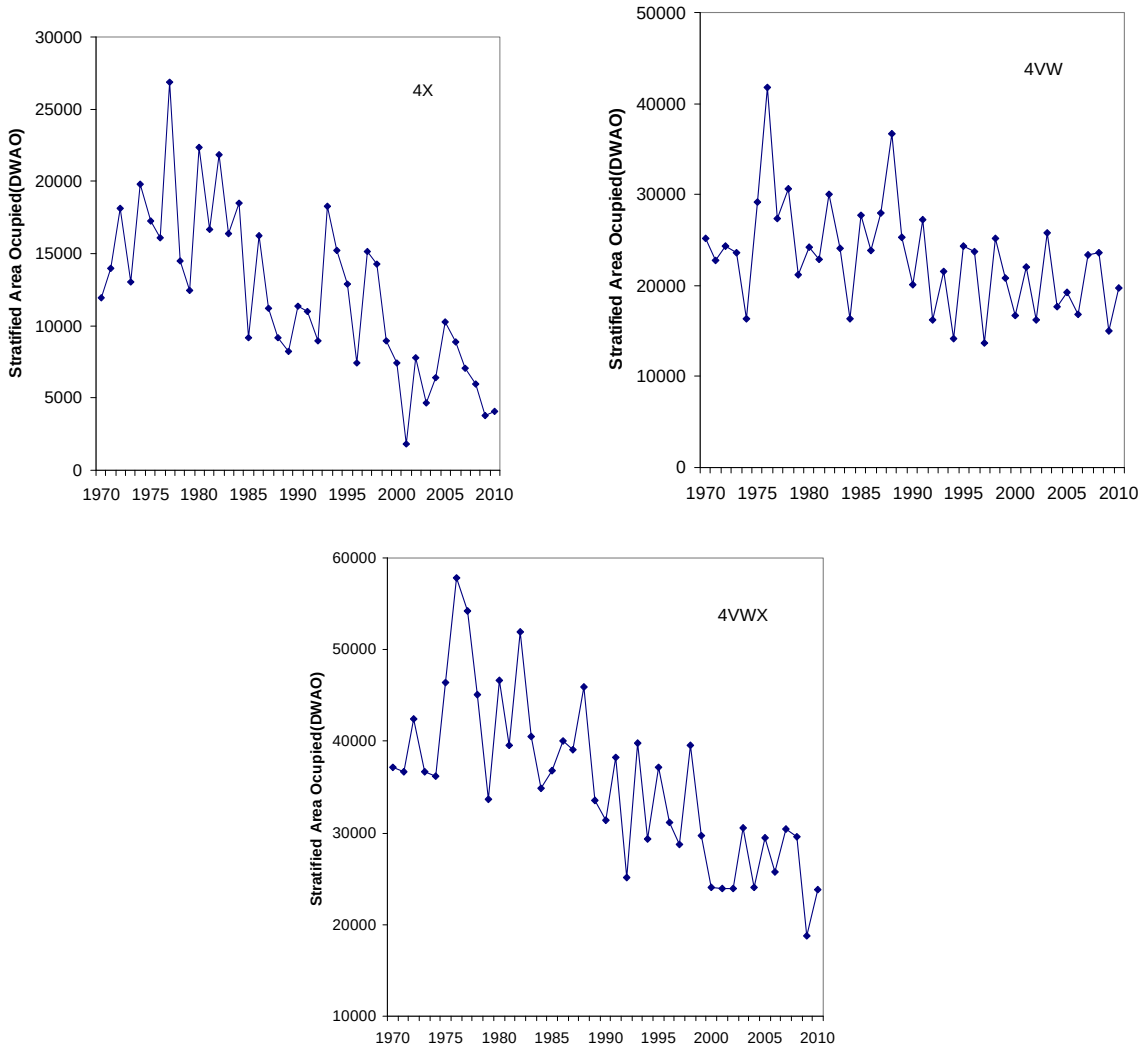


Figure 36. Design weighted area occupied (DWAO) of Atlantic wolffish as indicated by the Summer RV Survey.

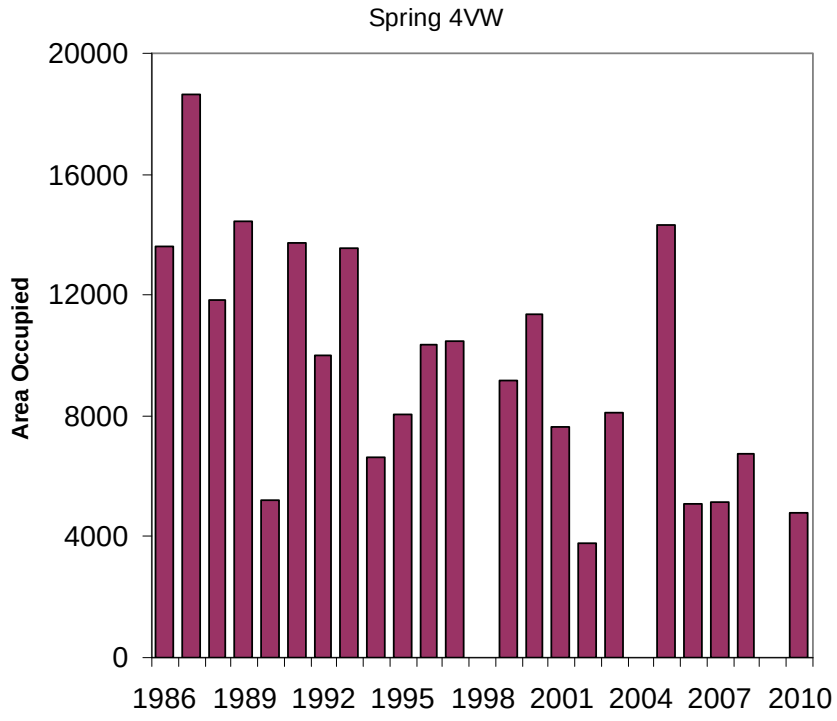


Figure 37. Design weighted area occupied (DWAO) of Atlantic wolffish as indicated by the 4VWCOD RV Survey, 1986-2010. Note that the 1998, 2004, and 2009 surveys are missing or incomplete.

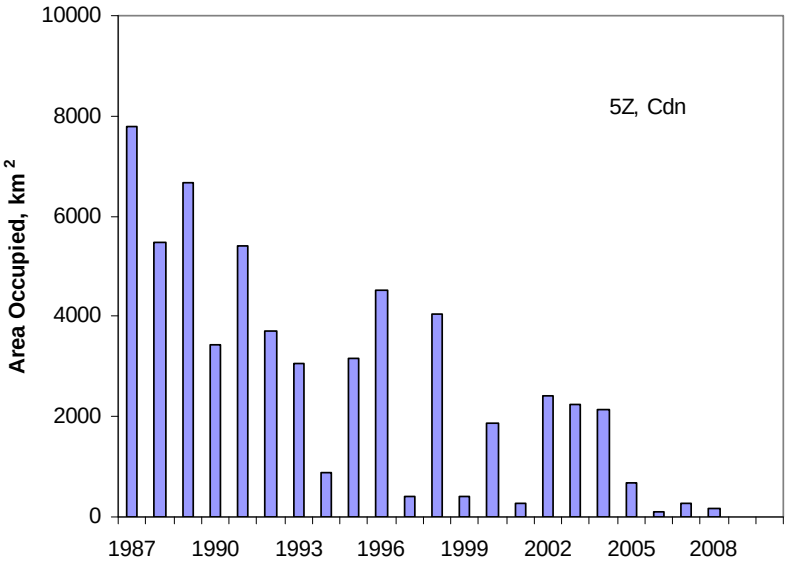


Figure 38. Design weighted area occupied (DWAO) of Atlantic wolffish as indicated by the Georges Bank RV survey in Div. 5Zc.

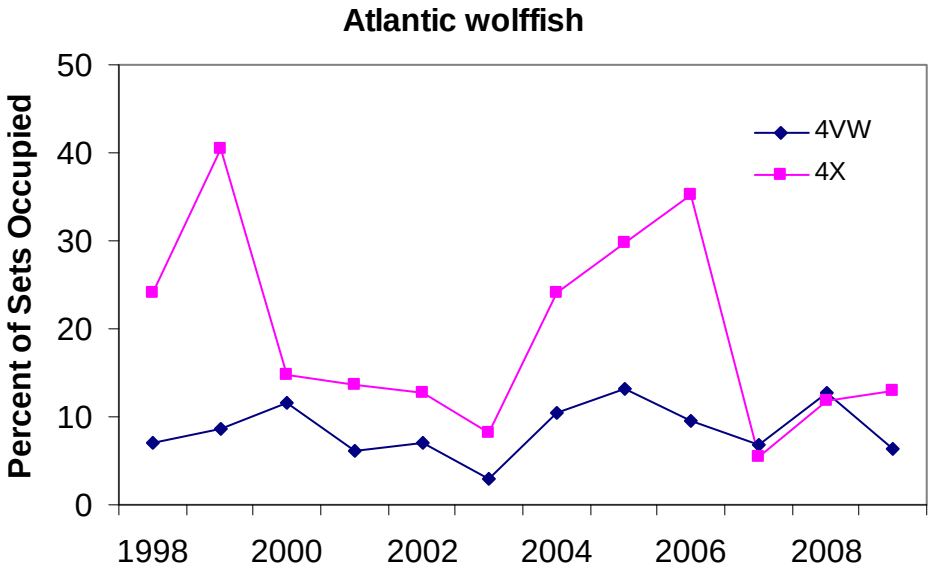


Figure 39. Percentage of sets containing Atlantic wolffish in the fixed station portion of the halibut industry longline survey.

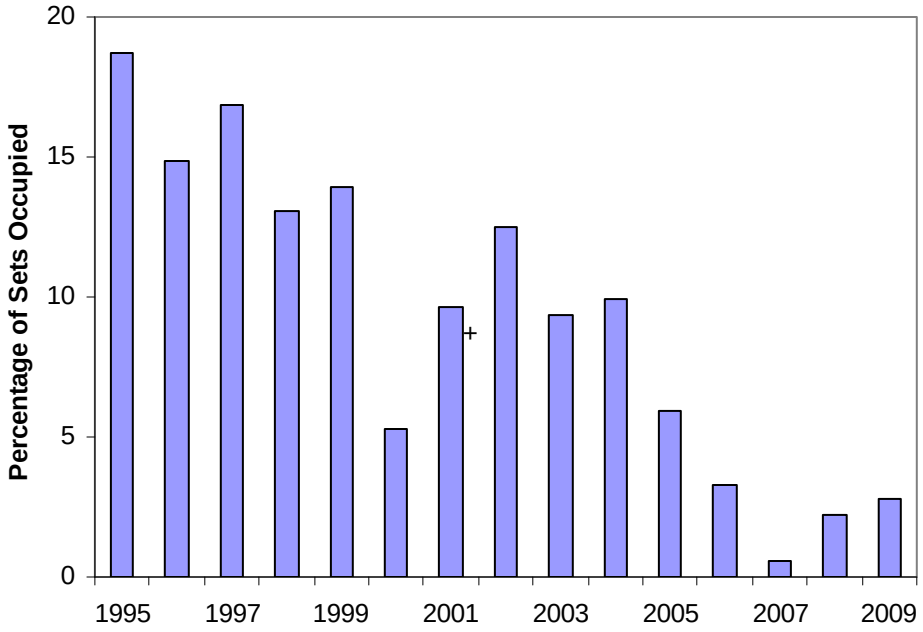


Figure 40. Percentages of sets containing of Atlantic wolffish in the ITQ industry OT survey in Div. 4X.

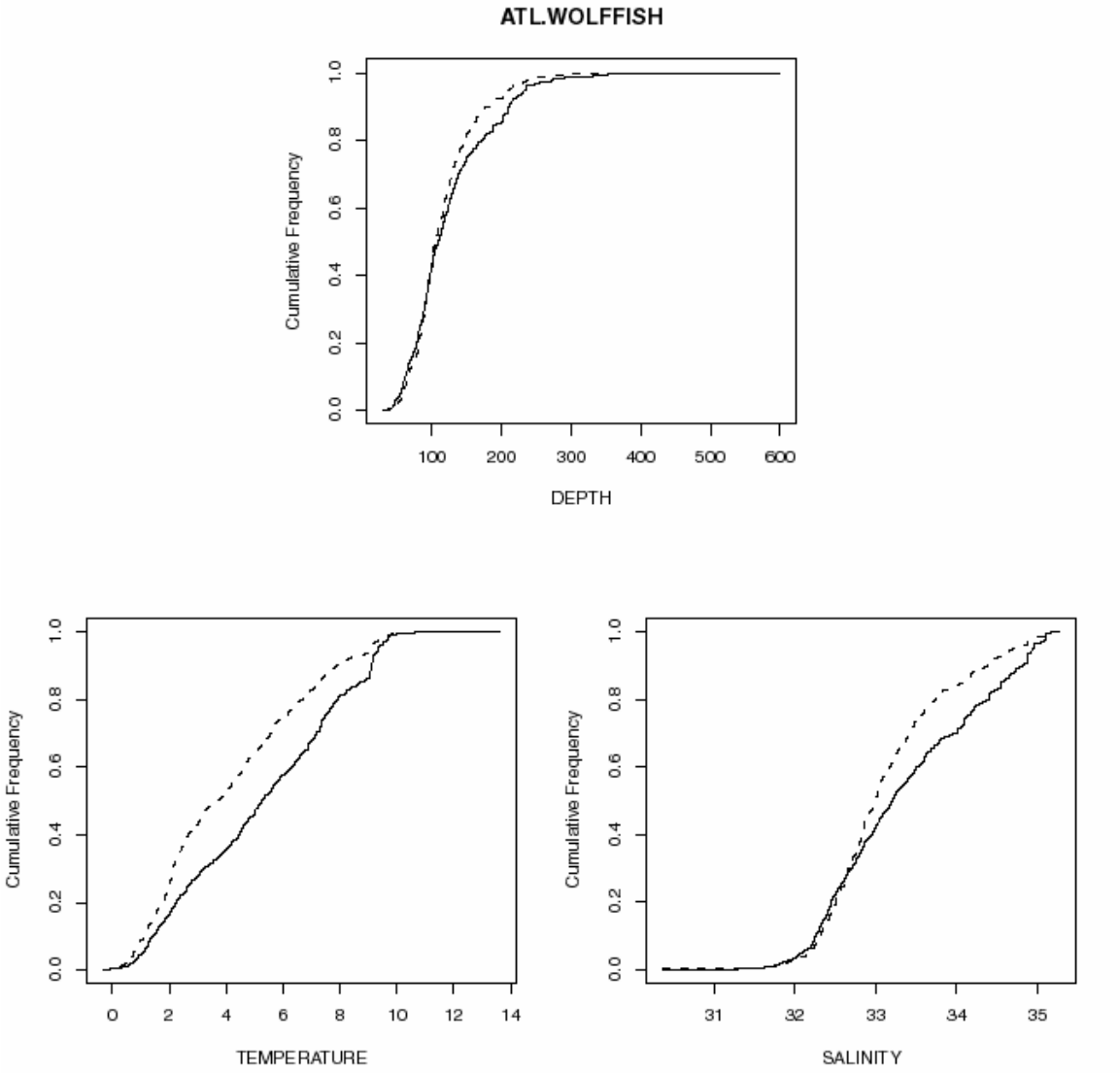


Figure 41. Cumulative stratified abundance of Atlantic wolffish compared to the cumulative stratified depth, temperature, and salinity from the summer RV survey. The solid line is the survey estimate while the dashed line is the estimate for Atlantic wolffish.

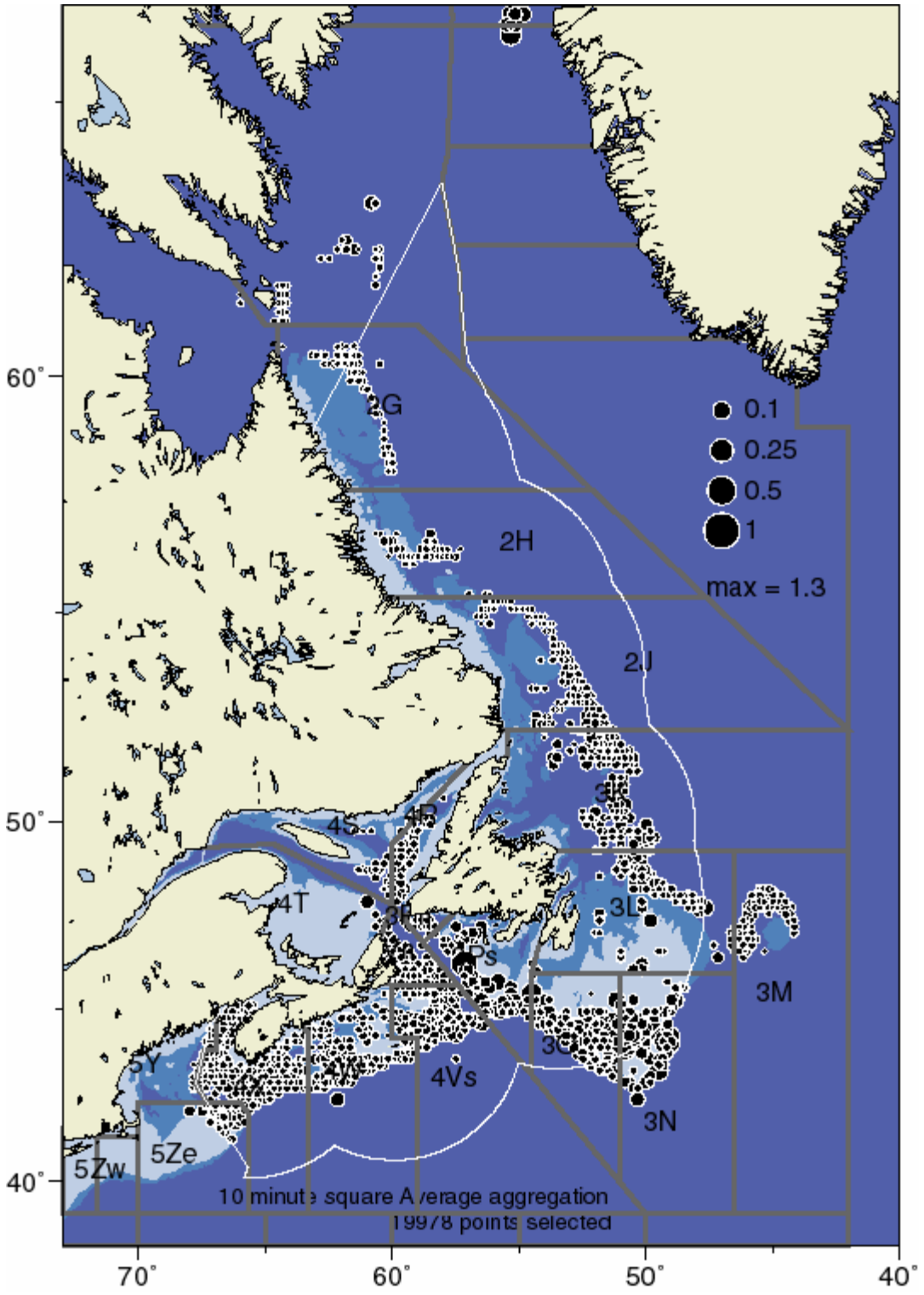


Figure 42. Reported locations of Atlantic wolffish from the Maritimes Observer Program, 1978-2009.

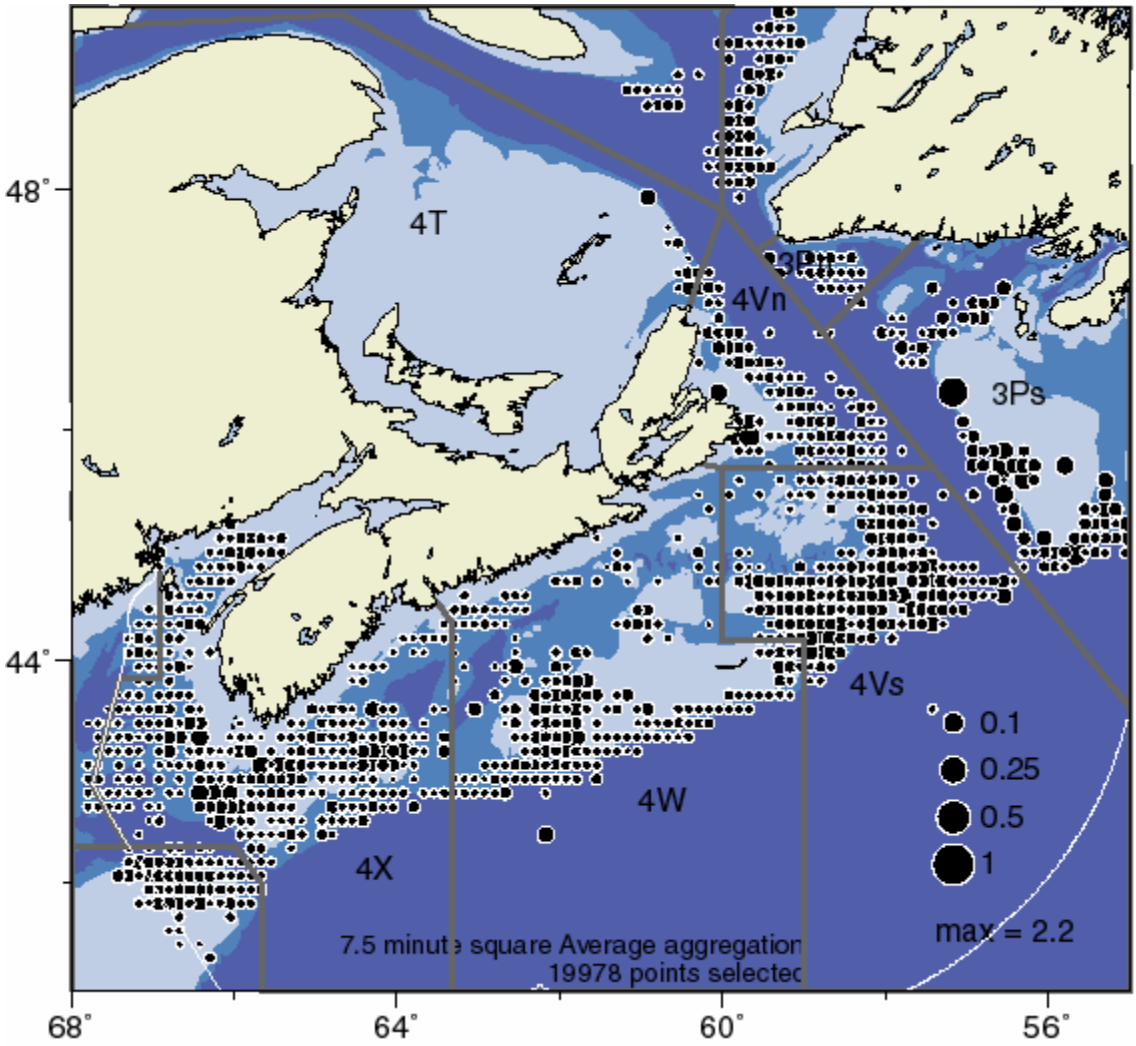


Figure 42b. Reported locations of Atlantic wolffish in Divisions 4VWX5YZ from the Maritimes Observer Program, 1978-2009. This plot shows the same data as the previous plot, but at a finer spatial scale.

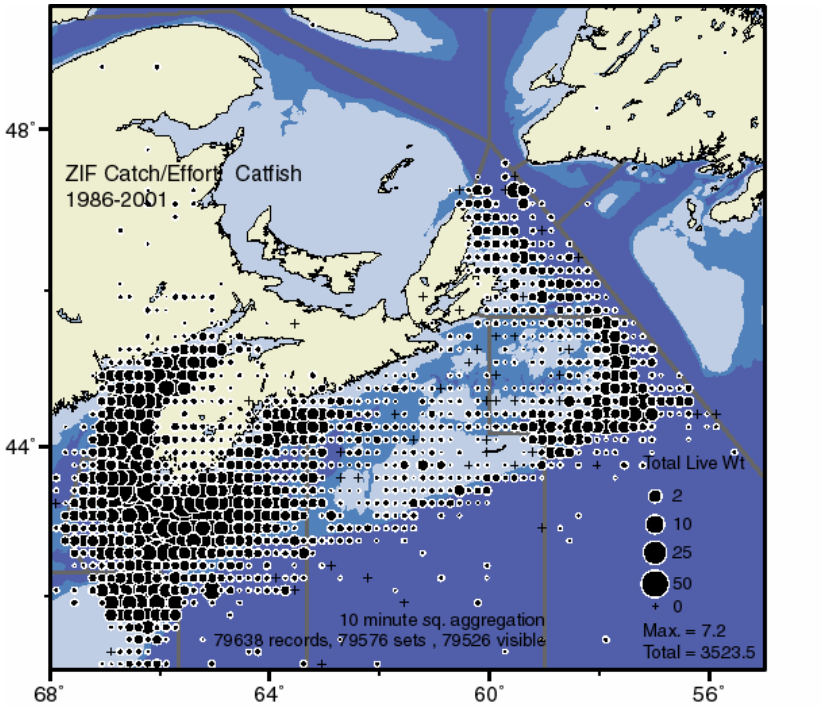


Figure 43. Location of commercial landings of wolffish from the Maritimes Region, 1986-2001.

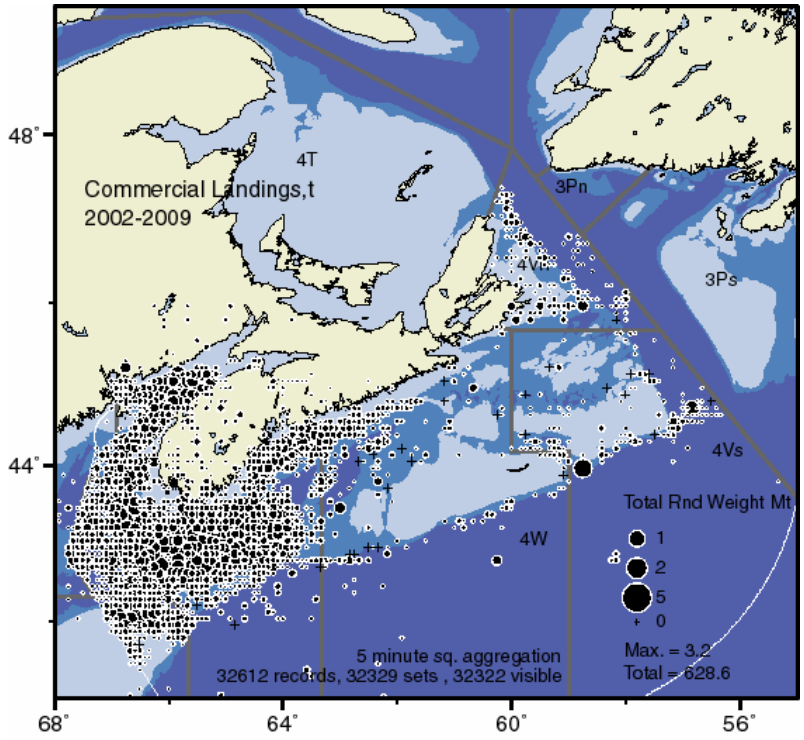


Figure 44. Location of commercial landings of wolffish from the Maritimes Region, 2002-2009.

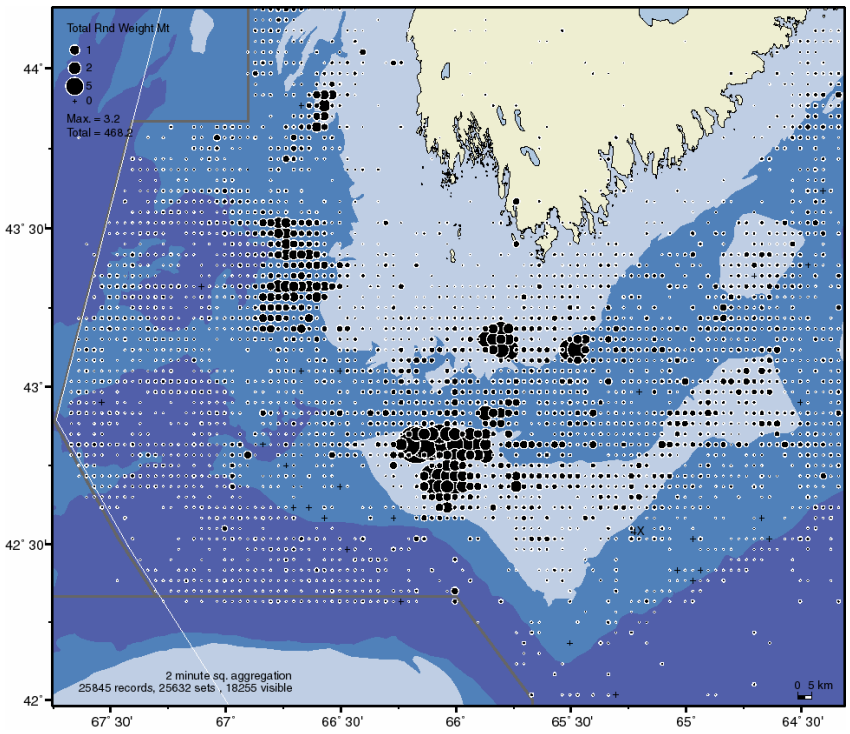


Figure 45. Locations of commercial landings of wolffish off southwest Nova Scotia, 2002-2009. This is based on the same data as the previous figure but at a finer scale and aggregation.

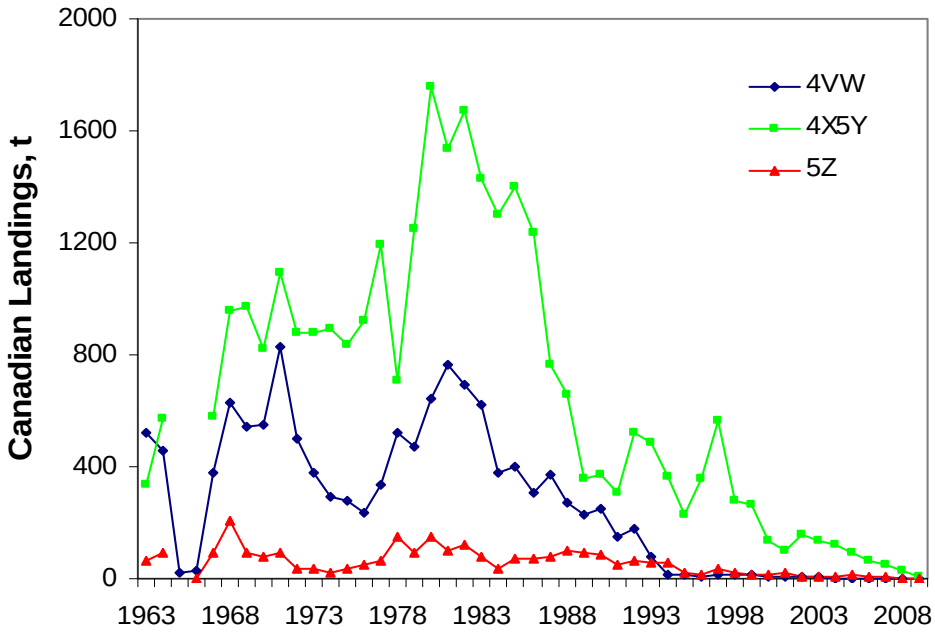


Figure 46. Commercial landings t by Canada of wolffish from Divs. 4VW, 4X5Y, and 5Z.

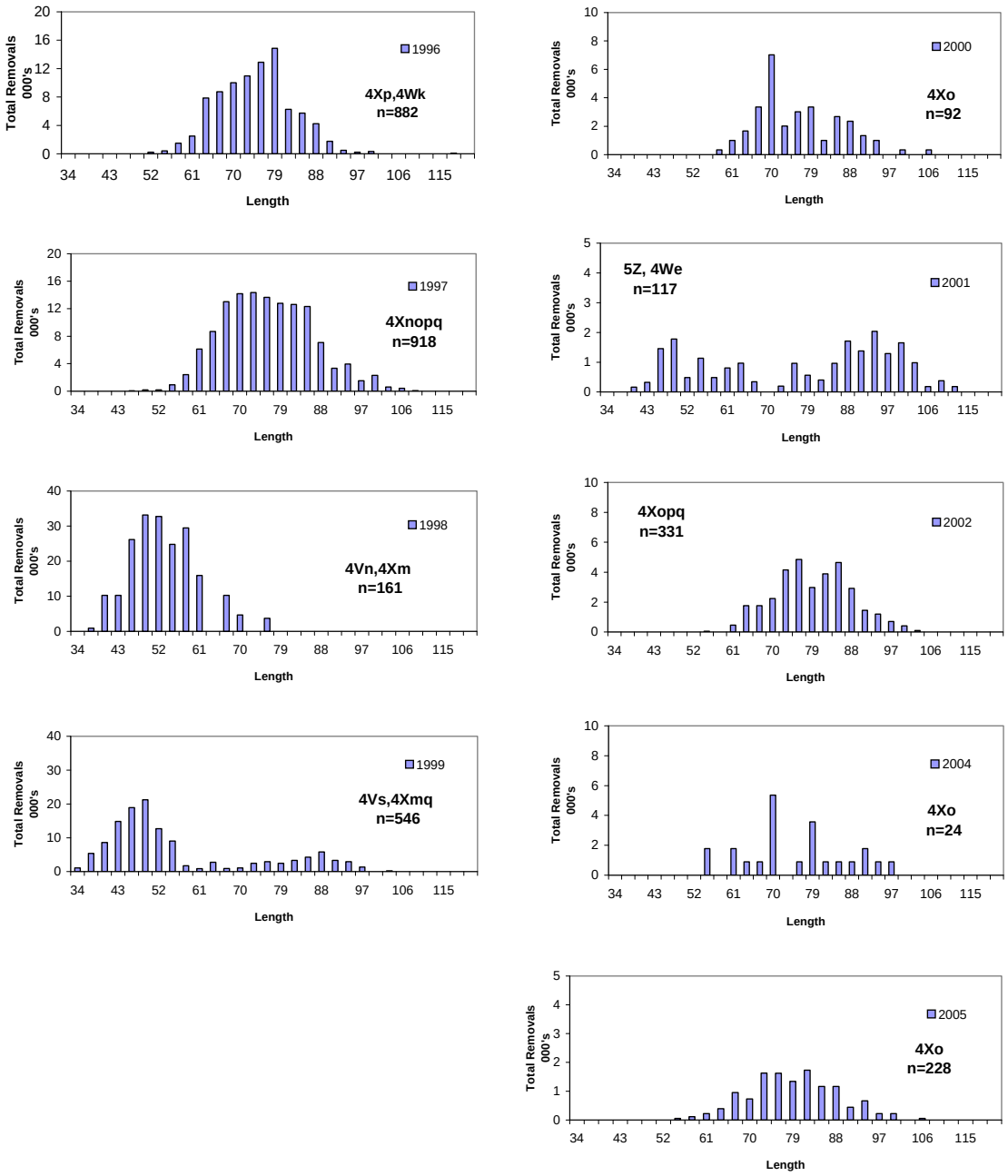


Figure 47. Annual estimated removals of wolffish based on commercial sampling on the Scotian Shelf, 1996 - 2005. No samples were available in 2003.

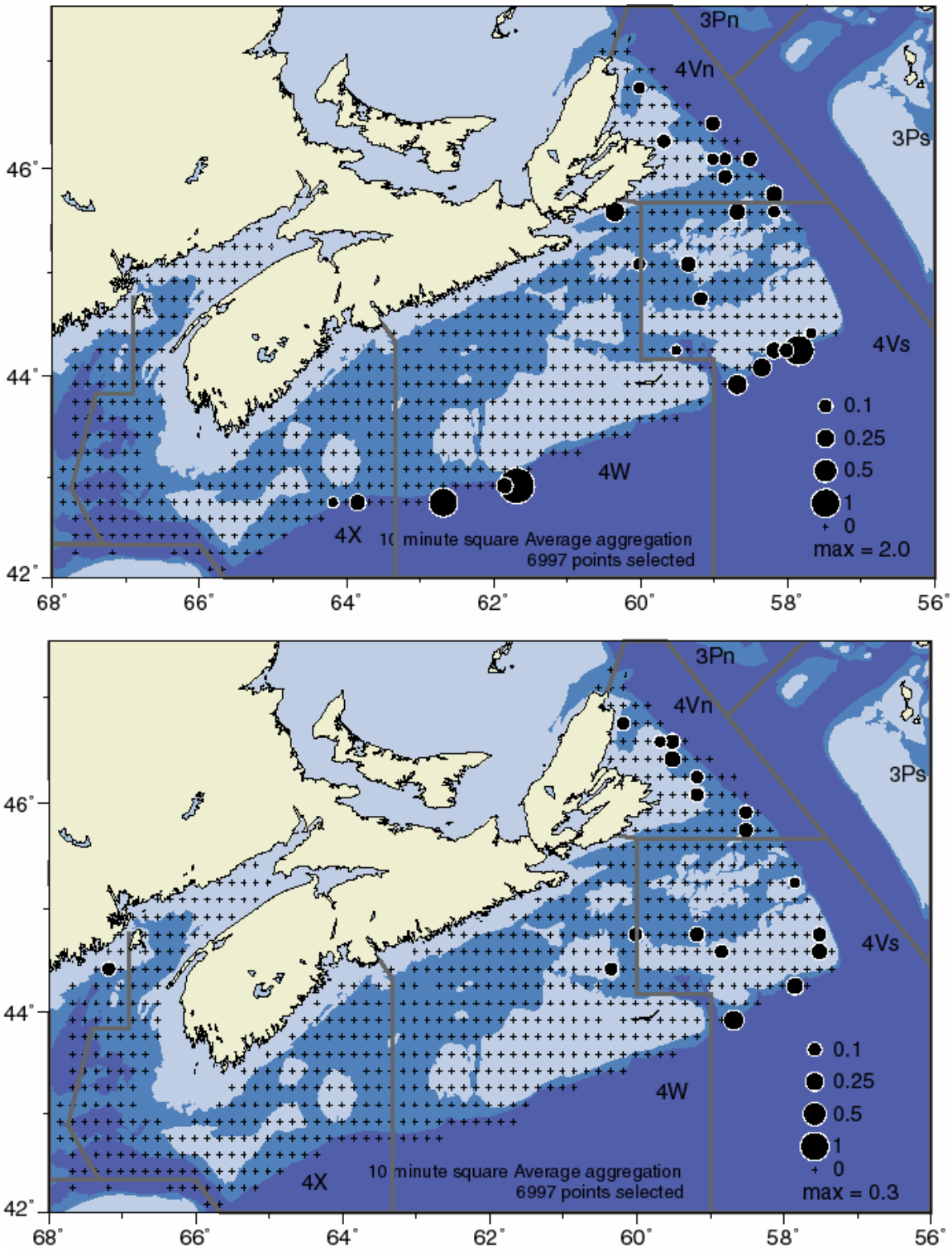


Figure 48. Distribution of Northern wolffish (upper panel) and Spotted wolffish (lower panel) as indicated by the summer RV survey, 1970-2010. Northern wolffish were caught in 0.4% of the sets while Spotted wolffish were caught in 0.3% of the sets.

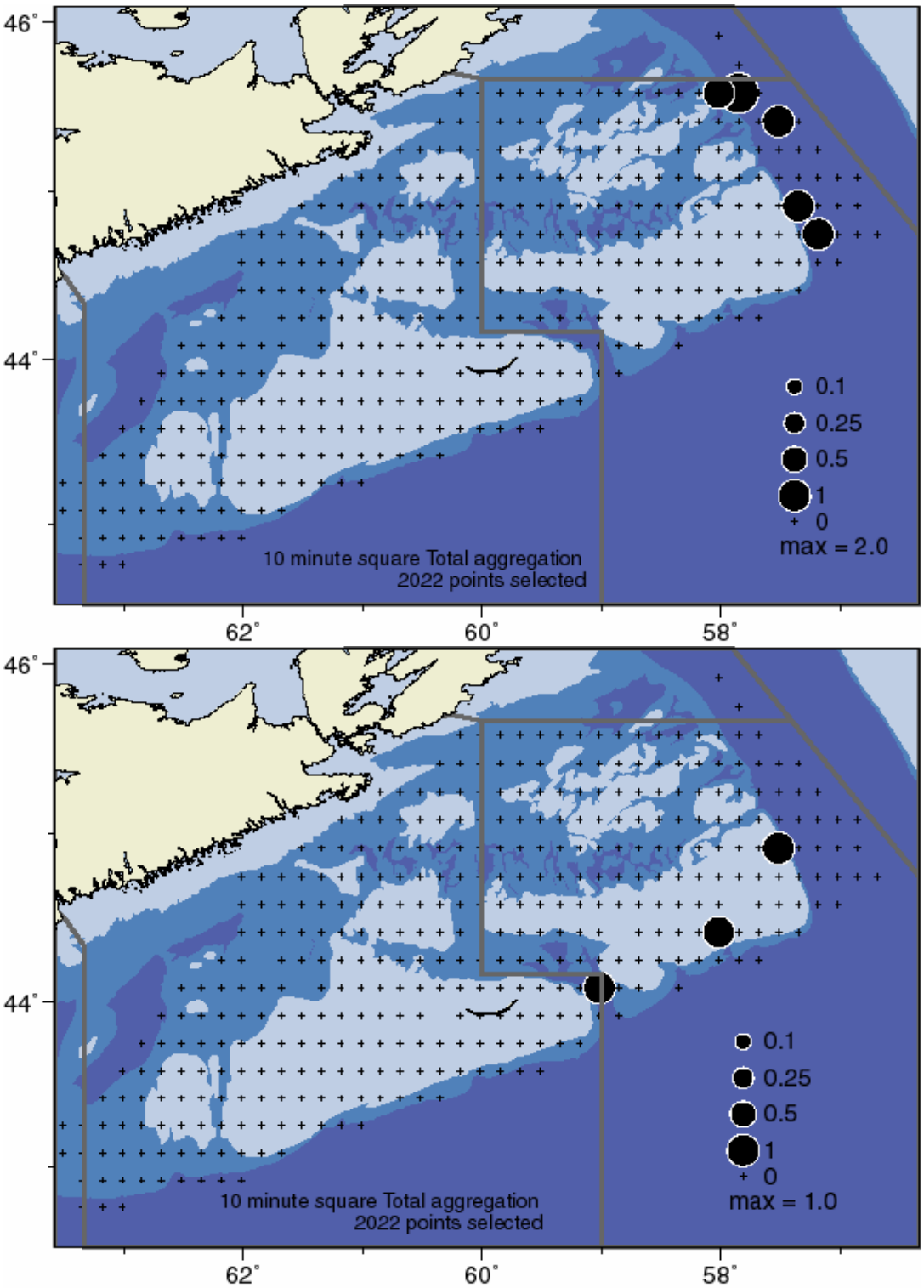


Figure 49. Distribution of Northern wolffish (upper panel) and Spotted wolffish (lower panel) from the 4VWCOD RV survey on the eastern Scotian Shelf, 1986- 2010. Note that during some of the years, coverage was incomplete and there were no surveys in 1998 and 2004.

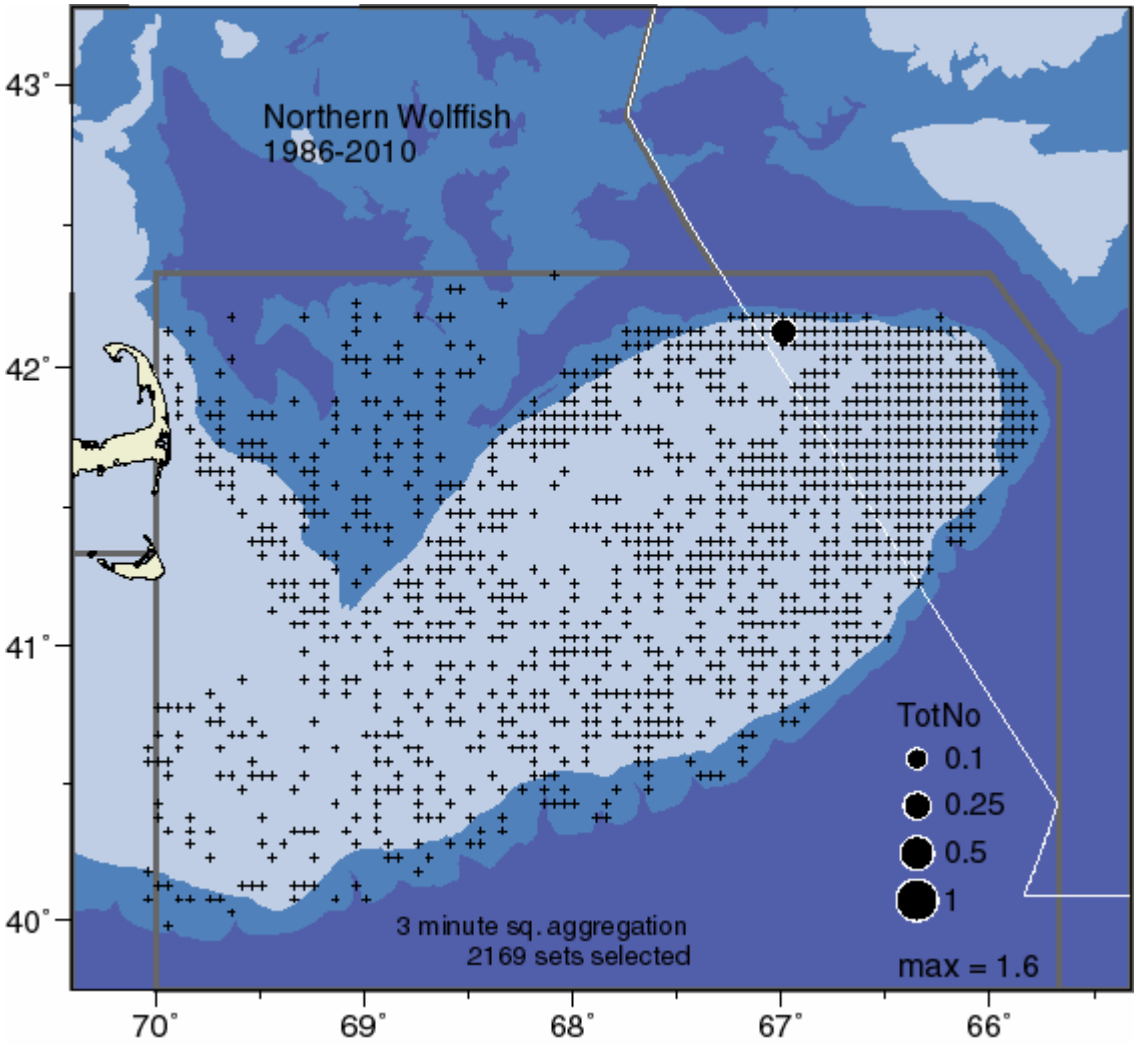


Figure 50. Distribution of Northern wolffish as indicated by the Georges Bank RV Survey, 1986-2009. No Spotted wolffish were caught during this survey series.

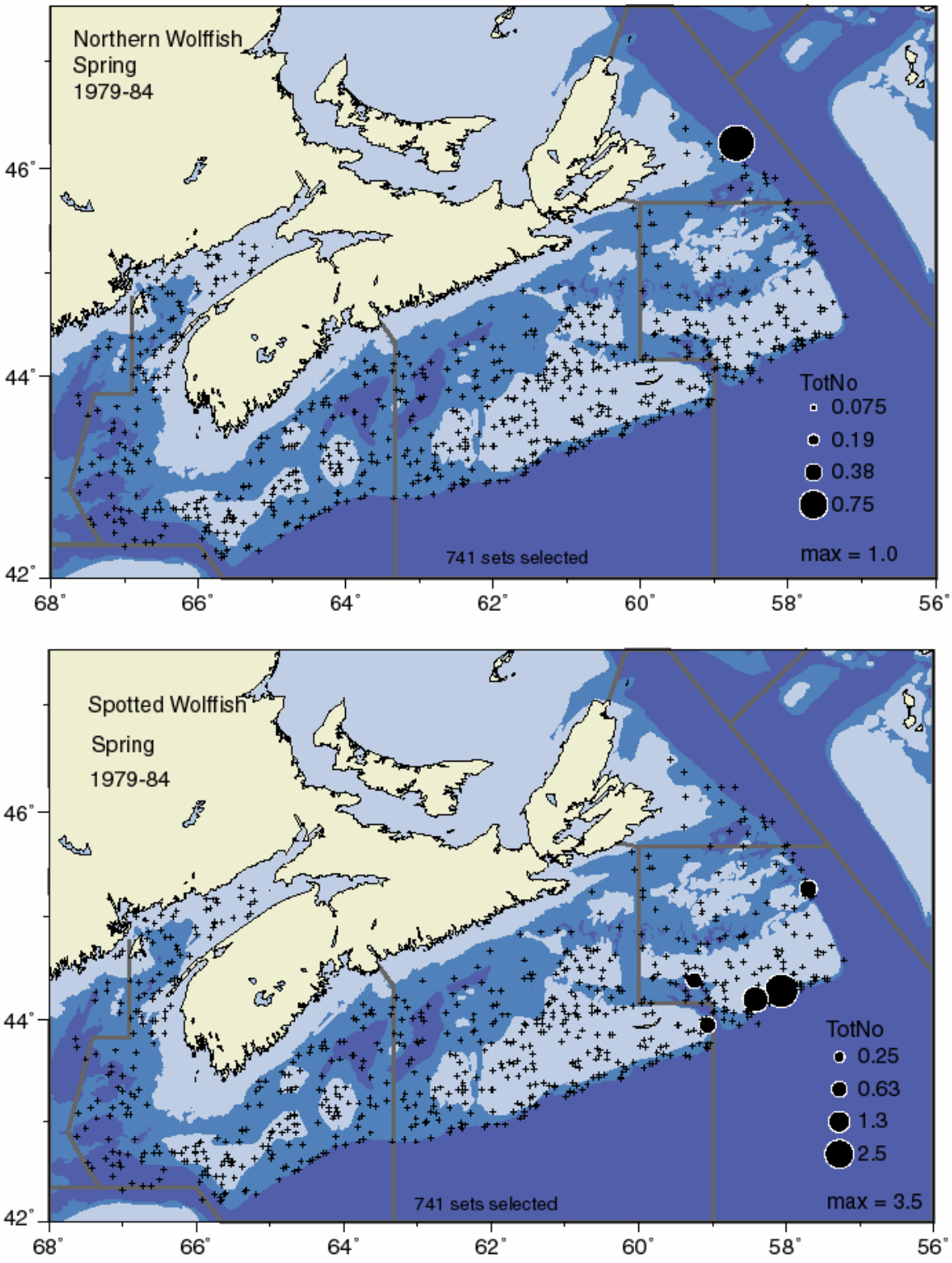


Figure 51. Distribution of Northern wolffish and Spotted wolffish as indicated by the Spring RV survey, 1979-1984.

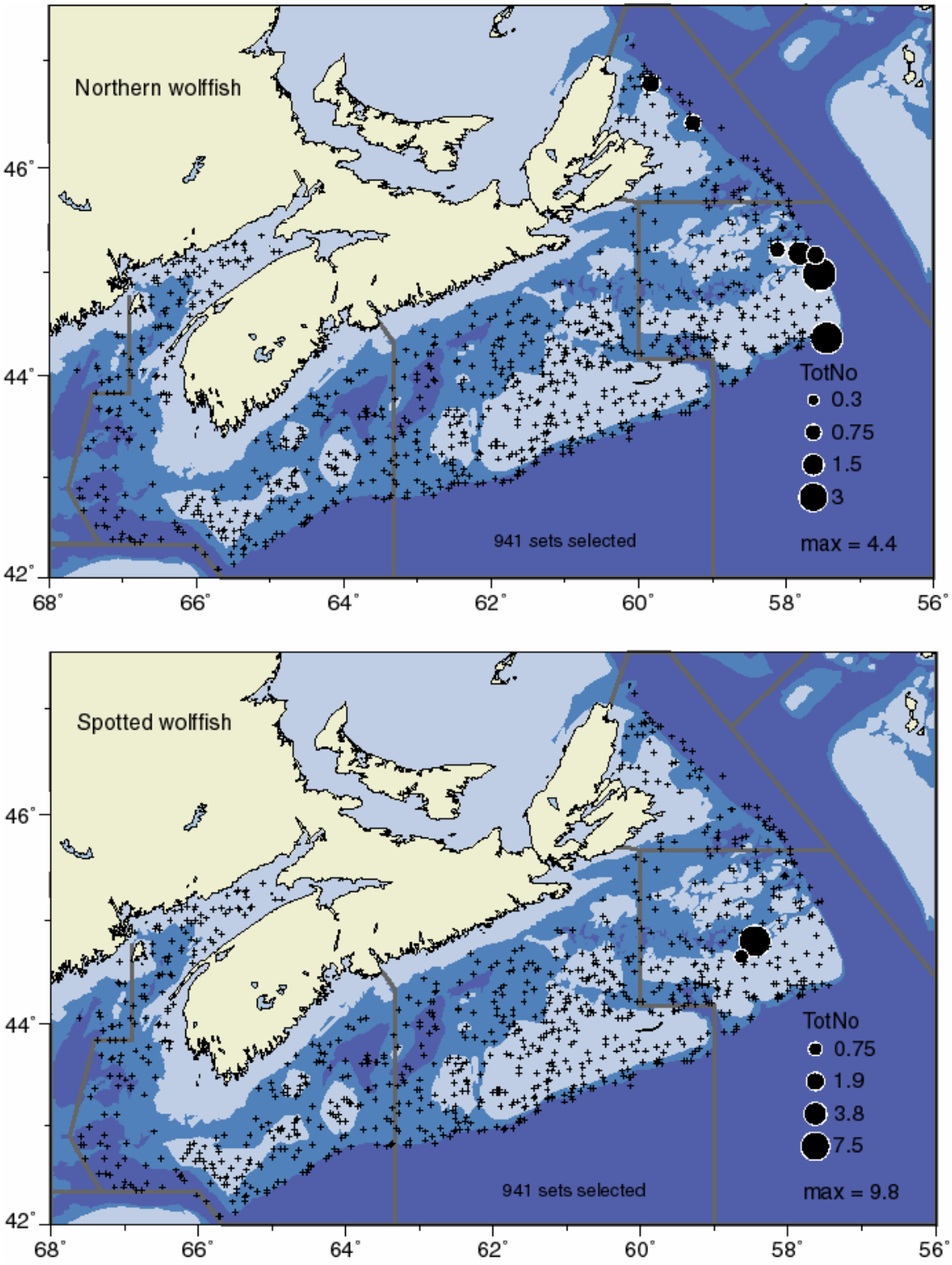


Figure 52. Distribution of Northern wolffish and Spotted wolffish as indicated by the Fall RV survey, 1978-1984.

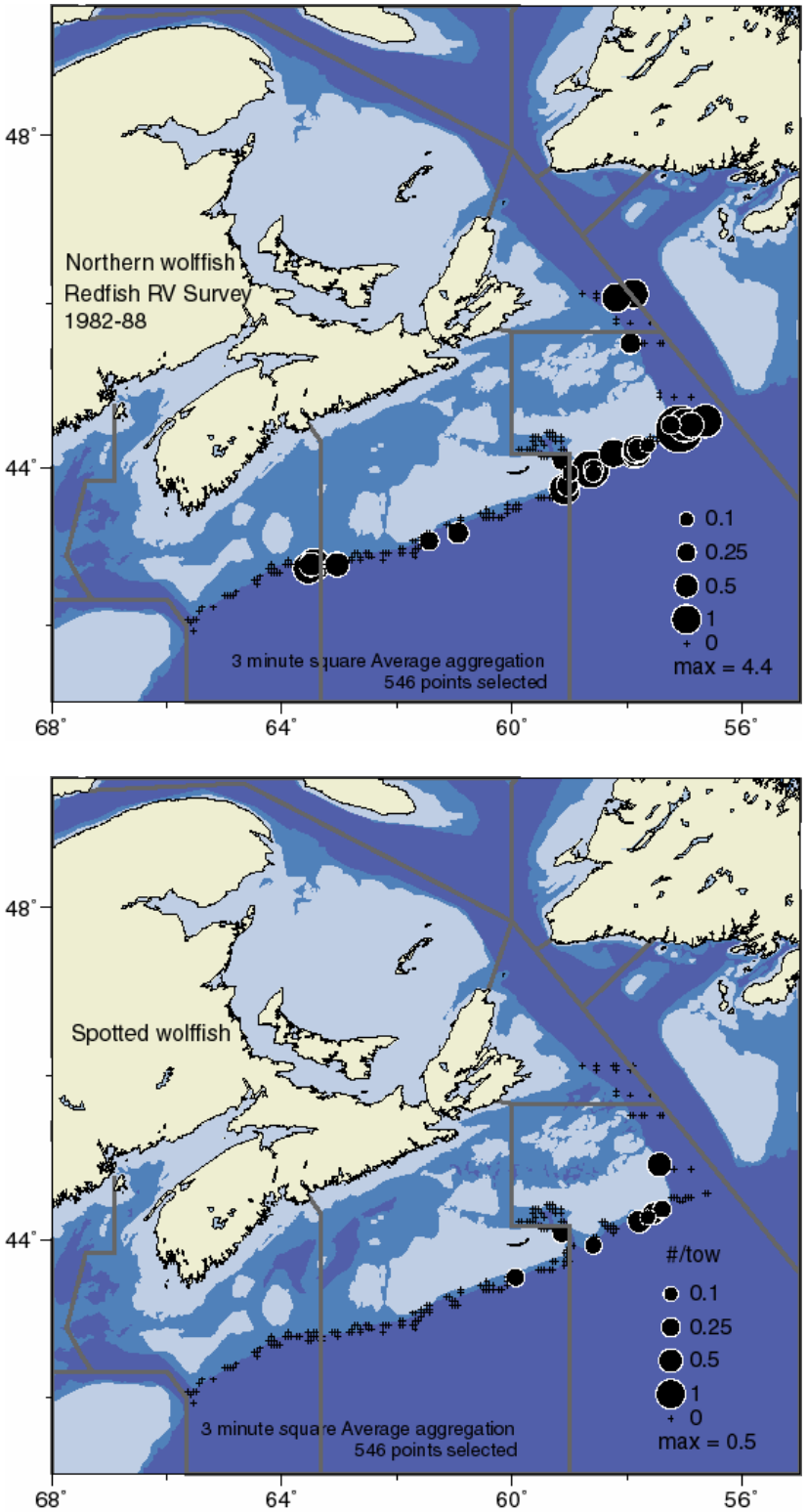


Figure 53. Distribution (#/tow) of Northern wolffish and Spotted wolffish, as indicated by the DFO Redfish Survey, 1982-1988.

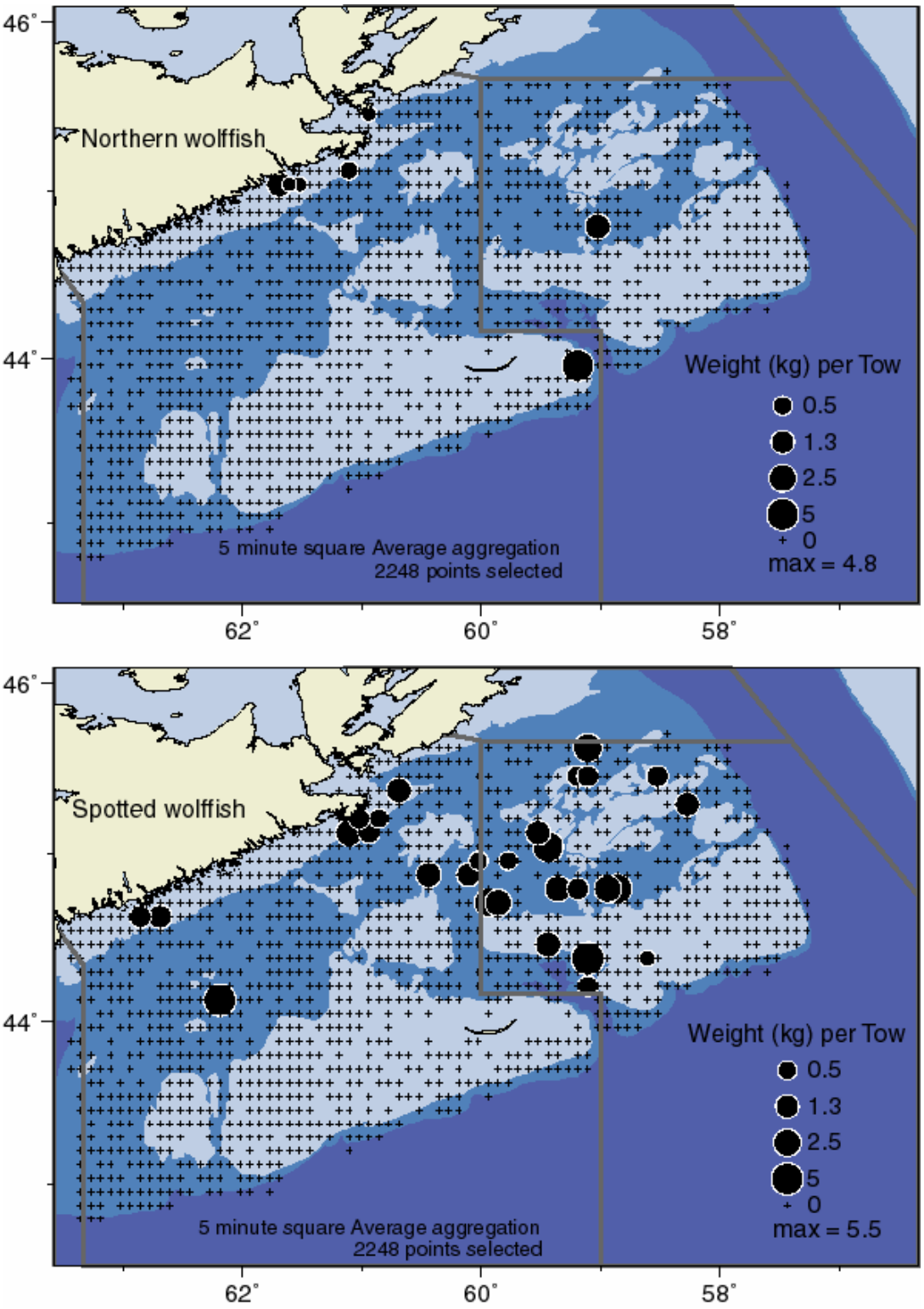


Figure 54. Distribution of Northern wolffish and Spotted wolffish (kg/tow), as indicated by the 4VsW Sentinel Survey, 1996-2009.

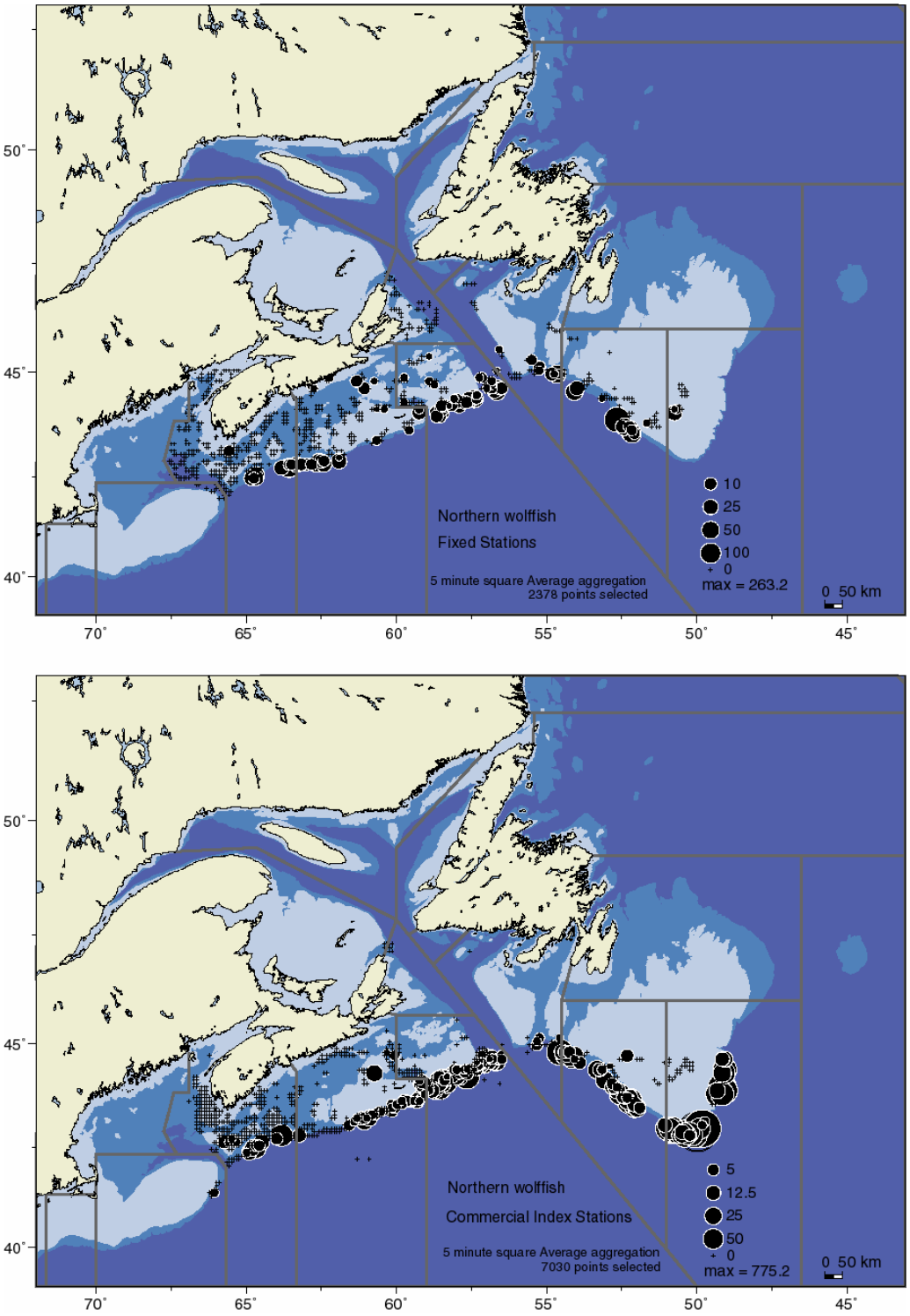


Figure 55. Distribution (kg/tow) of Northern wolffish as indicated by the Industry Halibut Longline Survey, 1998-2009. The upper panel is the fixed RV stations while the lower panel is the commercial index stations.

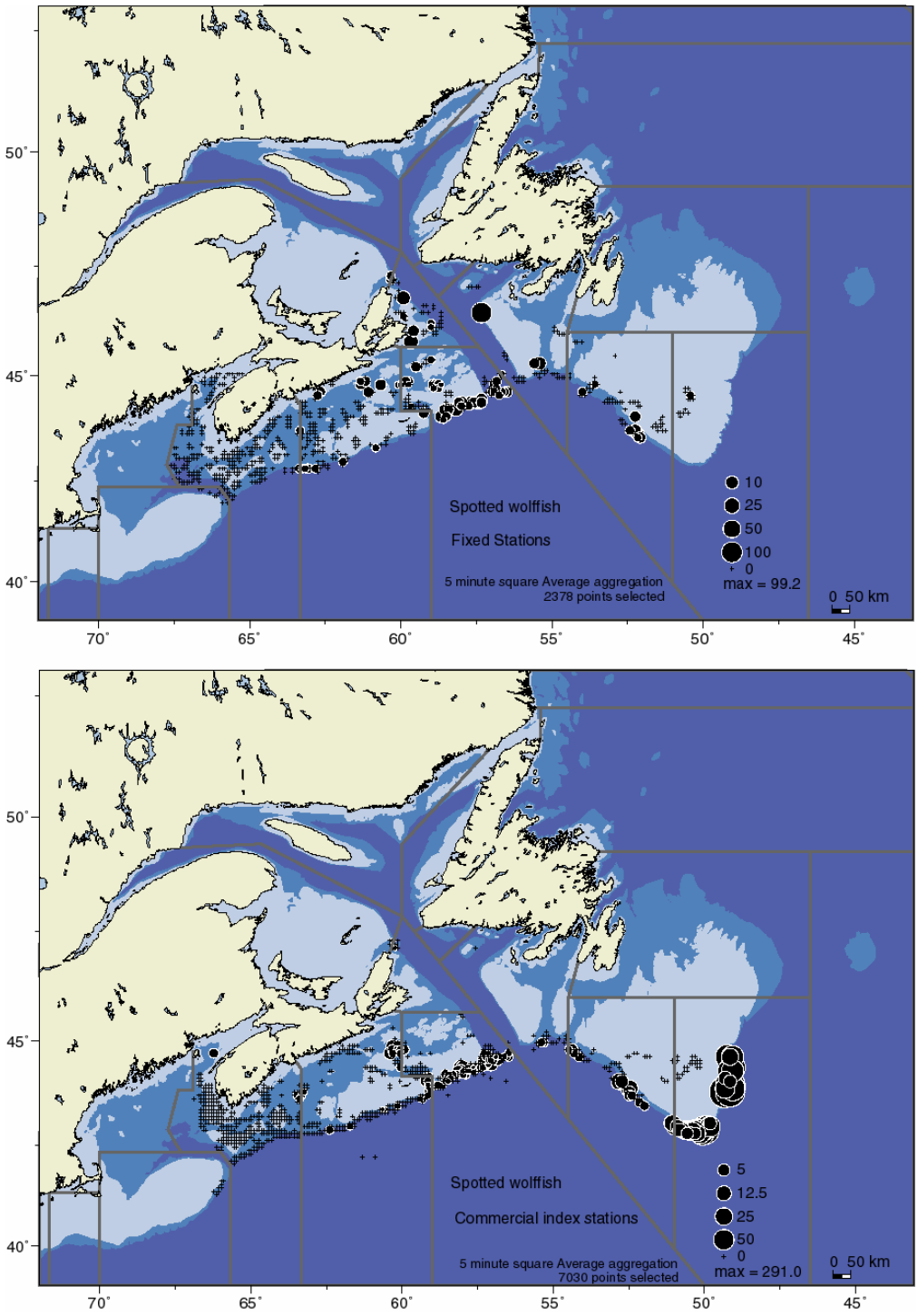


Figure 56. Distribution (kg/tow) of Spotted wolffish as indicated by the Industry Halibut Longline Survey, 1998-2009. The upper panel is the fixed RV stations while the lower panel is the commercial index stations.

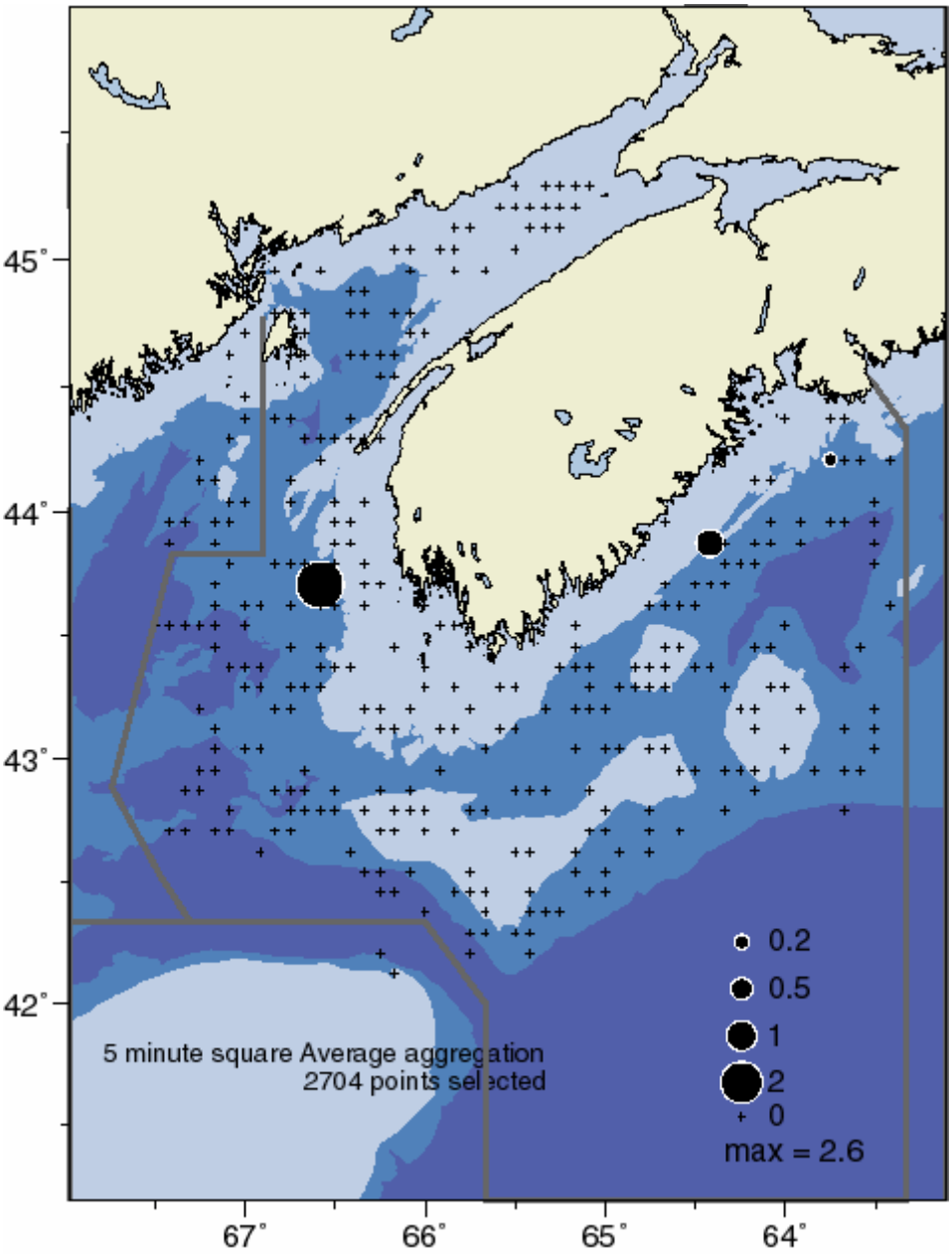


Figure 57. Distribution (kg/tow) of Northern wolffish as indicated by the ITQ industry survey, 1996-2009.

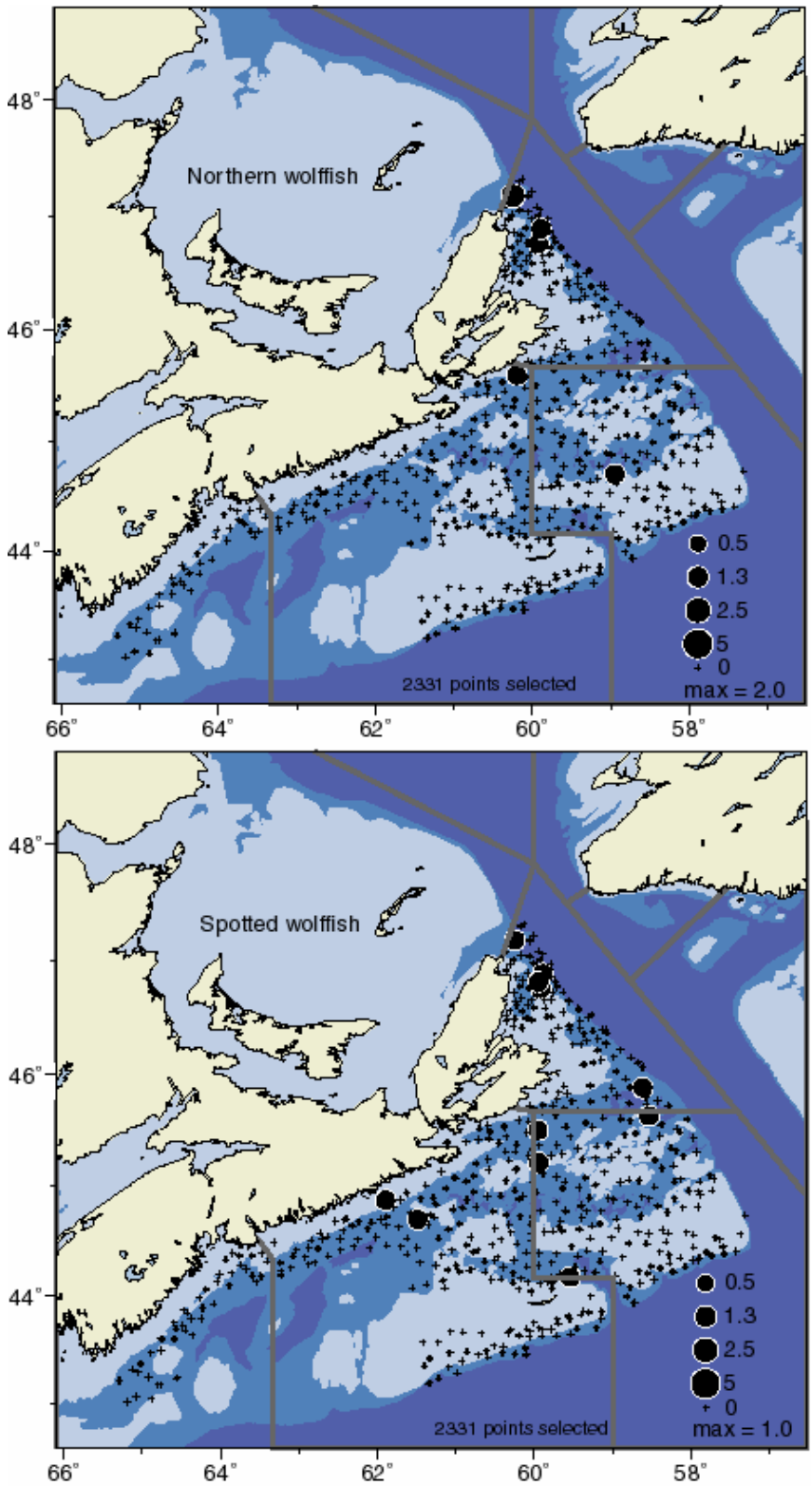


Figure 58. Distribution of Northern wolffish and Spotted wolffish (number/tow) as indicated by the Snow Crab Industry Survey, 2004-2009.

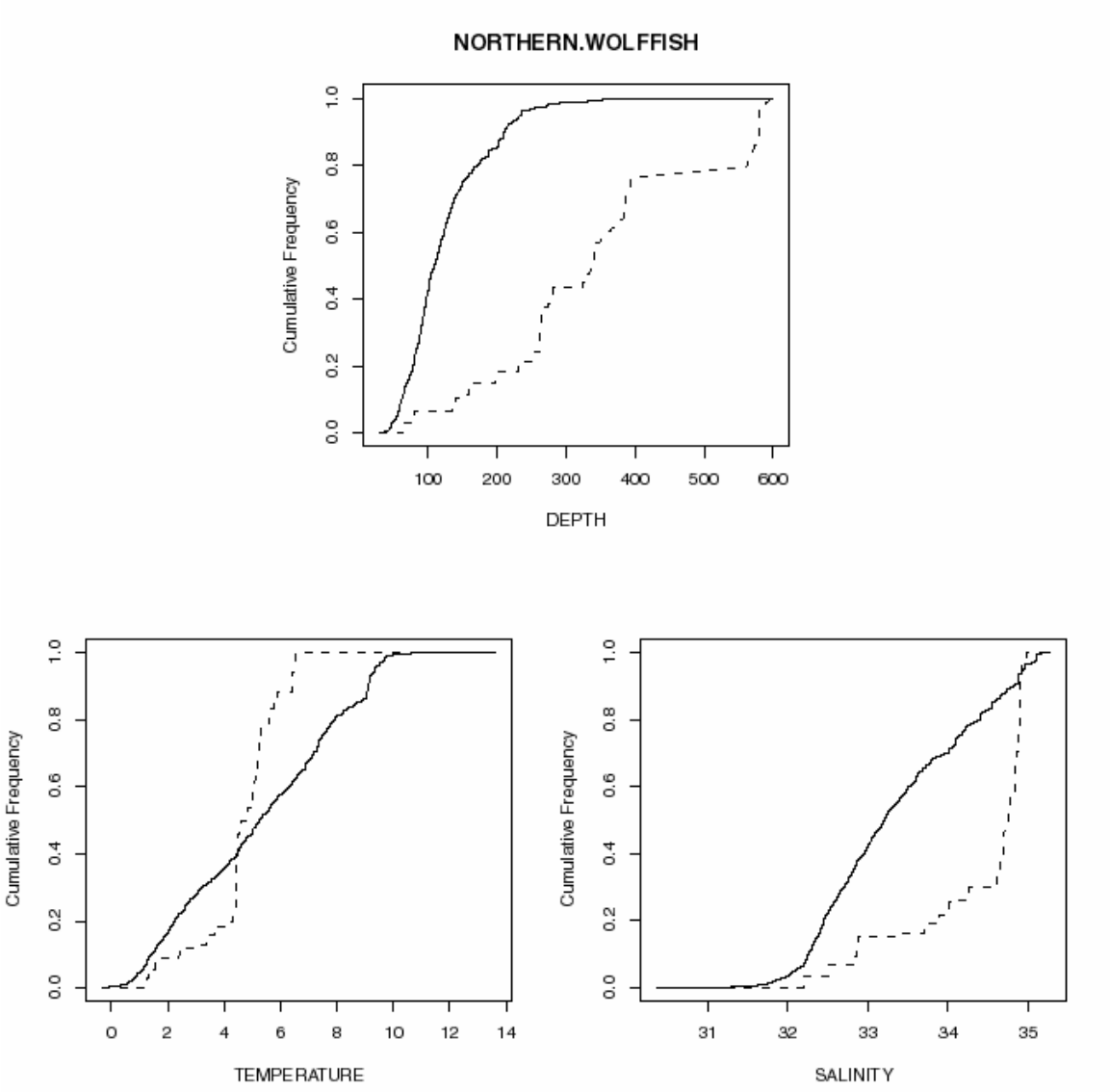


Figure 59. Cumulative stratified abundance of Northern wolffish compared to the cumulative stratified depth, temperature, and salinity from the summer RV survey. The solid line is the survey estimate while the dashed line is the estimate for Northern wolffish.

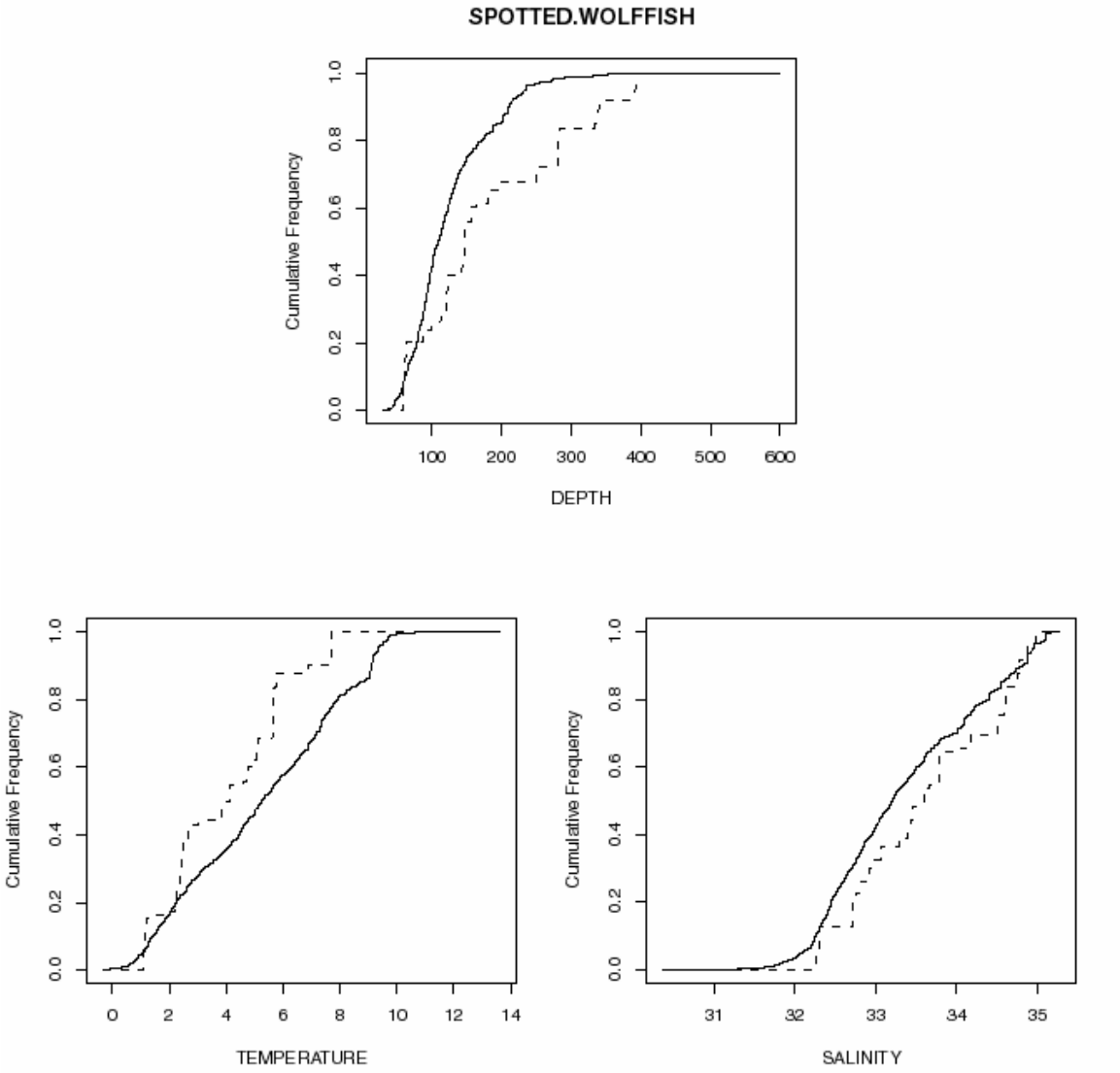


Figure 60. Cumulative stratified abundance of Spotted wolffish compared to the cumulative stratified depth, temperature, and salinity from the summer RV survey. The solid line is the survey estimate while the dashed line is the estimate for Spotted wolffish.

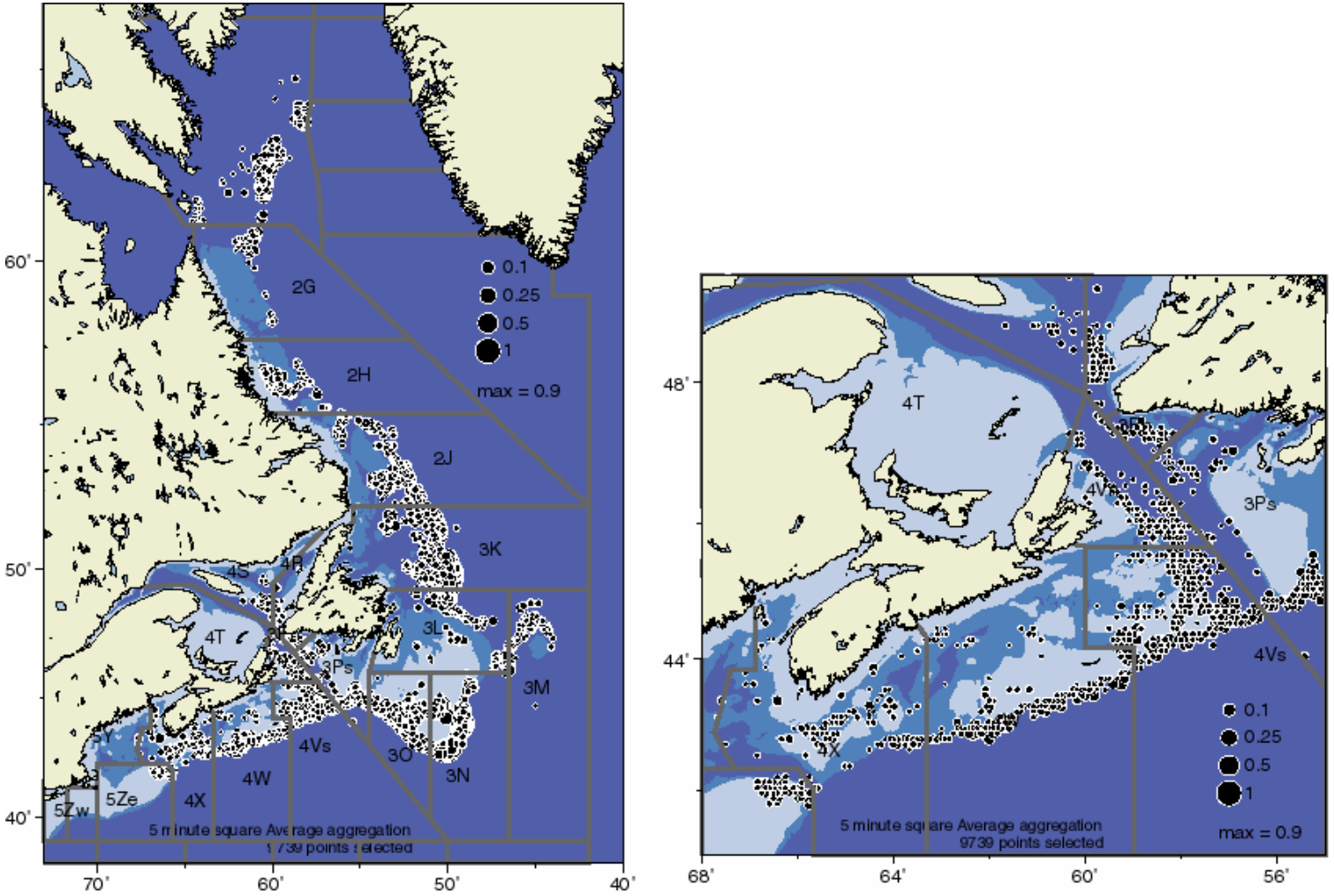


Figure 61. Distribution of Northern wolffish, tonnes, as indicated by the Maritimes Observer Program, 1978-2009. The right hand panel is the same data but at a finer scale.

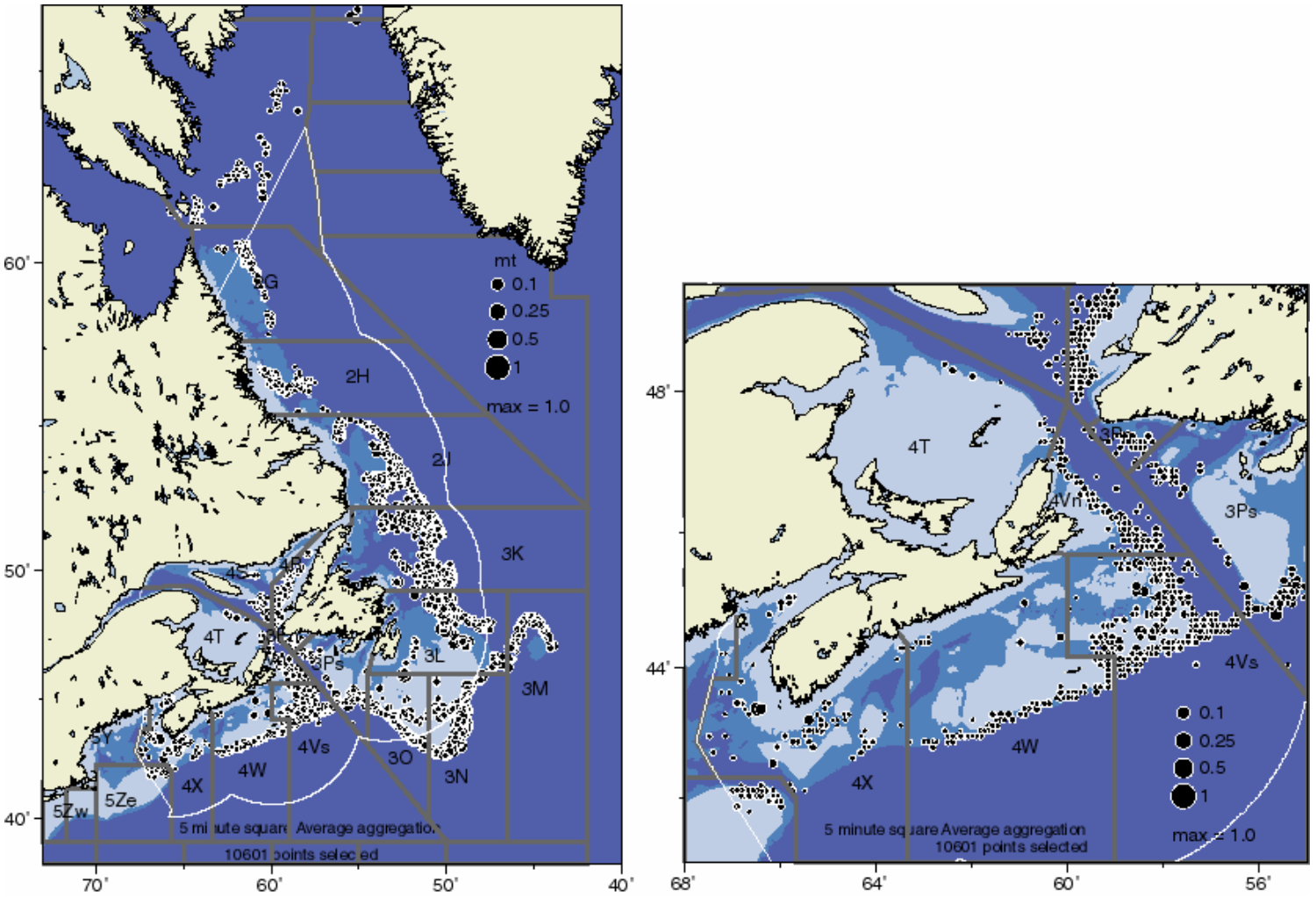


Figure 62. Distribution of Spotted wolffish, tonnes, as indicated by the Maritimes Observer Program, 1978-2009. The right hand panel is the same data but at a finer scale.