Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

Canadian Science Advisory Secretariat (CSAS)

Research Document 2013/024

Maritimes Region

Pre-COSEWIC Review of White Hake (*Urophysis tenuis*) for the Maritimes Region

James Simon and Adam Cook

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

June 2013

Canada

Foreword

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

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

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Simon, J., and Cook, A. 2013. Pre-COSEWIC Review of White Hake (*Urophysis tenuis*) for the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/024. iv + 82 p.

TABLE OF CONTENTS

ABSTRACT

Canadian Department of Fisheries and Oceans research vessel (RV) and industry surveys, USA RV surveys, and commercial landings data were examined to determine the status of white hake within the Maritimes Region with respect to the Committee on the Status of Endangered Wildlife in Canada criteria. Collectively, the research vessel surveys revealed a number of areas of concentration within the region, while the locations of white hake observed during industry surveys and commercial fisheries; suggest that these concentrations are not likely to be discrete. USA RV surveys indicate they are widespread in the deeper waters off Georges Bank, and these fish are contiguous with white hake in Canadian waters. Abundance of immature individuals on the Scotian Shelf has declined by 60% since the 1980s, while mature abundance over the same period has declined by 77%. The total number of immature and mature individuals in Northwest Atlantic Fisheries Organization Division 4VWX has averaged 12.1 and 7.4 million, respectively, since 2001. Although these estimates are about one half and one third, respectively, the observed estimates in the 1980s, they are similar to the estimates from the 1970s. Prior to 1996, white hake landings were unregulated. Landings on the Scotian Shelf varied between 3,000 and 8,000 t, but in 1999, a CAP on landings by gear and area, and bycatch limits were used to regulate catches. Subsequently, landings declined and have averaged 1250 t since 2006. In Div. 5Z, landings peaked near 1,700 t in 1993 and have declined to less than 100 t since 2004. Relative F (fishing mortality) on the Scotian Shelf has been stable, generally below 0.2 since 1973, and has been below the long-term mean since 2005.

Examen pré-COSEPAC de la merluche blanche (*Urophysis tenuis*) dans la région des Maritimes

RÉSUMÉ

On a examiné les relevés de l'industrie, ceux effectués par les navires de recherche de Pêches et Océans Canada et des États-Unis, et les données sur les débarquements commerciaux afin d'évaluer la situation de la merluche blanche dans la région des Maritimes par rapport aux critères du Comité sur la situation des espèces en péril au Canada. Globalement, selon les relevés des navires de recherche, il existe un certain nombre de concentrations de cette espèce dans la région. Cependant, les emplacements où la présence de la merluche blanche a été signalée par les relevés de l'industrie et de la pêche commerciale semblent indiquer que ces concentrations ne sont probablement pas séparées. D'après les relevés de navires de recherche des États-Unis, l'espèce est très répandue au large du banc de Georges dans les eaux plus profondes et contiguës aux eaux canadiennes. L'abondance de poissons immatures sur le plateau néo-écossais a chuté de 60 % depuis les années 1980 tandis que l'abondance de poissons matures est diminuée de 77 % au cours de la même période. Le nombre total de poissons immatures et matures dans la division 4VWX de l'Organisation des pêches de l'Atlantique Nord-Ouest est en moyenne respectivement de 12,1 millions et de 7,4 millions depuis 2001. Bien que ces estimations représentent environ la moitié et le tiers des valeurs observées dans les années 1980, elles coïncident avec les valeurs des années 1970. Avant 1996, les débarquements de merluche n'étaient pas réglementés. Les débarquements sur le plateau néo-écossais variaient entre 3 000 et 8 000 t, mais en 1999 on a établi un plafond de débarquements par engin de pêche et par zone et des limites de prises accidentelles afin de réglementer les prises. Par la suite, les débarquements ont diminué et s'élèvent en moyenne à 1 250 t depuis 2006. Dans la division 5Z, les débarquements étaient à leur maximum en 1993 (1 700 t); ils ont diminué depuis pour passer en dessous de la barre des 100 t après 2004. Le taux relatif de mortalité par la pêche (F) sur le plateau néo-écossais s'est maintenu stable, généralement en dessous de 0,2 depuis 1973 et en dessous de la moyenne à long terme depuis 2005.

INTRODUCTION

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has called for the evaluation of the status of white hake (*Urophysis tenuis*), in the western Atlantic within the Canadian Zone. As the department responsible for marine species, the Department of Fisheries and Oceans (DFO) is required to summarize available information on this species.

In 2004, regional information on the status of white hake was presented at a National Assessment Process (NAP) held in Halifax, Nova Scotia, Canada, by DFO. No proceedings or research documents are available from this meeting, but the regional information was provided to the COSEWIC author at that time. The draft document was not accepted by COSEWIC and DFO has been asked to update the regional information.

White hake was initially assessed in the Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX/5 in 1996 (Fowler et al., 1996) with subsequent assessments in 1998 (Fowler, 1998), 2001 (Bundy et al., 2001), with the last assessment in 2005 (Bundy and Simon, 2005). Bundy and Simon (2005) suggested that the stock structure in Div. 4VWX and 5Zc (Figure 1) might be complex with several sustaining components. White hake, in Subdiv. 4Vn slope waters were contiguous with fish in Div. 4T, while white hake in the Bay of Fundy and approaches were contiguous with fish from the Gulf of Maine. They assessed white hake as three components, Subdiv. 4Vn, Div. 4VsW and 4X. It was concluded that in Subdiv. 4Vn and Div. 4VsW the status of the stock was poor and required rebuilding. In Div. 4X, there had been a general decrease in abundance of white hake and that unless there was good recruitment over the next few years that current levels of catch may be unsustainable (Bundy and Simon, 2005). Those conclusions were made in the context of ongoing fisheries and COSEWIC does not use these criteria when determining the status of a species with respect to species at risk.

This document represents a re-examination of the DFO research vessel (RV) and industry surveys, extends the analysis to include USA RV surveys, and examines commercial landings and sampling information within the Maritimes Region. White hake are examined in detail with distributional plots, trends in abundance by immature and mature length categories, and area occupied presented where possible. Predator prey information for white hake is also presented.

METHODS

BIOLOGICAL BACKGROUND

Fowler et al. (1996), Bundy et al. (2001), and Bundy and Simon (2005) previously reviewed the biology of white hake on the Scotian Shelf and Bay of Fundy.

White hake (*Urophycis tenuis*) are bottom dwelling fish found in areas with a mud bottom from the southern Grand Banks to the mid-Atlantic Bight (Scott and Scott, 1988). White hake are pelagic spawners that are highly fecund, having several million eggs per female. The eggs and larvae drift in the upper 50m for about a month, and then the larvae metamorphose into juveniles in the pelagic zone and subsequently migrate into the shallow coastal zone. At an age of about two months, the small pelagic juveniles (approximately 4 cm) move to the bottom in shallow water. They appear to stay in shallow water for a year and then migrate to the offshore

adult distributional area at some time during their second year. In the Bay of Fundy, they are about 10 cm in length in August of the first year, and 30 cm in length at age 1 (August).

Growth rate varies with area (Bundy and Simon, 2005). In the Gulf of Maine area, length at 50% maturity has been reported to be 35 cm with an age of 1.5 years (O'Brien et al., 1993). On the Scotian Shelf, L_{50} was reported to be 45 cm with an age of approximately 3.5 years (Bundy and Simon, 2005). Bundy and Simon (2005) compared the growth rates from three periods and areas. Although there were minor differences in growth reported, these differences were not considered large. Growth was slightly slower on the Scotian Shelf than the Bay of Fundy and these were reported to be slower than on Georges Bank.

The spawning patterns and behaviour of white hake on the Scotian Shelf and in the Bay of Fundy, as outlined by Fowler et al. (1996) and Bundy et al. (2001) are not well understood. Fahay and Able (1989) suggested that there may be two stocks of white hake with separate spawning schedules: one occurring in the late spring/early summer in shelf slope waters from the Scotian Shelf and Georges Bank down to New England; and the second a late summer/early autumn spawning population occurring in the Gulf of St. Lawrence and on the Scotian Shelf. White hake on the eastern Scotian Shelf may be derived from 4T/Laurentian Channel early summer spawning (Markle et al., 1982). Thus, in total, there may be three spawning origins for white hake on the Scotian Shelf.

Hare et al. (2001) have shown that white hake off the northeastern USA spawn offshore. They found small white hake larvae (<5 mm) off the Middle Atlantic Bight in May and June. Such small larvae were not caught on the shelf. The authors hypothesized that white hake larvae actively cross the shelf/slope front to reach nearshore estuarine juvenile habitats. A similar mechanism may occur for the spring/early summer offshore spawning of white hake to the Scotian Shelf.

Data from the Scotian Shelf Icthyoplankton Surveys (SSIP) data (1977-1982) support the studies above. Juveniles occurred from May to November, with June to September being the peak months. Major concentrations occur around the northeast edge of Georges Bank from June through August, and just north of the slope in 4WI from August to October. A northerly trend in the timing of spawning as waters warm up might be inferred. Secondary concentrations shoreward of the slope on the western shelf in July are characterized by larger fish than were caught near Georges Bank in June.

There is some evidence of nursery areas for juvenile white hake in the inshore areas of the Scotian Shelf. Simon and Campana (1987) observed 0 or 1 age group white hake in the inshore areas of Div. 4X during an inshore trawl survey of southwest Nova Scotia. Some small fish are caught inshore in the Bay of Fundy in July and August, and a recent DFO Fishermen Scientist Research Society (FSRS) Inshore Ecosystem Study observed white hake less than 7 cm in inshore areas off Cape Breton and the southern shore of Nova Scotia (A. Bundy, DFO, personal communication). O'Conner (2008) caught juvenile white hake using a beach seine in most of the sampled bays from Chedabucto Bay to St. Mary's Bay. There are also anecdotal reports that the Bras D'Ors Lakes in Cape Breton are a nursery area (T. Lambert, DFO, pers. comm.). Markle et al. (1982), on the basis of SSIP data on the distribution of pelagic juveniles around the coast of Cape Breton from May to July (and the lack of pelagic juveniles inshore on the southern half of Nova Scotia), have suggested that these fish may originate in the southern Gulf of St. Lawrence.

OVERVIEW OF CANADIAN RV, INDUSTRY/SCIENCE, AND USA SURVEY INFORMATION

DFO Research Vessel Surveys

Maritimes Region (Div. 4VWX, 5Y, and Subdiv. 5Ze)

The DFO summer survey has been conducted annually on the Scotian Shelf (Div. 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 white hake. 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. Since 2009, the survey has been 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. Deepwater strata (365-549m) in the Laurentian Channel were added to this survey in 1993 and although not included in abundance trend analysis, the data from these strata are included in the distribution maps.

The February/March RV survey on Georges Bank (Subdiv. 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 white hake 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 (Figure 2).

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 900m.

Canadian Industry/Science Surveys

Five 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 4Vn Sentinel Survey is a stratified random longline survey and primarily covers the summer RV strata 440-442 (Figure 2), as well as an area closer to the shore. The survey has been conducted since September of 1994 with approximately 56 sets annually. Since 1994, there have been a number of other more restricted surveys in the area by the same participants using a variety of survey designs. The July survey that was conducted using the same survey design from 1995-1997 is used as a comparison with the September survey (Lambert, 1995).

The 4VsW Sentinel Survey is a stratified random longline survey conducted by industry participants. The series began in the fall of 1995 and includes all areas surveyed by the RV survey in Div. 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 Longline Survey began in 1998 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 and Div. 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 white hake since 2004.

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 summer RV survey gear and, therefore, has potentially higher catchability of white hake. The area sampled is similar to the RV survey except for an area inshore of the 50fm line that is also surveyed.

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. The *Henry B. Bigelow,* using a more

efficient 400x12 four-seam rockhopper trawl replaced the *Albatross IV* during the 2008-2011 spring surveys and the 2009-2010 fall surveys. Tow distance, duration, and towing speed were modified from those used previously. A conversion factor of 0.406 was applied to white hake catches during the Bigelow surveys to convert to 'Albatross units' (Miller et al., 2010).

POPULATION SIZES AND TRENDS

Estimates of minimum trawlable abundance were calculated for white hake 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 the catchability of the survey gear is much less than one. Minimum total population estimates were calculated from the research vessel surveys for Subdiv. 5Zc and Div. 4VWX from the Canadian and USA surveys. Minimum trawlable estimates are provided where possible for immature and mature individuals. Minimum trawlable estimates of abundance from the industry surveys were not calculated.

Trends in population levels for white hake, 1-44 cm, greater than 44 cm, as well as all lengths combined, were estimated using linear regression after log transformation. Length at 50% maturity was estimated to be approximately 42 cm for females, 48 cm for males, and 45 cm for the combined data (Bundy and Simon, 2005). Concern has been expressed on the use of this method when the data series in question is complex and non-linear. 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 (4 years old) plus 1/M where M (natural mortality) was assumed to be 0.2. This results in a period of 27 years for three generations.

In addition, Bundy and Simon (2005) reported on the identification problem between red and white hake during the summer RV surveys of the 1970s and early 1980s. Red hake were seldom recorded during this time although Leim and Scott (1966) only provided identification characteristics for red hake. They acknowledged that white hake were considered a separate species by some authorities but did not provide the diagnostics to differentiate the two species. Bigelow and Schroeder (1953) differentiated the two species using a combination of number of scales on the lateral line, as well as the position of the mouth in relation to the eye. Two 1981 internal DFO publications and Markle et al. (1982) provided more information to help in the separation of the two species. Given the identification problems between the two species and the changes in vessel and gear during the same time period, the trends in population levels for the summer survey from 1982 to 2011 are also presented. The maximum length of red hake is approximately 51 cm and the species is generally not found in Div. 4V making this issue irrelevant for some areas and length groups (>44 cm) (Figure 4).

Area Occupied

This section provides information on the trends in design weighted area occupancy (DWAO) within the Maritimes Region (Div. 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 white hake 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 white hake, 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

Chang et al. (1999) summarized the known information on geographic range, ichthyoplankton distribution, habitats, reproduction, food habits, size, age and growth, and maturity for white hake in USA waters. Although they focused on the species in USA waters, information was also reported for the remainder of its range.

Determining the relationship between species distribution and the habitat variables temperature and depth for the summer RV trawl data was done using the methods outlined by Perry and Smith (1994). Briefly, the cumulative distribution function (cdf) describing species associations with temperature and depth is calculated from the cdf for each habitat variable (x) for each set (i) in a stratum (h) incorporating the survey design as:

$$f(t) = \sum_h \sum_i \frac{W_h}{n_h} I(x_{hi}) \qquad I(x_{hi}) = \begin{cases} 1, & if\ x_{hi} \le t; \\ 0, & otherwise. \end{cases}$$

where W_h is the proportion of the survey area in stratum h, n_h is the number of sets performed within the stratum and t is an index ranging between the minimum and maximum levels of the observed habitat variable. Similarly, the cdf for catch of a particular species within a set (y_{hi}) with specific habitat conditions is:

$$g(t) = \sum_h \sum_i \frac{W_h}{n_h} \frac{y_{hi}}{\bar{y}_{st}} I(x_{hi}) \qquad I(x_{hi}) = \begin{cases} 1, & if\ x_{hi} \le t; \\ 0, & otherwise. \end{cases}$$

By scaling the catch to the stratified mean ($\bar{y}_{st}$) the sum of g(t) equals 1 across all values of t. Large values of $y_{hi} / \bar{y}_{st}$ which are consistently associated with a particular habitat condition suggest strong associations. Randomization tests were used to test the significance of habitat associations. The test statistic, L, is the maximum absolute difference between the f(t) and g(t) curves. Statistical significance of L was determined by its comparison with to the distribution of values from 2999 random perturbations of the data (3000 repetitions, including L; Perry and Smith, 1994).

Predator/Prey Relationships

Predation

Observed predation of white hake was compiled by querying the DFO Maritimes Region Population Ecology Division's stomach database (Cook and Bundy, 2010). This database consists of >156,000 stomachs for 68 predator species from 21 data sources focused on Div. 4VWX, but does include limited information from Div. 3OP, 4T and 5YZ. The data span four decades (1958-1969, 1981-1990, 1991-1998 and 1999-2010).

Diets

Data Source

Food habits data was collected during the Spring 4VsW (February-April) and Summer (July-August) DFO RV surveys between 1999 and 2010. Both surveys use a stratified random design and stomach contents are obtained from a length stratified sample of the catch. The summer RV survey is conducted across Div. 4VWX, whereas the spring RV survey is performed in Div. 4VsW. Stomachs were excised and either processed at sea or frozen and analyzed in the lab. Full details on stomach sampling protocols are given in Cook and Bundy (2010). Data were separated into two length groups, <=40 cm and >40 cm for diet comparisons.

Diet Summary

Mean stomach content weights of prey items were developed for each season and area. These estimates incorporate the survey design and the catch rates as suggested in Warren et al. (1994). Overall means and variances were obtained from the annual mean diet estimates. Additionally, the frequencies of occurrence of prey items were determined. Mean frequency of occurrence was obtained from the annual estimates and variances were obtained by bootstrapping (Efron and Tibshirani, 1993).

Threats

Landings of white hake since 1963 are summarized using data from NAFO and DFO landings statistics. These data are summarized by country, area and gear type. There were no restrictions on fishing effort for white hake in the Maritimes Region until 1996 when the first catch limits were placed on the fixed gear sector (Bundy and Simon, 2005). Other fleet sectors were regulated through bycatch restrictions (20% for the ITQ fleet and 10% for larger trawlers). In 1999, the Fisheries Resource Conservation Council recommended that white hake be caught as bycatch only and a quota cap was placed on the fixed gear fleet (<45') that has varied from year to year. The fixed gear fleet >45' and the mobile fleet have been managed under a separate cap since 2001. This species is generally a bycatch in other groundfish fisheries, but directed sets have been made to reach bycatch limits permitted within a trip. A summary table of the current cap estimates, as provided by Fisheries Management, is below.

Gear Sector	NAFO Division	Cap Value, t
FG<45	4Vn	90
FG<45	4VsW	225
FG<45	4X5	1475
FG 45-65	4VW	40
FG 45-65	4X5	160
MG<65/Aboriginal	4VWX5	200

RESULTS

LIFE HISTORY CHARACTERISTICS

Bundy and Simon (2005) summarized the von Bertalanffy growth parameters for white hake for the Bay of Fundy and the Scotian Shelf for the 1970s, 1980s, and 2000s. As described previously, the differences in growth between the Bay of Fundy and the Scotian Shelf were not large. These growth parameters were then compared with the new aging material from the summer RV survey from 2005-2010. The recent growth parameters were not significantly different from the growth parameters reported from the 2000s (A. Cook, DFO, pers. comm.) and, therefore, the 2000s estimates of growth and maturity used by Bundy and Simon (2005) were used in this analysis. The length of 50% maturity was 45 cm and age of 50% maturity was 4 years. Three generations was estimated to be three times 50% age of maturity (4 years old) + 1/m assuming m=0.2 ((4+1/0.2)*3 = 27 years).

OVERVIEW OF CANADIAN RV, INDUSTRY/SCIENCE, AND USA SURVEY INFORMATION

Canadian Research Vessel Surveys (Scotian Shelf)

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

The summer RV survey is the longest running survey in the Maritimes Region and has been conducted annually since 1970. Out of the 7,435 sets completed during 1970–2011, 39.2% or 2,914 sets captured white hake. Simon and Comeau (1994) reported that white hake was caught in 43.1% of the sets from the summer RV survey from 1970-1992 when it was the 7th most common groundfish on the survey.

The composite distribution pattern from 1970-2011 revealed a number of areas of concentration. They were observed on the eastern edge of the Scotian Shelf notably along the Laurentian Channel, the Gully and the southern edge of the shelf, the central Scotian Shelf centred on the LaHave and Emerald Basins, and in the deep waters adjacent to the USA border extending into the Bay of Fundy (Figure 5). The mean catch rate (number per tow) from the survey indicates that the highest catch rates were observed at a depth between 301-600m, while the highest sampling effort was between 101-300m (Figure 6). Sampling effort appears to extend beyond the observed range of the species indicating that the survey adequately samples the range of the species in the Maritimes Region. The distributional data were also disaggregated into two length groups approximating immature and mature white hake. The distribution of immature (1-44 cm) and mature (>44 cm) did not differ significantly (Figure 7). The immature length group was further disaggregated into white hake less than 17 cm representing recruitment into the population of age groups 0 and 1 (Figure 8). The distribution of white hake at this length group indicates that the highest concentrations were found in Div. 4X, primarily in the upper Bay of Fundy. They are found scattered across the shelf in the areas previously mentioned, except there are no small white hake in the deeper waters along the Laurentian Channel in Div. 4V. As previously reported, year over year, age 1 white hake are likely found inshore of the survey area.

The distributional data were aggregated into approximately decadal periods (1970-1981, 1982-1991, 1992-2001, and 2002-2011) to examine the persistence of these areas of concentration

over time (Figure 9). These data do not indicate that there have been significant changes in the distribution of white hake since the beginning of the summer RV survey (Figure 9). The length frequencies for these decadal periods are shown in Figure 10. The minimum, maximum, and peak lengths are similar for all four-time blocks (range 10-90 cm with a peak between 35 and 50 cm, but there has been a decrease in the number of mature individuals in the most recent period.

Catch at age information from the summer RV survey is available from 1977, 1978, 1983, 1984, 2002, and 2003 and from 2005 to 2010 (Table 2, Figure 11). The data from 1977 to 2003 was previously reported by Bundy and Simon (2005) but is presented here for completeness. It does not appear that one can track age cohorts using the RV survey. Ages 2-6 are most commonly caught by the survey, peaking near 4-year old.

Trends in abundance (number per tow) of white hake from the summer RV survey were examined separately for Subdiv. 4Vn, Div. 4VsW, Div. 4X and for the entire survey area (Div. 4VWX) (Figure 12). The deepwater strata that have been sampled since 1995 have not been included in the abundance estimates, although they have been included in the distribution maps.

In Subdiv. 4Vn, abundance of white hake, 1-44 cm, has generally increased from an average of 5 fish per tow in the 1970s to near 15 fish per tow in the 2000s. The number of sets allocated to this area is low (less than 15) and there is high interannual variability in the estimates. The abundance of larger (>44 cm) white hake was low in the 1970s, increased to a peak in the mid 1980, decreased to less than 10 fish per tow by 1987 and has been less than 5 fish per tow since then. In Div. 4VsW, the average abundance of fish 1-44 cm was generally near 1.5 fish per tow in the 1970s, increased sharply in the early 1980s to 11 fish per tow in 1983 and then fell to about 4 fish per tow in the 1990s. In the 2000s, abundance fell again to estimates seen in the 1970s. Abundance of fish >44 cm was similar to immature abundance in the 1970s , increased to a peak of 6 fish per tow in 1985 and subsequently fell to estimates below 1 fish per tow since 1992. In Div. 4X, abundance of both length groups has been highly variable between 2 and 18 fish per tow. Both length groups have exhibited an overall decline in abundance since the mid 1980s with catches generally below 6 fish per tow. When the entire Scotian Shelf is considered for both length groups, abundance was relatively low in the 1970s, peaked near 8 fish per tow in the mid 1985s and has declined to 3 fish per tow for fish 1-44 cm and 2 fish per tow for fish >44 cm (Figure 12).

The total number of individuals by length group in Subdiv. 4Vn, Div. 4VsW, and 4X was calculated as the catch rate times the number of trawlable units for the four decadal periods presented in Figure 9. The average number of mature individuals in Subdiv. 4Vn by approximate time blocks was 1.6, 2.4, 0.7 and 0.9 million fish for the 1970s, 1980s, 1990s and 2000s, respectively. In Div.4VsW, the total number of mature individuals for the same time blocks was 3.1, 6.1, 1.6, and 1.1 million fish. In Div. 4X, the average number of mature individuals was 8.4, 13.0, 9.9, and 5.3 million fish per time block.

The log transformed catch rates of white hake are presented for fish 1-44 cm, fish >44 cm and for all sizes classes combined in Subdiv. 4Vn, Div. 4VsW, and 4X (Table 3, Figures 13, 14, 15). These catch rates were then examined for three time periods, the entire survey period (1970-2011, 42 years) (Figure 13), 1982-2011 (30 years) representing a period when there was less of an identification problem (Figure 14) and 1985-2011 (27 years) which represents a period of three generations (Figure 15). The data for the summer survey as a whole (Div. 4VWX) is also presented for the three time periods and separate length groups.

The log transformed data from the RV survey from 1970-2011 exhibited non-linearity in all NAFO divisions. Declines rates between 43 and 79% were evident in the mature length group in all NAFO divisions, while in the immature length group increases of 394 and 119% were evident in Subdiv. 4Vn and 4VsW, respectively. In Div. 4X, there was a slight decline of 9% (Table 3, Figure 13). The problem of non-linearity was eliminated when only the data from 1982 or 1985 onward were considered (Figures 14, 15). In both cases, declines were evident in both length groups, as well as all three areas examined. Decline rates ranged from 13 to 78% in the immature length grouping and from 67 to 90% in the mature length group from 1982-2011, with the greatest decline observed in Div. 4VsW. The decline rate over 27 years (1985-2011) ranged from 6-70% for the immature length group and 68-88% for the mature length group. The decline rates (27 years) in Div. 4VWX, for the immature and mature length groups were 58 and 76%, respectively (Table 3, Figure 16).

Spring 4VsW Survey (4VWCOD)

A total of 2,022 sets have been sampled since 1986 with 543 or 26.9% of the sets capturing white hake. The species is distributed primarily in the deepwater sets in the Laurentian Channel, in the Gully, and along the edges of Emerald Basin (Figure 17). The distribution of white hake, 1-44 cm, differs somewhat from fish greater than 44 cm. The immature component is located in all the areas noted above while the mature component is primarily restricted to the deepwater sets of the Laurentian Channel, with lesser amounts in the Gully and along the southern edge of the Scotian Shelf. There are a few reports of mature fish near Emerald Basin, but none north of the Gully (Figure 18). Given the differences in observed distributions, the length frequencies of the deepwater strata and the remainder of the surveyed area were compared. This plot suggests that in the core surveyed area (strata 401-411) the mean length frequency ranged from 7 to 68 cm with a peak near 31 cm. The deepwater strata length frequency ranged from 25 to 82 cm with a peak near 46 cm (Figure 19).

There has been an overall decline in the abundance (number per tow) of white hake 1-44 cm, falling from 3 fish per tow in the late 1980s to less than one fish per tow recently (Figure 20). In 1987, there were very high catches of mature white hake on the edge of the Laurentian Channel that resulted in an annual estimate peaking near 6 fish per tow, otherwise abundance of this size group has been very low (Figure 20).

The log transformed catch rate (total number) was calculated for the immature, mature and all sizes combined for the survey from 1986-2010. The declines were estimated to be 56, 81 and 67% for the three categories, respectively (Table 3, Figure 21).

Spring and Fall Surveys of the Scotian Shelf (Div. 4VWX)

These two surveys series were examined for the presence of white hake. In both surveys, the distribution of the species was similar to that observed in the summer RV survey; and in addition, white hake were more widespread between LaHave Basin and the Bay of Fundy than in the summer series (Figure 22). A total of 741 sets were completed during the spring surveys with 255 or 34.4% of the sets containing white hake. A total of 941 sets were completed during the fall RV survey with 468 or 49.7% of the sets contained white hake. The issue of red hake identification, which would have occurred during these surveys, was not taken into account.

The average cumulative length frequencies from the two surveys are presented in Figure 23. These plots indicate that during the spring RV survey the length range was from 12-143 cm

with two peaks in abundance at 31 and 43 cm. The fall survey indicated that white hake ranged in length from 6-131 cm with a peak near 40 cm.

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

A total of 546 sets were completed from1982 to 1988 with 313 or 57.3% containing white hake. White hake were distributed throughout the surveyed area (Figure 24). Mean abundance was binned by depth range and then compared to the sampling intensity at depth. This indicates that white hake were most abundant between 201-300m and were commonly captured as deep as 700 m. The deepest record at which a white hake was caught in this survey was 952 m (Figure 25). Given the amount of sampling effort below 500m, it is likely that the survey adequately surveyed the depth distribution of the species

Canadian Industry/Science Surveys

4Vn Sentinel Survey (Longline)

A total of 879 sets have been completed since 1994 during the September 4Vn Sentinel Survey with 237 or 27% containing white hake. White hake are distributed primarily on the edges of the Laurentian Channel and in the deeper waters off the northern half of Cape Breton Island. White hake are also found in shallower inshore waters off Sydney, Nova Scotia, but are relatively uncommon to the east of Scatarie Island at depths less than 91 m (Figure 26). The abundance (weight per tow) of white hake has varied without trend since the beginning of the September survey between 1 and 25kg per set. Since 2006, the abundance has varied little averaging about 8kg per tow (Figure 27). Additional surveys of the area were conducted during July of 1995-1997, but catches of white hake were uncommon when compared to the September survey (12 out 154 sets; 7.8%) (Figure 28).

4VsW Sentinel Survey (Longline)

The distribution of white hake as indicated by the 4VsW Sentinel Survey was similar to the distribution observed during the summer RV survey. White hake were distributed along the edges of the surveyed areas of the Scotian Shelf, as well as almost continuously from south of Emerald Bank, northward into the Emerald Basin and in the adjoining strata (Figure 29). There were scattered reports of white hake in the western inshore strata but none within the eastern inshore strata (Figure 29). The stratified mean number per tow of white hake from the four offshore strata that have been sampled continuously since 1995 suggests that there is no trend in the series (Figure 30). An examination of the mean number per tow at length reveals that the survey captures white hake from 25 to 103 cm in length peaking near 58 cm (Figure 31).

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

A total of 2,600 sets have been completed since 1998 during the fixed portion of the Halibut Survey, with 1,222 or 47% containing white hake. White hake were broadly distributed throughout the surveyed area of the fixed portion of the Halibut Longline Survey (Figure 32). White hake were found in all deepwater strata, except in the areas north of the Gully and Banquereau Bank. They were also not found in the inshore strata of Subdiv. 4Vn and southwest Nova Scotia (Figure 32). An examination of the commercial index stations that normally fish in waters deeper than the fixed station survey revealed that white hake were broadly distributed in the deepwater strata except to the east of Middle Bank. They were also not observed in the shallow waters off southwest Nova Scotia. Both aspects of this survey extend into the

Newfoundland/ Labrador Region where white hake were again observed in the deepwater strata of the southern Grand Banks as far east as the tail of the bank. No white hake were observed in the deepwater sets fished east of the Grand Banks or the southeast Shoal (Figure 32).

Stratified mean catch (kg) per tow from the fixed station portion of the survey for Div. 4VWX averaged approximately 25kg per set with no trend in abundance over the 13 years of the survey (Figure 33). The cumulative length frequency of white hake from Div. 4VWX revealed that white hake ranged in length from 30-118 cm peaking near 55 cm (Figure 34).

Snow Crab Survey of the Scotian Shelf (Div. 4VWX, Nephrops trawl)

Since 2004, a total of 2,738 sets have been surveyed during the Snow Crab Survey with white hake occurring in 642 or 23.4% of the sets. White hake were distributed primarily along the edge of the Laurentian Channel in Subdiv. 4Vn with a secondary concentration along the eastern and south shores of Nova Scotia. There are scattered reports from the remainder of the surveyed area especially along the shelf edges (Figure 35).

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 3,019 sets have been completed with white hake occurring in 922 or 30.5% of the sets. White hake were broadly distributed throughout Div. 4X with their highest concentration in the deeper waters west of German Bank and Brier Island. Very few white hake were caught in the shallower waters of Browns and German Banks (Figure 36).

Abundance, between 1995 and 2002, varied without trend from a low of 1.8kg per tow in 1998 to a peak of 6.2 kg per tow in 2002. Since 2004, abundance has been steady near 3kg per tow (Figure 37). No length frequencies are available from this survey.

Canadian Research Vessel Survey (Georges Bank)

Canadian Winter Survey of Georges Bank (Div. 5Ze)

A total of 2,266 sets have been completed since 1986 with 333 or 15% containing white hake. When only the Canadian portion of the survey is considered white hake were caught in 83 out 1,051 sets or 7.9%. White hake were primarily distributed north of the Great Southwest Channel and on the southern flanks of Georges Bank (Figure 38). The survey has not consistently fished at depths in the Canadian zone where white hake have been observed by other surveys. In the last two survey years, additional sets have been made in an area north of the northeast peak of Georges Bank and white hake have been caught in this new strata. The data from those sets has not been included in this report.

The length frequency of white hake as indicated by the Canadian strata of Georges Bank range from 12-86 cm, peaking between 28 to 34 cm (Figure 39). The figure also indicates that there are many fish caught less than 12 cm, but given the problems separating juvenile red and white hake, these observations should be considered suspect.

An examination of the stratified number per tow by length category from the Canadian side of the bank revealed that white hake were not caught in 9 out of the 25 years of either length category and abundance was generally below 0.3 fish per tow (Figure 40). The log transformed

decline rate was calculated for the combined total length frequency, excluding the three years in which no white hake were caught, resulting in a decline of 43% since 1987 (Figure 41).

USA Research Vessel Surveys, SubArea 56

The spring RV survey has been conducted annually since 1968. A total of 6,208 sets were examined with 2,573 (41.4%) records of white hake. The survey suggests that white hake are distributed throughout the Gulf of Maine and on the slopes of Georges Bank (Figure 42). White hake 1-44 cm, tend to be more concentrated in the northern half of the Gulf of Maine, while larger white hake (>44 cm) tend to be more concentrated in the southern half of the Gulf (Figure 42).

Spring RV survey abundance was aggregated into the same length groups (1–44 cm and >44 cm) as the Canadian surveys for comparison. The survey indicates that white hake abundance of both length groups generally increased from low estimates in the late 1960s to high estimates from the early 1970s to the late 1980s. Interannual variability was high. Since the early 1990s, overall abundance has been relatively low and is similar to the estimates observed from 1968-1971(Figure 43).

The log transformed decline rate (total number) was calculated for both length groups, as well as combined, for the entire survey period (1968-2011) and three generations (1985-2011) (Figure 44). The decline rates for the 1-44 cm length group was 25% while the decline in the fish >44 cm was 63% from 1968-2011. From 1985-2011, the decline rate was approximately 47% for both length groups (Table 3, Figure 44).

The fall RV survey began in 1963 and of 9,625 sets examined, white hake occurred in 4,234 or 44% of the sets. During the fall survey, white hake occur in areas similar to that observed in the spring, but abundance is higher north of Georges Bank and in the nearshore area of the northern Gulf of Maine in both length groups (Figure 45). White hake 1-44 cm were observed in fairly high concentrations on top of Georges Bank. White hake were also observed south of Long Island, USA, but in low numbers (Figure 45).

The fall RV survey abundance trends were grouped into the same length groups as the spring RV survey (Figure 46). The trends in abundance differed from the spring survey in that abundance of both length groups gradually increased until the early 1990s but with high interannual variability. Abundance fell to below average in the mid 1990s, where it has remained in most years (Figure 46).

The log transformed decline rate for the 1-44 cm, >44 cm, and combined length groups from 1963-2010 was 4, 41, and 21%, respectively. The decline rate for the same three length groups for 1985-2010 (approximately three generations) was 68, 63, and 66%, respectively (Table 3, Figure 47).

Area of Occupancy

The area of occupancy based on the summer RV survey from 1970 to 2011 was examined for the entire survey area (Div. 4VWX) (Figure 48). Area occupied has varied between 53,000 and 94,000 km^2 since the beginning of the survey. Area occupied was slightly above average from 1970 to 1987 (79,400 km^2) and slightly below average (69,800 km^2) from 1988 to 2011. Recent estimates have been near the long-term mean (Figure 48).

The area of occupancy, based on the core strata of the Spring 4VsW RV survey has varied without trend since the beginning of the survey from 7,400 to 24,000 km^2 (Figure 49).

On the Canadian portion of Georges Bank (Subdiv. 5Zc), the area of occupancy has varied without trend since the beginning of the survey. The average estimate for the survey is 600 km^2 with the highest estimate of 1,400 km^2 in 2001 (Figure 50).

Because area of occupancy was not available for the industry surveys that were examined, the percentage of sets in which white hake occurred was used. Due to the changes in survey design, the 4VsW Sentinel Survey was not evaluated. There was no clear signal in the percentage of sets occupied in the 4Vn Sentinel (Figure 51), the Halibut Fixed Station (Figure 52), the Snow Crab (Figure 53) or the ITQ (Figure 54) Industry Surveys. The percentage of sets occupied in the 4Vn Sentinel Survey has varied between 18-55% (Figure 51), 35-50% in the Halibut Fixed Station Survey (Figure 52), 18-28% in the Snow Crab Survey (Figure 53) and 15-46% in the ITQ Survey (Figure 54).

HABITAT ASSOCIATIONS

Salinity, Temperature and Depth Preferences

The habitat preferences of white hake in Div. 4VWX from the summer RV survey are presented in Figure 55. White hake are distributed significantly different from the median habitat as indicated by the summer RV survey with respect to salinity, temperature and depth in most years. White hake seem to prefer temperatures in the range of 5-9^{o}C and a salinity range of 33.8 -34.5 ppt, which are warmer and more saline than the means observed during the survey. The preferred depth range as indicated by the survey was 274-457 m. Chang et al. (1999) reported that USA RV surveys indicated that white hake preferred temperatures between 6-11^{o}C and depths from 50-325 m. They suggest that the depth distribution of adults in the Gulf of Maine varies with age and season; tending to move inshore in summer-autumn and disperse to the deeper basins in winter-spring.

Predator Prey Relationships

Predation on white hake by fish predators was generally low. White hake were observed in the stomachs of 13 different species of fish, occurring in less than 0.3% of the species reported, i.e. cod, winter skate and longhorn sculpin (Table 4). They occurred in 0.7% of the monkfish stomachs and 2.6% of the Atlantic halibut stomachs examined (Table 4).

The frequency of occurrence of white hake prey items differed between the two length groups examined. As expected, white hake less than 40 cm consumed primarily invertebrates such as euphasids and decapods by weight. The second most common prey items by weight were unidentified fish. Other important food items included silver hake, squid, shrimps, herring, deepsea eels and isopods (Figure 56). White hake greater than 40 cm consumed more fish by weight than smaller white hake. The primary fish species consumed by weight were herring, unidentified fish, gadidae and silver hake. Euphasids were the fifth most common prey item followed by redfish and squid (Figure 56).

THREATS

The distribution of white hake from Canadian commercial landings was summarized into two periods (1986-2002 and 2003-2010) separately for fixed and mobile gears (Figures 57 and 58). These figures indicate that from 1986-2002, white hake from both gear types were more broadly distributed in Div. 4X than observed during the summer RV survey (Figure 57). In Div. 4VW, for the same period, reported locations were similar to those observed during the summer RV survey. From 2003-2010, landings were much reduced from the previous period, but there was no apparent loss of areas of concentration (Figure 58). White hake were also recorded from the middle of the Laurentian Channel in Subdiv. 4Vn and east of Banquereau Bank by mobile gear (Figure 57) and these fish would be adjacent to white hake in the Newfoundland and Gulf Regions. An examination of the monthly landings in Div. 4V, revealed seasonal changes in the distribution of the fishery (Figure 59). White hake were landed from the middle of the channel north of St. Paul's Island from February to May suggesting seasonal out-migration from the Gulf of St. Lawrence in the winter months.

Annual landings of white hake by Canada are presented in Figure 60 and Table 5 for Subdiv. 4Vn, Div. 4VsWX5Y and Div. 5Z from 1963 to 2010. In Div. 5Z, landings were below 200 t from 1963 to 1979, increased to 500 t annually by 1991 and peaked at 1700 t in 1993. Landings fell to approximately 200 t by 2001 and have been less than 100 t since 2004. In Div. 4VsWX5Y, landings averaged about 1,000 t in the mid 1960s, increased to a peak of 5,500 t in 1974, declined to an average of 3,000 t in the early 1980s and then sharply increased to a peak of 7,500 t in 1987 (Figure 60). Subsequently, landings steadily declined to a low of about 1250 t by the late 2000s. In Subdiv. 4Vn, landings were generally between 100-300 t from 1963 to the late 1970s. In 1980 and 1981, landings peaked over 550 t and subsequently declined so that landings have been below 100 t since 1995.

Canadian landings were further disaggregated by gear type and NAFO division (Figure 61). Highest annual landings were by the fixed gear (longline, handline) sector in Div. 4X and Div. 4W. There was a spike in mobile gear landings in Div. 4X of 3000 t. These landings fell to approximately 600 t by the early 1990s and have slowly decline to estimates near 300 t. The 1964 report of 2000 t being landed by miscellaneous gear in Div. 4X, is most likely a misreport of another species.

Foreign landings on the Scotian Shelf are presented in Figure 62 and Tables 6 and 7. USA landings in Div. 4X were generally below 100 t except in 1983 and 1984 when they exceeded 240 t (Figure 62, Table 6). It is not possible to disaggregate the reported USA landings in Div. 5Y and Div. 5Z into Canadian and USA sides of the EEZ (Table 6). Non-USA foreign landings on the Scotian Shelf are presented in Table 7. Distribution of non-USA foreign landings was approximated by observer reports (Figure 63). Since the extension of jurisdiction in 1977, these landings have been generally below 100 t annually and have been below 40 t since 1989. These observer reports were primarily from directed silver hake and squid fisheries in Div. 4WX and fisheries (i.e. cod) by other countries such as France.

Canadian commercial sampling information is available from 1949 to present, but consistent length frequency data is only available from 1993 to 2010 (Table 8). Removals at length were calculated by gear type and then combined to produce annual removals at length from Div. 4VWX from 1993 to present (Table 9, Figure 64). The length frequency sampling information did not appear to track cohorts in the population. White hake ranged in length from 25-136 cm with annual peaks in the length frequencies ranging from 35-58 cm. The data has not been disaggregated at this time to examine the possibility that some of the fish in Div. 4WX

may be red hake. Minimum length of capture in other gadid fisheries was 43 cm until the late 1990s and this was replaced with small fish protocols for cod, haddock and pollock. It is unclear whether this applied to white hake, but white hake has been used as lobster bait over last few years (P. Comeau, DFO, pers. comm.). A Jones model was used to calculate Z's from the descending limbs of the annual length frequencies. The 2002, 2003 growth parameters by Bundy and Simon (2005) were used in the model but the model was not able to calculate estimates in 1997, 2002 or 2003. Total mortality averaged 0.7 from 1993 to 1996, approximately 0.4 between 1998 and 2008, and then increased in 2009 and 2010 to a series peak of 0.89 (Figure 65).

Removals (number of fish '000s) at age from the commercial fishery were calculated from 1999-2009 (Table 10, Figure 66). White hake begin to appear in the fishery at age 3. Peak landings are between ages 4-6 with few fish older than 10 in the fishery. The oldest fish observed was 16 years old. As with the RV catch at age and the commercial length frequencies, it does not appear that you can track age cohorts with the commercial sampling information.

Relative F (fishing mortality) was calculated by dividing the removals estimated for each division by the aerial expanded summer RV biomass in Div. 4X and Div. 4VW, as well for the entire Scotian Shelf (Figure 67). In Div. 4X, relative F generally decreased from a high in the early 1970s of 0.5 to less than 0.1 in the early 1980s. Relative F has varied without trend since the early 1980s averaging about 0.15. In Div. 4VW, relative F declined from a peak in 1971 of 0.5 to a low of 0.15 in 1984. Subsequently, relative F increased to 0.2 in the early 1990s and has been below 0.1 since 1997.

SUMMARY

This paper examined the Canadian DFO RV and industry surveys, USA RV surveys, and commercial landings data within the Maritimes Region. Collectively, the RV surveys revealed a number of areas of concentration. They were observed on the eastern edge of the Scotian Shelf notably along the Laurentian Channel, the Gully and the southern edge of the shelf, the central Scotian Shelf centred on the LaHave and Emerald Basins, and in the deep waters adjacent to the USA border extending into the Bay of Fundy, with the highest abundance observed in Div. 4X. Given the locations of white hake observed during industry surveys and commercial fisheries, these concentrations are not likely to be discrete.

Abundance of immature individuals over the entire shelf has declined by about 60% since the 1980s. If the entire survey period was examined (1970 to 2011) abundance has actually increased. Mature abundance over the same periods has declined by approximately 77% since the 1980s and 56% since 1970. Since 2001, the number of immature and mature individuals in Div. 4VWX has averaged 12.1 and 7.4 million, respectively. Although these estimates are about one half and one third, respectively, the observed estimates in the 1980s, they are similar to the estimates from the 1970s.

On the northeast peak of Georges Bank, most of the observations of white hake are on the edges of the surveyed area. Seasonal USA RV surveys indicate they are widespread in the deeper waters off Georges Bank and these fish are contiguous with white hake in Canadian waters.

Prior to 1999, white hake landings were unregulated. Landings on the Scotian Shelf varied between 3,000 and 8,000 t. In 1999, a CAP on landings by gear and area, and bycatch limits was used to regulate catches. This resulted in landings declining to about 2,000 t by the early 2000s and landings have averaged 1250 t since 2006. In Div. 5Z, landings gradually increased from 1968 to 1991 to 600 t, peaked at 1,700 t in 1993 and have subsequently declined to less than 100 t since 2004. These landings are contiguous with white hake landings in Div. 4X.

Total mortality as estimated from commercial samples on the Scotian Shelf, suggests that Z was higher in the mid 1990s than the late 1990s/early 2000s. This was coincident with the imposition of catch limits in 1999. The increase in Z over the last two years is unexplained. Relative F (fishing mortality) on the Scotian Shelf has averaged 0.14 since 1973 and has been below the mean over the last six years.

REFERENCES

Armsworthy, S., Wilson, S., and Mohn, R.K. 2006. Atlantic halibut on the Scotian Shelf and Southern Grand Banks (Division 3NOPs4VWX5Zc) – Industry/DFO Longline Survey results to 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/065.

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

Bundy, A., Fowler, M., MacEachern, W., and Fanning, P. 2001 Assessment of the status of 4VWX/5 white hake, 2001. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/104.

Bundy, A., and Simon, J. 2005. Assessment of white hake (*Urophysis tenuis*) in NAFO Divisions 4VWX and 5. DFO Can. Stock Assess. Sec. Res. Doc. 2005/081.

Chang, S., Morse, W.W., and Berrien P.L. 1999. Essential fish habitat source document: White hake, Urophycis tenuis, life history and habitat characteristics. NOAA Tech. Memo NMFS NE 136.

Cook, A.M., and Bundy, A. 2010. The food habits database: an update, determination of sampling adequacy and estimation of diet for key species. Can. Tech. Rep. Fish. Aquat. Sci. 2884.

Efron, B., and Tibshirani R. 1993. An introduction to the bootstrap. Chapman and Hall, London, UK.

Fahay, M.P., and Able, K.W. 1989. White hake, Urophycis tenuis, in the Gulf of Maine: Spawning seasonality, habitat use, and growth in young of the year and relationships to the Scotian Shelf population. Can. J. Zool. 67: 1715-1724.

Fowler, M. 1998. 4VWX and 5 white hake 1998 stock assessment. DFO. Can. Stock Assess. Sec. Res. Doc. 98/143.

Fowler, M., Black, J., Mohn, B., and Sinclair, M. 1996. 4VWX and 5Zc white hake 1996 stock assessment. DFO. Can. Stock Assess. Sec. Res. Doc. 96/103.

Hare, J.A., Fahay, M.P., and Cowen, R.K. 2001. Springtime icthyoplankton of the slope region off the north-eastern United States of America: Larval assemblages, relation to hydrography and implications for larval transport. Fish. Oceanogr. 10: 164-192.

Lambert, T.C. 1995. The first report of the 4Vn Sentinel Survey Autumn 1994. A government/industry cooperative venture. DFO Atl. Fish. Res. Doc. 95/107.

Leim, A.H., and Scott, W.B. 1966. Fishes of the Atlantic Coast of Canada. Bull. Fish. Res. Board Can. 155.

Markle, DF, Methven, D.A., and Coates-Markle, L.J. 1982. Aspects of spatial and temporal co-occurrence in the life history stages of the sibling hakes, *Urophycis chuss* (Walbaum 1792) and *Urophycis tenuis* (Mitchill 1815) (Pisces: *Gadidae*). Can. J. Zool. 60: 2057-2078.

Miller, T.J, Das, C., Politis, P.J., Miller, A.S, Lucey, S.M, Legault, C.M., Brown, R.W., and Rago, P.J. 2010. Estimation of *Albatross IV* to Henry B. Bigelow calibration factors. NEFSC Ref. Doc. 10-05.

O'Brien, L., Burnett, J., and Mayo, R.K. 1993. Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990. NOAA Tech. Rep. NMFS 113.

O'Conner, S.E. 2008. Relationships between juvenile fish assemblages and the physical features of bays along the Atlantic coast of mainland Nova Scotia, with implications for coastal Marine Protected Areas. MSc Thesis, Acadia University, Wolfville, NS.

Perry, R.I., and Smith, S.J. 1994. Identifying habitat associations of marine fishes using survey data - an application to the Northwest Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 51(3): 589-602.

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

Simon, J.E., and Campana, S.E. 1987. Species composition and distribution in inshore waters of southern Nova Scotia: Results of exploratory trawl surveys. Can. Tech. Rep. Fish. Aquat. Sci. 1582.

Simon, J.E., and Comeau, P.A. 1994. Summer distribution and abundance trends of species caught on the Scotian Shelf from 1970-92, by the research vessel groundfish survey. Can. Tech. Rep. Aquat. Sci. 1953.

Smedbol, R.K., Shelton, P.A., Swain, D.P., Fréchet, A., and Chouinard, G.A. 2002. Review of population structure, distribution and abundance of cod (*Gadus morhua*) in Atlantic Canada in a species-at-risk context. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/082.

Warren, W.G., Lilly, G.R., and Shelton, P.A. 1994. Estimating the population mean stomach content weight of cod from a stratified-random trawl survey and length stratified stomach sampling. ICES C.M. Doc. D:13.

Table 1. Temporal and spatial extent of data used in examining the distribution, abundance, and threats of white hake in the Maritimes Region (1963-2011).

	Canadian RV Surveys						Canadian Industry Surveys					US RV Survey		Commercial Landings	
Identifier NAFO AREA	Georges Bank 5Z	4VWCOD 4VsW	Summer 4VWX5Y	Spring 4VWX	Fall 4VWX	Redfish 4VWX	Sentinel (LL) 4Vn	Sentinel (LL) 4VsW	Halibut (LL) 3NOP4VWX5	Snow Crab 4VWX	ITQ (OT) 4X	Spring 4X5	Fall 4X5	Canada 4VWX5	Foreign 4VWX5
1963													x	x	x
1964													x	x	x
1965													x	x	x
1966													x	x	x
1967													x	x	x
1968												x	x	x	x
1969												x	x	x	x
1970			x									x	x	x	x
1971			x									x	x	x	x
1972			x									x	x	x	x
1973			x									x	x	x	x
1974			x									x	x	x	x
1975			x									x	x	x	x
1976			x									x	x	x	x
1977			x									x	x	x	x
1978			x		x							x	x	x	x
1979			x	x	x							x	x	x	x
1980			x	x	x							x	x	x	x
1981			x	x	x							x	x	x	x
1982			x	x	x	x						x	x	x	x
1983			x	x	x	x						x	x	x	x
1984			x	x	x	x						x	x	x	x
1985			x			x						x	x	x	x
1986	x	x	x			x						x	x	x	x
1987	x	x	x			x						x	x	x	x
1988	x	x	x			x						x	x	x	x
1989	x	x	x									x	x	x	x
1990	x	x	x									x	x	x	x
1991	x	x	x									x	x	x	x
1992	x	x	x									x	x	x	x
1993	x	x	x									x	x	x	x
1994	x	x	x				x					x	x	x	x
1995	x	x	x				x				x	x	x	x	x
1996	x	x	x				x	x			x	x	x	x	x
1997	x	x	x				x	x			x	x	x	x	x
1998	x		x				x	x	x		x	x	x	x	x
1999	x	x	x				x	x	x		x	x	x	x	x
2000	x	x	x				x	x	x		x	x	x	x	x
2001	x	x	x				x	x	x		x	x	x	x	x
2002	x	x	x				x	x	x		x	x	x	x	x
2003	x	x	x				x	x	x		x	x	x	x	x
2004	x		x				x	x	x	x	x	x	x	x	x
2005	x	x	x				x	x	x	x	x	x	x	x	x
2006	x	x	x				x	x	x	x	x	x	x	x	x
2007	x	x	x				x	x	x	x	x	x	x	x	x
2008	x	x	x				x	x	x	x	x	x	x	x	x
2009	x	x	x				x	x	x	x	x	x	x	x	x
2010	x	x	x				x	x	x	x	x	x	x	x	x
2011	x		x									x			

Table 2. Catch at age (number per tow) of white hake from the summer RV survey from 1977-2010. (Note that -1 indicates unknown age.)

AGE	1977	1978	1983	1984	2002	2003
-1	0	0.08	0.03	0.05	0.03	0.01
0	0.04	0.07	0	0	0.13	0
1	0.08	0.18	1.04	0.03	0.09	0.16
2	0.67	0.94	4.75	1.97	0.95	1.18
3	0.55	0.49	2.41	1.77	0.79	0.84
4	1.25	0.82	4.75	2.4	0.52	0.75
5	1.36	0.87	3.08	2.13	0.86	0.39
6	0.8	0.79	0.9	1.49	0.36	0.24
7	0.22	0.3	0.32	0.45	0.1	0.03
8	0.05	0.15	0.24	0.07	0.01	0.03
9	0.02	0.02	0.06	0.04	0	0
10	0.04	0.03	0.01	0.04	0.02	0
11	0.01	0.01	0.01	0.01	0.01	0
12	0.01	0	0	0.02	0	0
13	0.01	0	0.01	0.01	0	0
14	0.01	0	0	0	0	0
SUM	5.12	4.75	17.61	10.48	3.87	3.63

AGE	2005	2006	2007	2008	2009	2010
-1	0	0		0.01	0	0
0	0	0.07	0.04	0.01	0.07	0.20
1	0.21	0.44	0.32	0.15	0.34	0.23
2	1.3	1.06	1.32	0.93	1.31	1.70
3	0.94	0.58	0.76	1	1.03	1.25
4	2.07	0.94	0.87	2.19	1.82	1.27
5	0.98	0.45	0.48	1.16	1.25	0.71
6	0.35	0.09	0.1	0.29	0.71	0.44
7	0.09	0.03	0.04	0	0.16	0.09
8	0.09	0.03	0.02	0	0.02	0.03
9	0.04	0.02	0.01	0.01	0	0.01
10	0.01	0	0	0.01	0	0.01
11	0.02	0.01	0	0	0.01	0.00
12	0	0	0	0	0	0.01
13	0	0	0	0	0	0.01
14	0	0	0	0	0	0.01
SUM	6.1	3.72	3.96	5.76	6.72	5.98

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

Survey	Years	Area	Abundance Trends		
			Immature	Mature	Combined
Summer RV	1970-2011	4Vn	394	-59	162
	(42 years)	4VsW	119	-79	-33
		4X	-9	-43	-30
		4VWX	117	-56	-24
Summer RV	1982-2011	4Vn	-13	-67	-34
	(30 years)	4VsW	-78	-90	-83
		4X	-55	-73	-65
		4VWX	-62	-78	-70
Summer RV	1985-2011	4Vn	-6	-68	-26
	(27 years)	4VsW	-70	-88	-77
		4X	-60	-70	-65
		4VWX	-58	-76	-66
4VWCOD RV	1986-2010	4VsW	-56	-81	-67
	(25 years)				
Georges Bank RV	1986-2011	5Z,Cdn			-43
	(26 years)				
US Fall RV	1963-2010	4X5YZ	-4	-41	-21
	(47 years)				
	1985-2010	4X5YZ	-68	-63	-66
	(26 years)				
US Spring RV	1968-2011	4X5YZ	-25	-63	-46
	(42 years)				
	1985-2011	4X5YZ	-46	-48	-48
	(27 years)				

*three generations=27 years
From 1970-81 the summer RV survey the abundance of white hake was adjusted downwards to account for identification issues between red/white hake This issue should primarily affect the abundance of immature (<45cm) fish and fish caught in Divs. 4XW

Table 4. Summary of species identified as predators on white hake from the Maritimes Region Stomach Database from all years and areas.

Species	Code	Number Stomachs Examined	Number_with White hake	Occurrence
Altantic Cod	10	32498	56	0.17
Haddock	11	38648	11	0.03
White Hake	12	5889	9	0.15
Red Hake	13	1610	1	0.06
Silver hake	14	9744	3	0.03
Pollock	16	5498	4	0.07
Halibut	30	1404	36	2.56
Greenland halibut	31	2277	4	0.18
Winter skate	204	1109	3	0.27
Spiny dogfish	220	2043	2	0.10
Blue shark	231	1452	1	0.07
Longhorn sculpin	300	3090	8	0.26
Monkfish	400	1033	7	0.68

Table 5. Canadian commercial landings (t) of white hake by gear sector and division from 1963-2010.

	Fixed(gillnet,longline)							Mobile (otter trawl)							Miscellaneous		
Year	4Vn	4Vs	4W	4X	5Y	5Z		4Vn	4Vs	4W	4X	5Y	5Z		4Vn	4Vs	4W
1963	151	12	113	193				68	19	170	456				10		36
1964	37	2	11	140				75	21	152	435	3			80		157
1965								6	1								
1966	77	6	433	827				234	3						37		
1967	47	9	240	506				52	18	1	1				26		
1968	71	19	234	763		62		49	14	53	178	5	18		18		38
1969	86	28	293	1131		15		34	10	117	356	4	15		17		133
1970	98	22	371	1417		30		60	25	104	287	12	4		24		243
1971	116	36	1047	2302		58		281	81	117	414	18	24		25		289
1972	96	34	810	3489		28		62	61	89	297	8	4		15		304
1973	106	40	1138	3429		62		162	86	107	288	17	38		5		200
1974	68	40	1056	3633		177		142	97	57	316	36	19		13		216
1975	57	59	1214	2526	14	95		116	79	58	186	3	34		8		64
1976	30	111	588	2007		178		230	46	42	144		17		2		126
1977	107	85	617	1765		148		166	67	99	161		21		15		132
1978	51	91	613	2186		70		144	151	119	245	20	65		7		37
1979	82	69	288	1870		137		252	112	63	245	102	12		4		15
1980	231	237	264	2218		234		337	132	50	263	14	57		17		27
1981	236	124	361	1700	15	413		321	98	51	446	6	20		7		
1982	253	148	560	2838	2	389		161	56	34	539	350	23				1
1983	315	281	615	1876	57	318		86	34	11	472	384	51				
1984	210	263	654	1757	72	405		27	35	21	1386	407	129				13
1985	210	473	1082	1934	13	368		135	53	23	1114	439	133				
1986	255	446	1350	1770	57	299		110	48	56	2906	251	349		0		
1987	194	644	1505	3200	71	428		268	72	83	1866	33	127		0		
1988	128	339	761	2571	47	424		129	35	27	1322	38	110		0		0
1989	94	458	911	2846	213	565		76	17	27	315	8	17				
1990	81	291	1207	2762	35	500		75	16	29	775	16	46		0		
1991	61	275	1024	2332	24	519		56	17	52	475	10	31				0
1992	45	283	800	2511	72	1110		68	15	29	804	54	27				0
1993	41	274	760	2910	24	1655		83	7	5	650	49	27				4
1994	60	185	579	2400	64	928		109	27	3	737	33	27				16
1995	5	247	553	3893	41	462		16	36	41	301	7	19				
1996	5	110	406	2372	52	348		13	16	115	371	9	24				
1997	61	68	250	2125	139	274		4	9	2	421	8	16				
1998	84	102	189	1050	48	218		6	2	4	314	9	10				
1999	113	66	172	966	24	164		2	5	3	376	11	10				
2000	87	51	215	1248	50	210		2	1	7	573	8	14				
2001	48	45	215	1199	54	170		2	4	8	610	6	33				
2002	48	40	136	1402	123	149		1	5	11	583	21	9				0
2003	30	55	88	1075	180	120		4	12	12	366	18	8				
2004	35	39	63	1061	74	81		4	2	10	419	9	9				
2005	43	38	100	1102	159	51		6	11	26	459	26	34				
2006	58	17	92	799	54	57		13	11	2	268	11	34				
2007	31	24	91	627	23	41		5	11	1	220	14	14				
2008	23	17	92	735	13	39		2	7	5	436	14	0				
2009	22	21	60	771	10	76		1	3	3	249	45	3				
2010	22	17	80	892	10	69		0	3	30	327	89	36				

Table 6. Commercial landings (t) of white hake by the USA by gear sector and NAFO division. Landings in Div. 5Y and 5Z cannot be disaggregated into Canadian and USA sides of the border from 1963-2010.

	Fixed(gillnet,longline)							Mobile (otter trawl)							Miscellaneous		
Year	4Vn	4Vs	4W	4X	5Y	5Z		4Vn	4Vs	4W	4X	5Y	5Z		4Vn	4Vs	4W
1963					1423					8	221	627					
1964					1325				2	6	181	830					
1965					1568					2	114	437					
1966					3												
1967					313												
1968					249	18											
1969					291	43					43	526	421				
1970					132	1		1		2	69	853	526				
1971				2	468	34				4	60	1127	819				
1972					1194	25				9	82	925	703				
1973				1	1178	59				5	24	1103	599				
1974					1688	144				2	43	1177	599				
1975					1549	72					27	607	320				2
1976					1694	56				1	51	785	333				
1977				2	1784	38					97	1121	485				
1978					1820	47					27	1007	546				
1979					1273	28					12	874	591				
1980					1243	54					37	1223	629				
1981					2441	29					182	2012	1164				
1982				1	2275	13					193	2611	1012				
1983					1448	23					243	3577	1037				
1984					1482	24					272	3494	1387				
1985					1407	40					60	3660	1155				
1986					1019						160	2908					
1987					814						67	3436					
1988				6	1157						21	2559					
1989				19	1844						22	2076					
1990				35	1591						104	2293					
1991				3	1888						21	2549					
1992					2650						6	3658					
1993					1870							2548					
1994																	
1995																	
1996																	
1997																	
1998																	
1999																	
2000																	
2001																	
2002																	
2003																	
2004																	
2005																	
2006																	
2007																	
2008																	
2009																	
2010																	

Table 7. Reported landings (t) of white hake by non-USA foreign countries from the Maritimes Region from 1963-2010.

Year	4Vn	4Vs	4W	4X	5Y	5Z
1963						
1964						
1965		86	60			
1966		13				
1967	2	227				
1968		17				
1969		27	1	7		6
1970	6	36	21	16		143
1971	11	7	1	29		105
1972	26	176	86	91		159
1973		20				1
1974		5				
1975						
1976			2	1		
1977						48
1978		15	4	1		1
1979		1	1			2
1980	1.1		11.3	9.8		
1981	0.5	0.0	28.5	4.3		
1982	0.6		7.6	0.2		
1983	2.3	5.8	13.5	1.7		
1984	2.2	3.0	27.0	0.9		
1985	16.8	47.6	54.0	0.4		
1986	6.3	15.5	80.2	0.7		
1987	1.3	10.9	95.2	0.3		
1988		0.3	50.6	1.9		
1989			30.3	1.6		
1990	6.4	0.0	15.5	8.0		
1991	0.4		31.4	1.2		
1992			2.9	2.3		
1993			3.0	0.0		
1994			0.0			
1995			14.0	3.4		
1996		0.37	32.0	2.0		
1997			22.0	2.5		
1998			4.5			
1999			7.3			
2000			0.4	0.2		
2001			9.3			
2002			0.1			
2003			1.8			
2004			0.1	0.0		
2005						
2006						
2007						
2008						
2009						
2010						

1963-1979 based on NAFO reports
1980-2010 based on observer reports

Table 8. Summary of commercial sample lengths (upper panel) and ages (lower panel) from the Maritimes Region from 1949-2010.

Lengths	4V	4Vn	4Vs	4VsW	4VW	4W	4WX	4X	4X5Y	5Y	5Z
1949								200			
1950								200			
1965								561			
1967						129		194			
1972								166			
1973						107					
1974								275			
1975							200				
1976								233			
1977	204	564						169			
1978								317			
1982						122					
1983				255							
1985								432			135
1986						218					
1987						141		60			
1988								299			
1989								173			
1993			268					1202			367
1994			353			268		1557			288
1995		397	566			1418	215	4607			428
1996		775				9		2430			293
1997		504	129	75		51		4256			762
1998		1362	219					2480			1035
1999		2099	1567			191		2368		229	989
2000		3617	351					4724			967
2001		3222				295		7210			1184
2002		2298				397		6719		432	1314
2003		2304						5519		473	1033
2004		2477	578			280		6396			1579
2005		2036	493					6262		490	69
2006		1600						5289	306	465	411
2007		1621						5453		273	426
2008		1453	464					6737			477
2009		1127	1765					4358			1070
2010						228		6631			1191

Ages	4V	4Vn	4Vs	4VsW	4VW	4W	4WX	4X	4X5Y	5Y	5Z
1949								0			
1950								0			
1965								0			
1967						34		0			
1972								0			
1973						41					
1974								60			
1975							0				
1976								68			
1977	0	0						0			
1978								0			
1982						34					
1983				0							
1985								0			0
1986						0					
1987						0		0			
1988								0			
1989								0			
1993			0					0			0
1994			0			0		0			0
1995		0	0			0	0	0			0
1996		0				0		0			0
1997		0	0	0		0		0			0
1998		158	26					228			25
1999		143	102			0		290		0	143
2000		302	25					707			85
2001		281				73		788			96
2002		277				49		488		42	81
2003		279						561		52	143
2004		260	90			45		486			302
2005		210	75					456		39	24
2006		216						485	65	51	0
2007		121						858		30	108
2008		203	113					855			49
2009		126	261					705			39
2010						0		0			0

Table 9. Removals (number of fish) at length of white hake by the commercial fisheries in Div. 4VWX from 1993-2009.

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Tonnage	4806	4213	5141	3469	3087	1809	1737	2242	2191	2370	1840	1715	1971	1325	1048	1344	1184
Length																	
25				3046													
28			120	33510													
31			120	92250	482										182		
34			2582	182771	39	299		176			23	333	76	21	1111	47	701
37		395	11945	171333	0	2077	646	658	155	46	284	3911	20	663	5082	1587	2616
40	29010	12261	27155	102546	5340	14359	4054	3636	1576	2962	1394	19456	302	4840	19036	4635	10801
43	75725	15461	75773	100326	17639	35448	25968	21559	22366	7369	5262	30743	1626	13291	44320	16739	22576
46	112628	70824	193566	117748	46619	67667	236156	80364	51124	20362	10897	43844	6320	21822	58799	34137	29007
49	224216	113953	311731	146167	93590	155545	465750	128623	84010	43414	21524	47926	16397	38251	65586	53950	47464
52	319828	173400	304032	195919	109363	179070	223695	123535	88484	65484	26549	52149	29243	44238	61930	80128	64721
55	357732	230167	326746	269270	99252	131790	177230	113445	93392	69389	30703	56940	45000	46729	68478	93178	70479
58	271920	242495	271746	246333	97155	100169	75718	110553	78684	68103	33817	49456	54338	38639	57569	84464	59442
61	319775	297531	250848	225347	115933	77895	53465	107721	90266	84261	37871	55114	70380	39956	46306	99882	58712
64	302171	194074	215868	161223	166652	78539	33377	102468	102434	119201	43011	57106	88657	42211	39124	88929	62319
67	225348	153224	208650	162927	155023	49722	28653	88302	99234	157797	56650	57181	90727	47155	36084	71999	50951
70	131231	128128	191050	115330	147707	47097	15035	69343	91757	154426	67235	54486	69411	54601	27367	39143	41515
73	96109	88986	115206	70823	116101	28241	7354	53557	58615	99354	73397	37311	53319	46029	19436	14992	27820
76	36235	76530	64812	28691	67335	16059	6730	38737	32806	45353	63571	25905	35966	28981	11867	9654	23979
79	31883	75564	39790	20850	38489	13301	4549	24218	22901	20116	54558	21507	23407	12940	7002	6624	16448
82	21820	29717	25614	14324	16833	6609	2593	17842	10229	10192	35989	18910	12616	5070	3646	3390	6109
85	24936	29121	22312	5178	8905	5138	2553	10043	6789	5243	20559	18393	8642	2702	2131	2929	3184
88	12354	11870	11507	3342	1904	2179	2662	4743	4055	3957	14354	15067	9238	1396	2009	1892	1878
91	0	7164	7233	1720	2069	2147	2322	4442	5601	2202	6232	15390	11467	1730	724	1110	488
94	0	1297	7335	59	988	1285	1527	2345	3679	2817	2635	8017	11213	2018	1183	2067	219
97	2753	1643	5754	1068	1997	1121	1511	1624	4658	1424	1633	3338	11055	3463	942	1469	330
100	0	1803	2173	1332	1020	157	1143	1305	3835	2496	668	1149	7400	4223	1351	683	241
103	2047	0	2303	266	1459	686	1172	74	2667	2265	989	472	2914	4095	931	165	255
106	0	1032	1237	0	2128	1044	370	2223	1448	1197	467	141	1736	2856	1316	1165	213
109	0	611	816	0	1756	863	274	322	2670	512	933	170	1288	1198	2475	613	201
112	0	0	272	0	471	964	279	691	1573	373	897	619	645	230	1557	598	64
115	2589	395	963	0	286	157	578	218	688	667	775	383	194	61	634	392	461
118	82	1120	1458	0	537	155	237	104	496	171	271	166	365	161	37	50	170
121			544	0	169	0	199	73	553	397	336	127	211	258	39	483	213
124			544	202	0	132	0	76	242	262	25	136	85	71	72		
127			1156		0		66		0	33	51	25	47	23	0		
130			216		0				166	0	0				66		
133					286					33	0						
136											84						

Table 10. Removals (number of fish, X 1000) at age of white hake from commercial fisheries in Div. 4VWX from 1999-2009.

Age	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1	0	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	1	0	0	0	3	1	2
3	71	15	29	6	7	20	3	9	28	8	10
4	650	214	187	70	44	127	47	66	178	140	111
5	507	448	372	287	158	223	216	158	221	333	229
6	110	303	260	421	230	164	212	148	96	181	185
7	21	82	84	115	114	93	101	76	26	29	47
8	6	28	27	55	38	40	41	19	13	10	8
9	5	12	12	18	13	20	20	13	10	4	5
10	2	4	5	11	2	6	14	9	5	6	4
11	1	4	5	3	4	1	5	4	6	3	2
12	1	2	2	4	2	3	2	5	2	1	1
13	0	1	1	1	0	0	2	2	1	0	0
14	0	1	4	1	0	0	1	0	0	0	0
15	0	0	0	0	0	0	0	1	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0

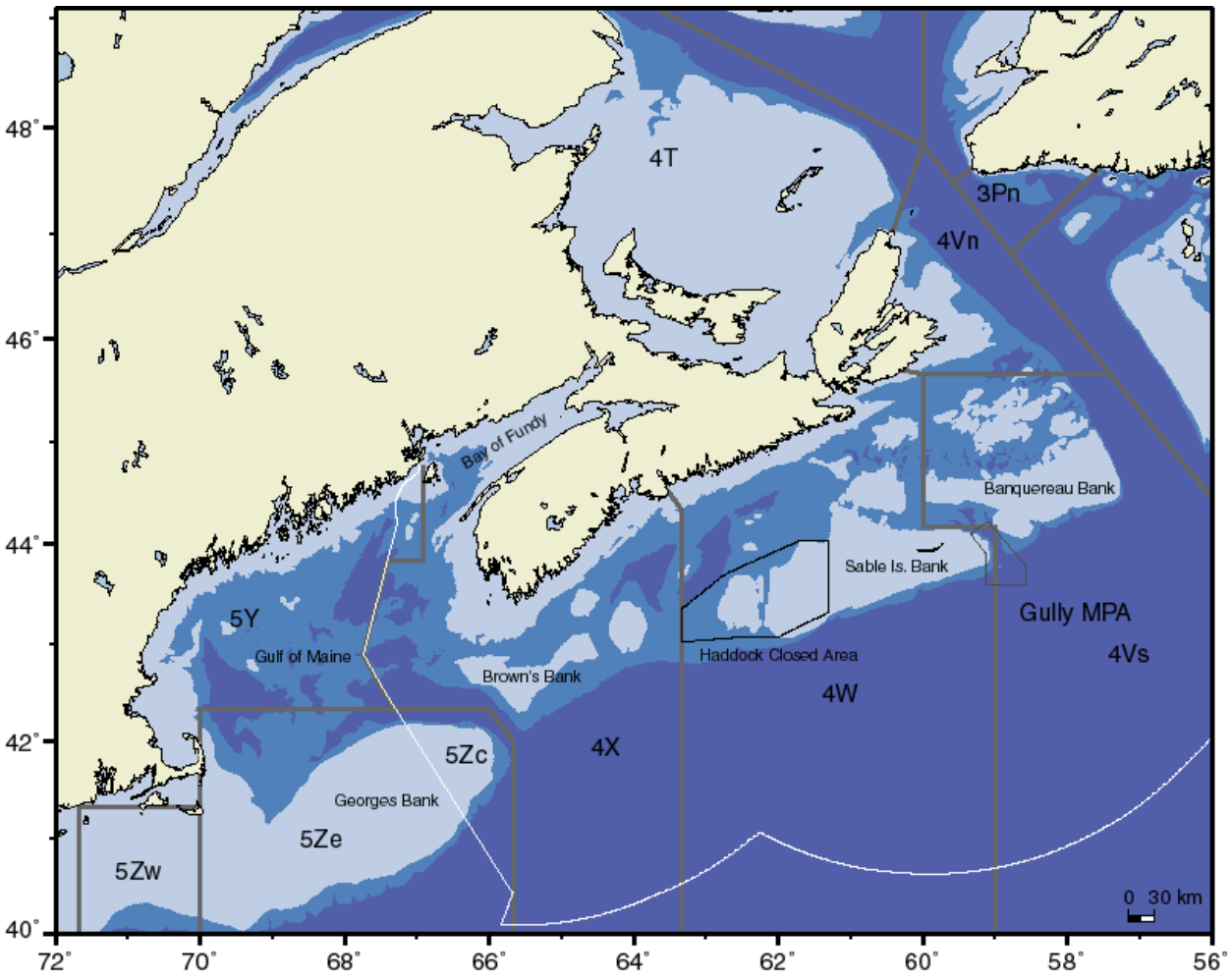

Figure 1. NAFO Divisions and principle areas described in this document.

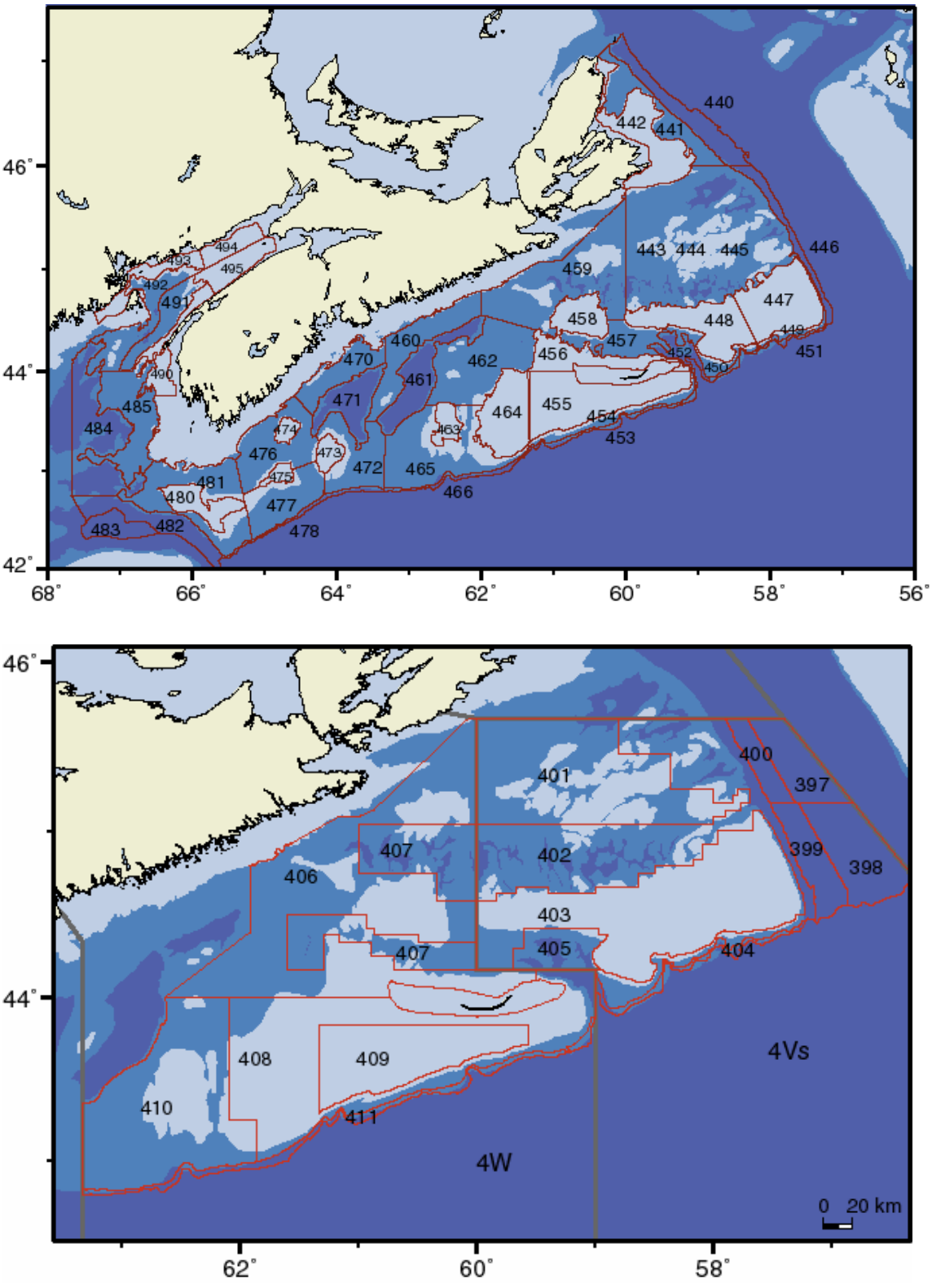

Figure 2. Survey strata used during the summer RV survey (top panel) and the Spring 4VsW (4VWCOD) RV Survey (bottom panel). The deepwater strata added in 1995 to the summer RV survey are not displayed.

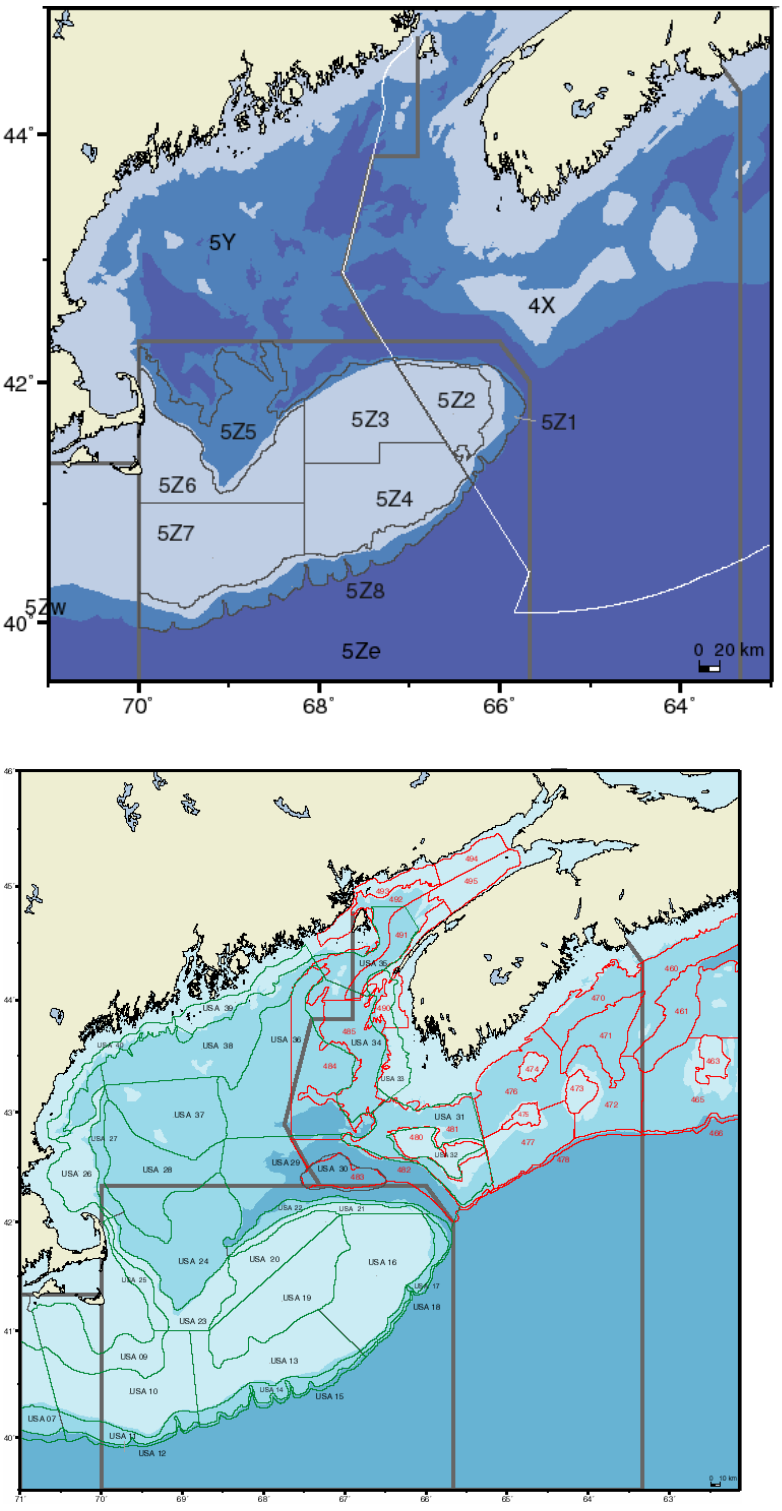

Figure 3. Survey strata used during the Canadian RV survey on Georges Bank (top panel), as well as survey strata used during the USA spring and fall RV surveys of Georges Banks and the Gulf of Maine (bottom panel). The Canada/USA border is indicated in the top panel.

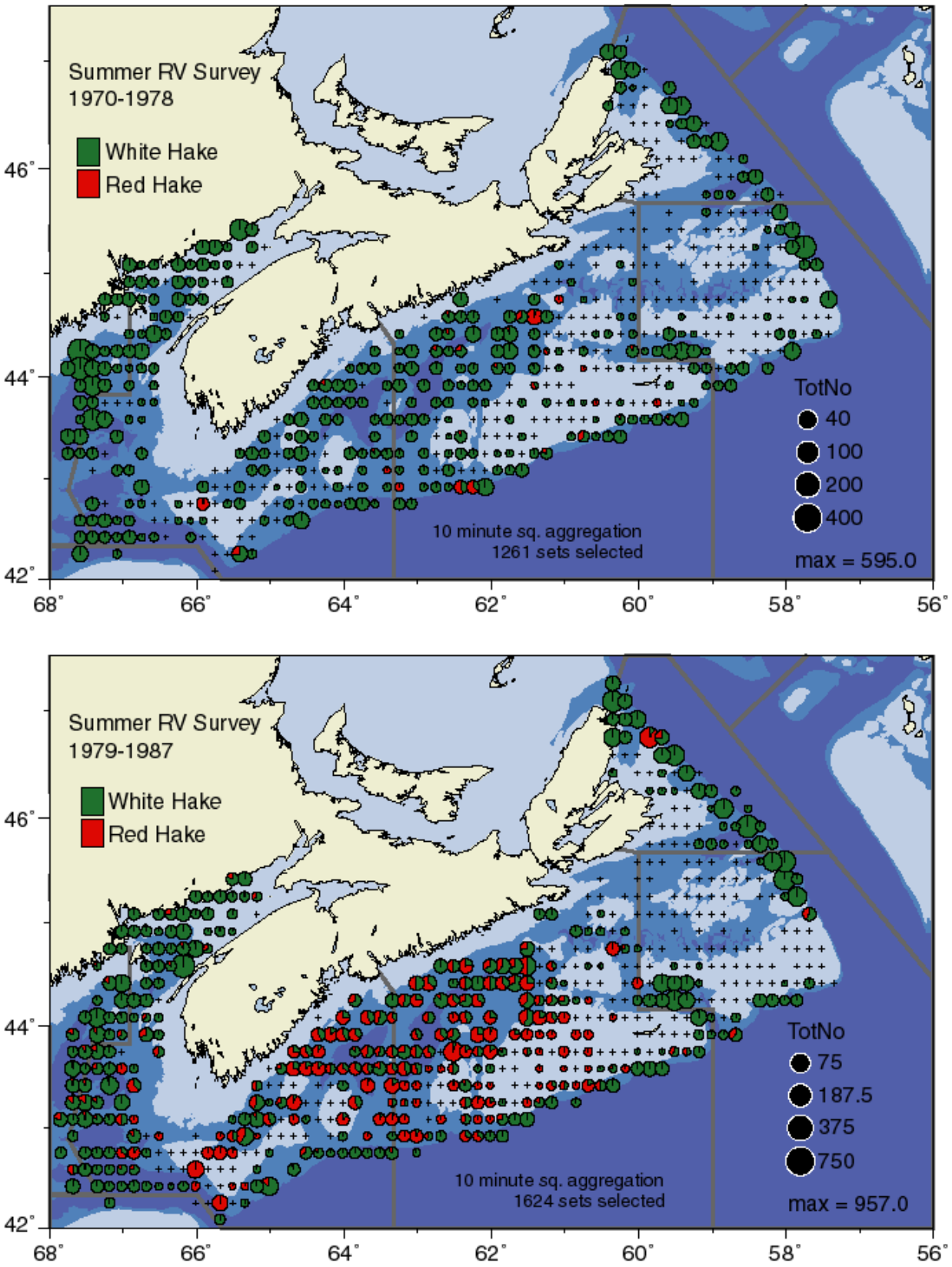

Figure 4. Distribution of white and red hake from the summer RV survey, 1970-1978 (top panel), 1979-1987 (bottom panel).

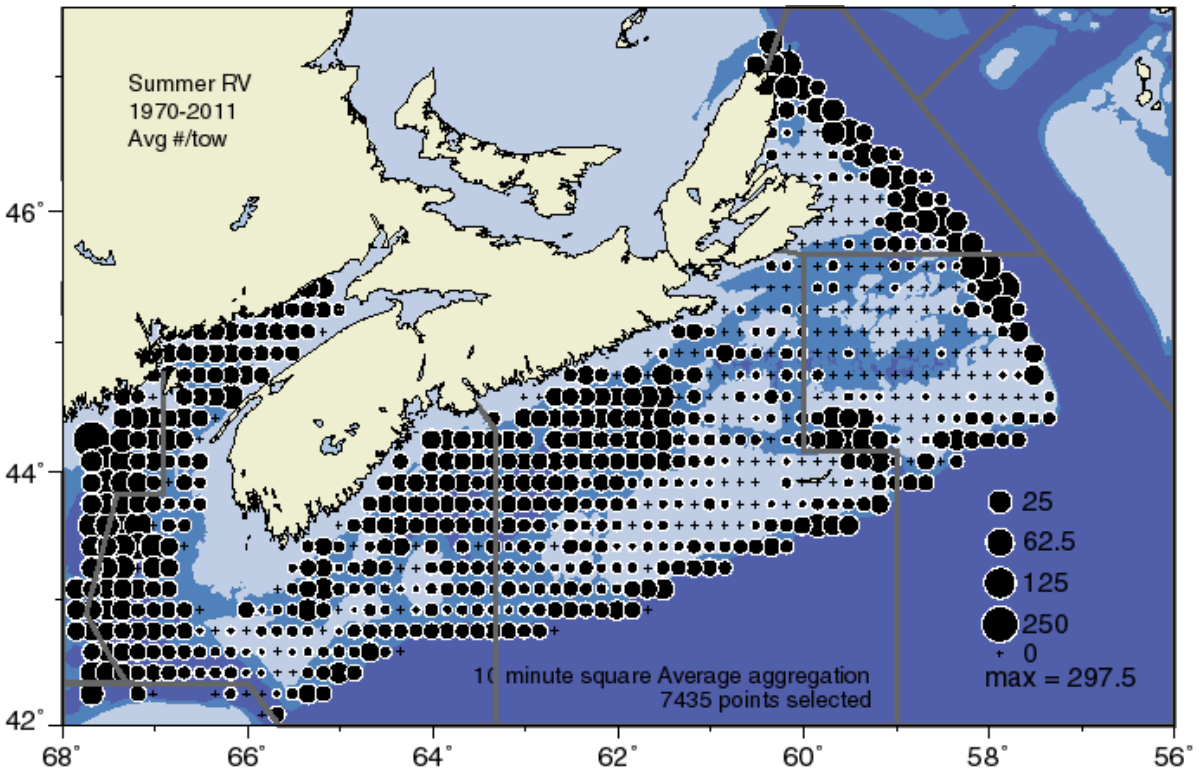

Figure 5. Distribution of white hake as indicated by the summer RV survey on the Scotian Shelf, 1970-2011.

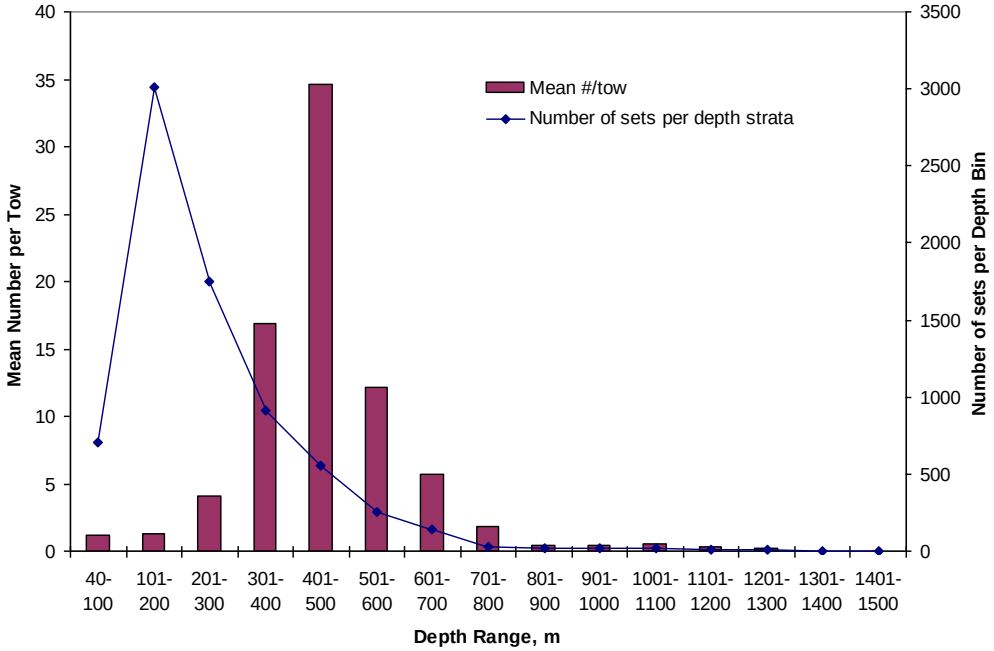

Figure 6. Mean catch rate (number per tow) of white hake and number of sets by depth bin as indicated by the summer RV survey, 1970-2011.

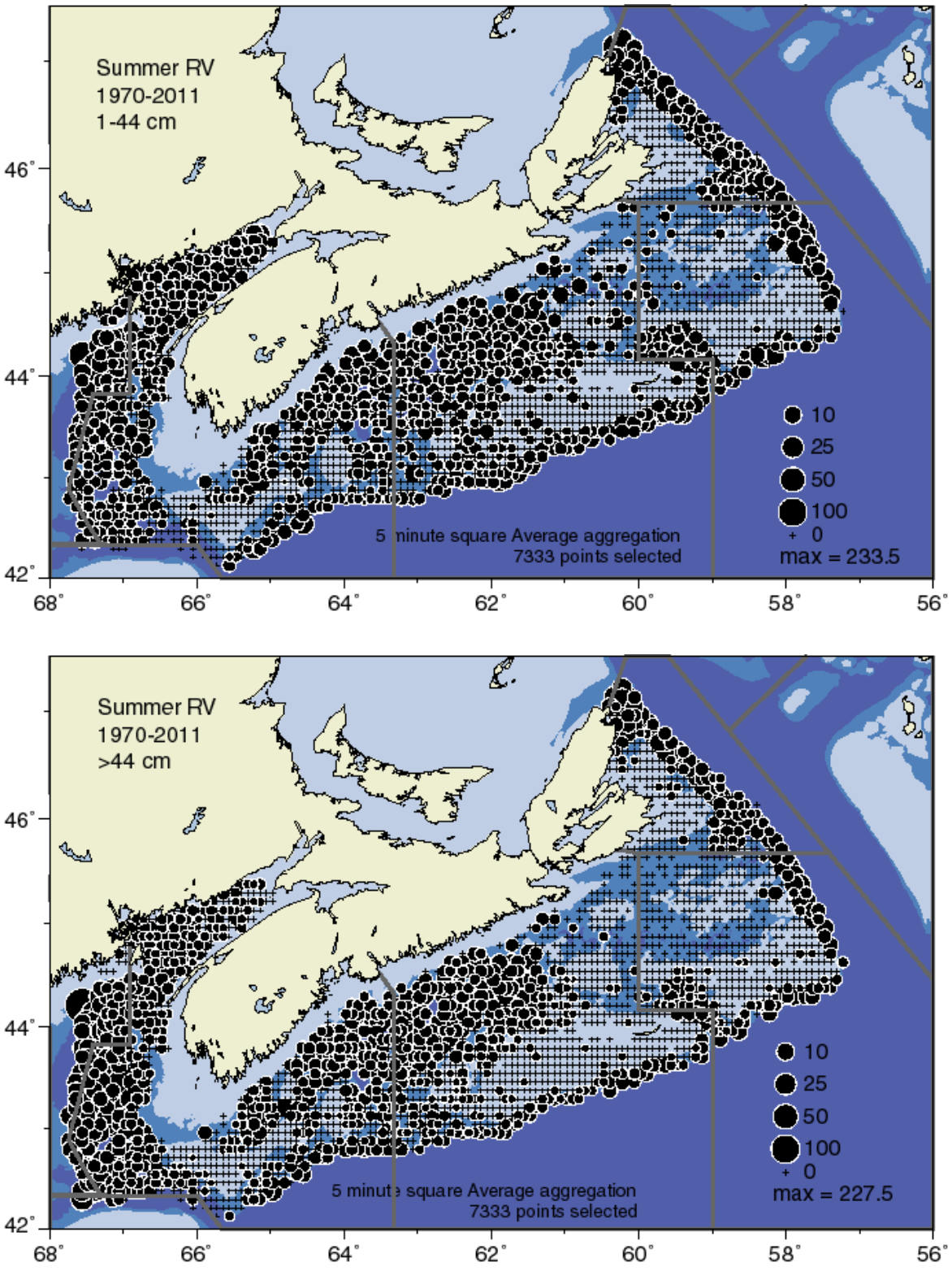

Figure 7. Distribution of immature (1-44 cm; top panel) and mature (>44 cm; bottom panel) white hake as indicated by the summer RV survey, (1970-2011). This figure does not include the deepwater sets on the edge of the Scotian Shelf.

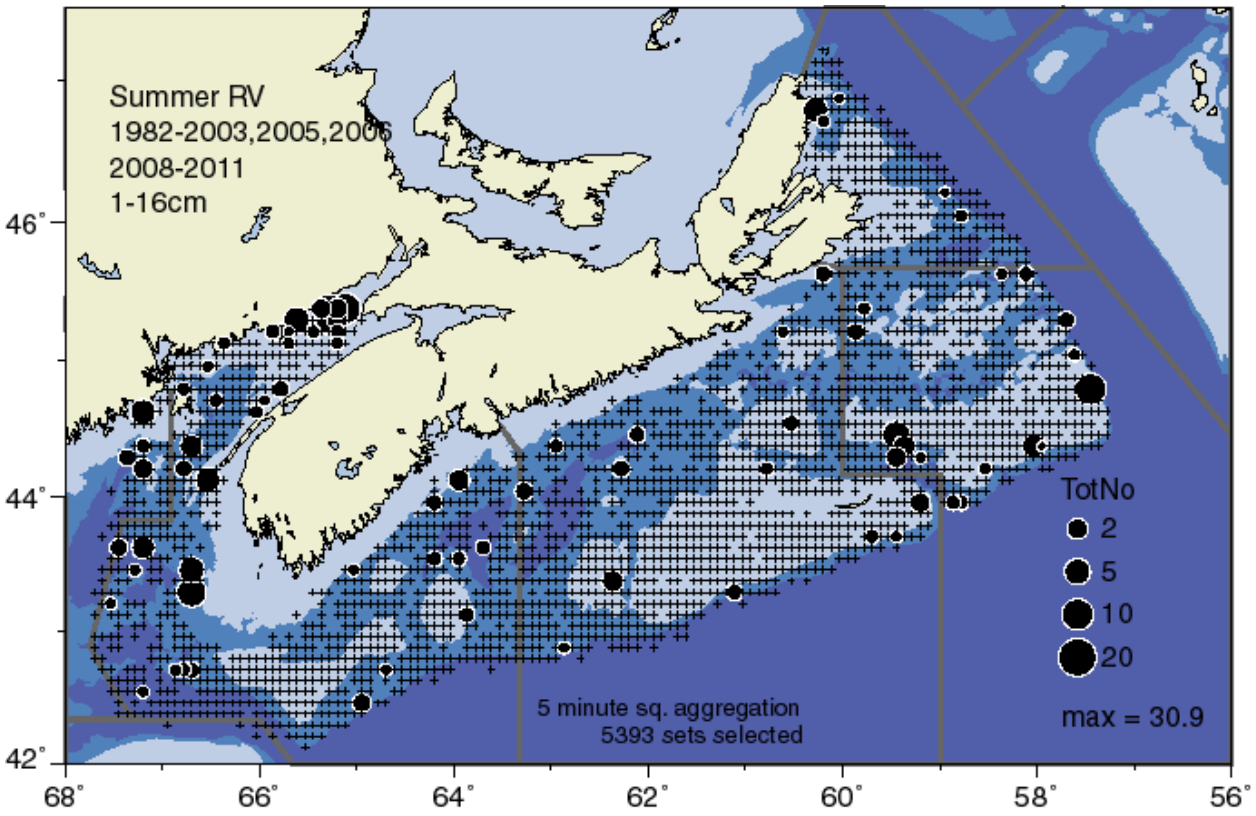

Figure 8. Recruitment of white hake 1-16 cm onto the Scotian Shelf as indicated by the summer RV survey, 1982-2003, 2005, 2006, 2008-2011.

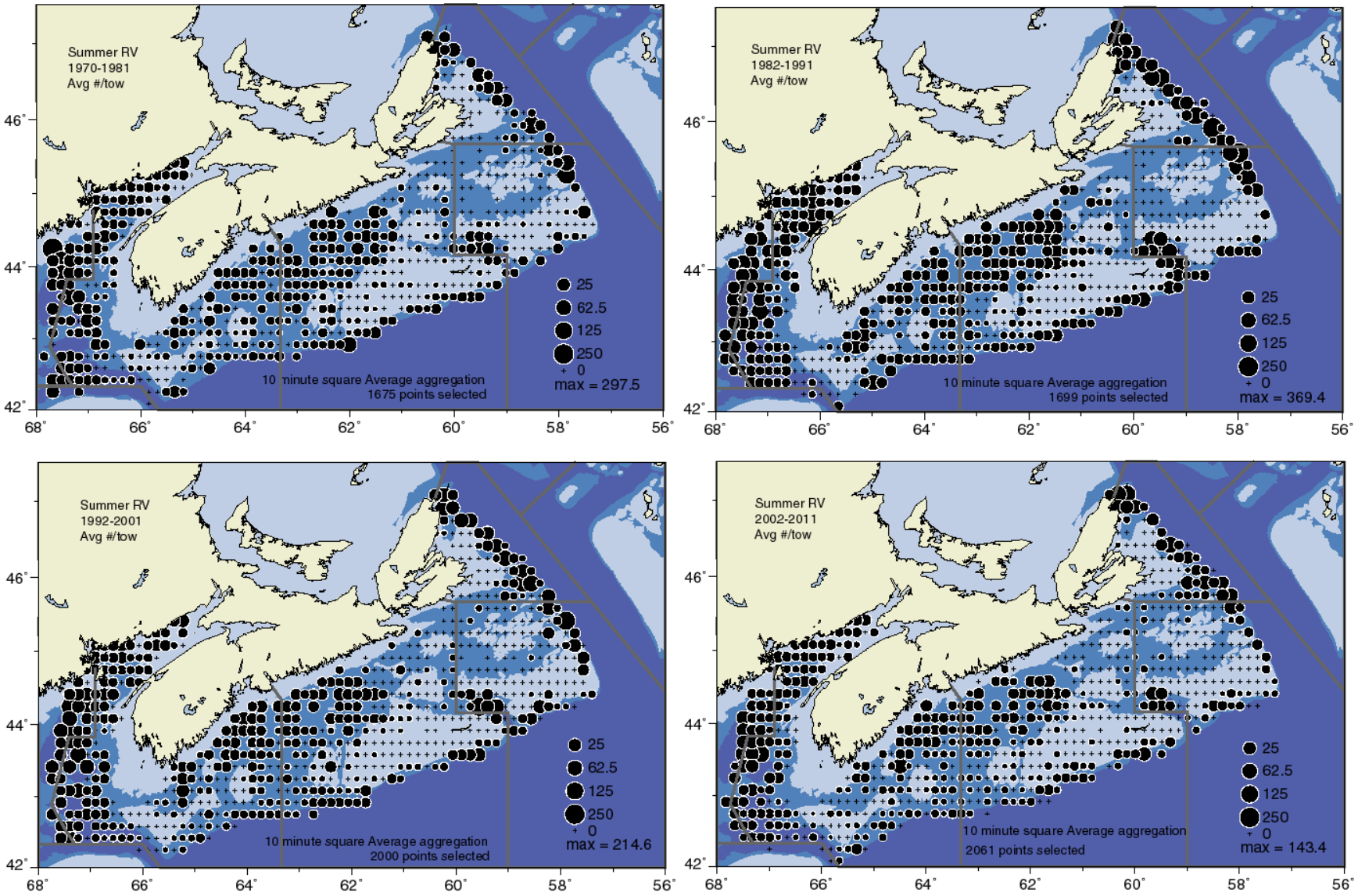

Figure 9. Distribution of white hake as indicated by the summer RV survey, by approximate decadal periods, 1970-1981, 1982-1991, 1992-2001 and 2002-2011.

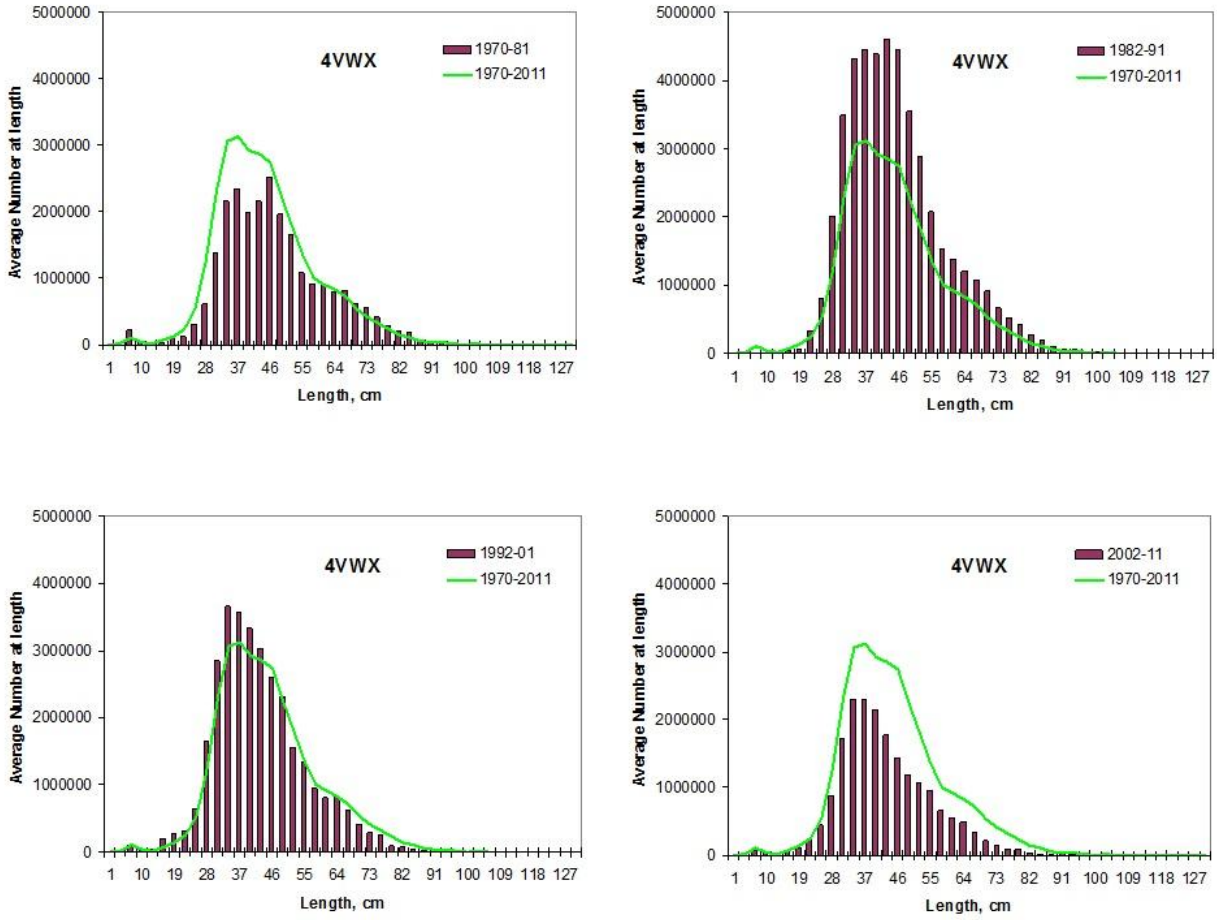

Figure 10. Mean total number at length from the summer RV survey by decadal period in Div. 4VWX. These periods correspond to the distribution plots in Figure 9.

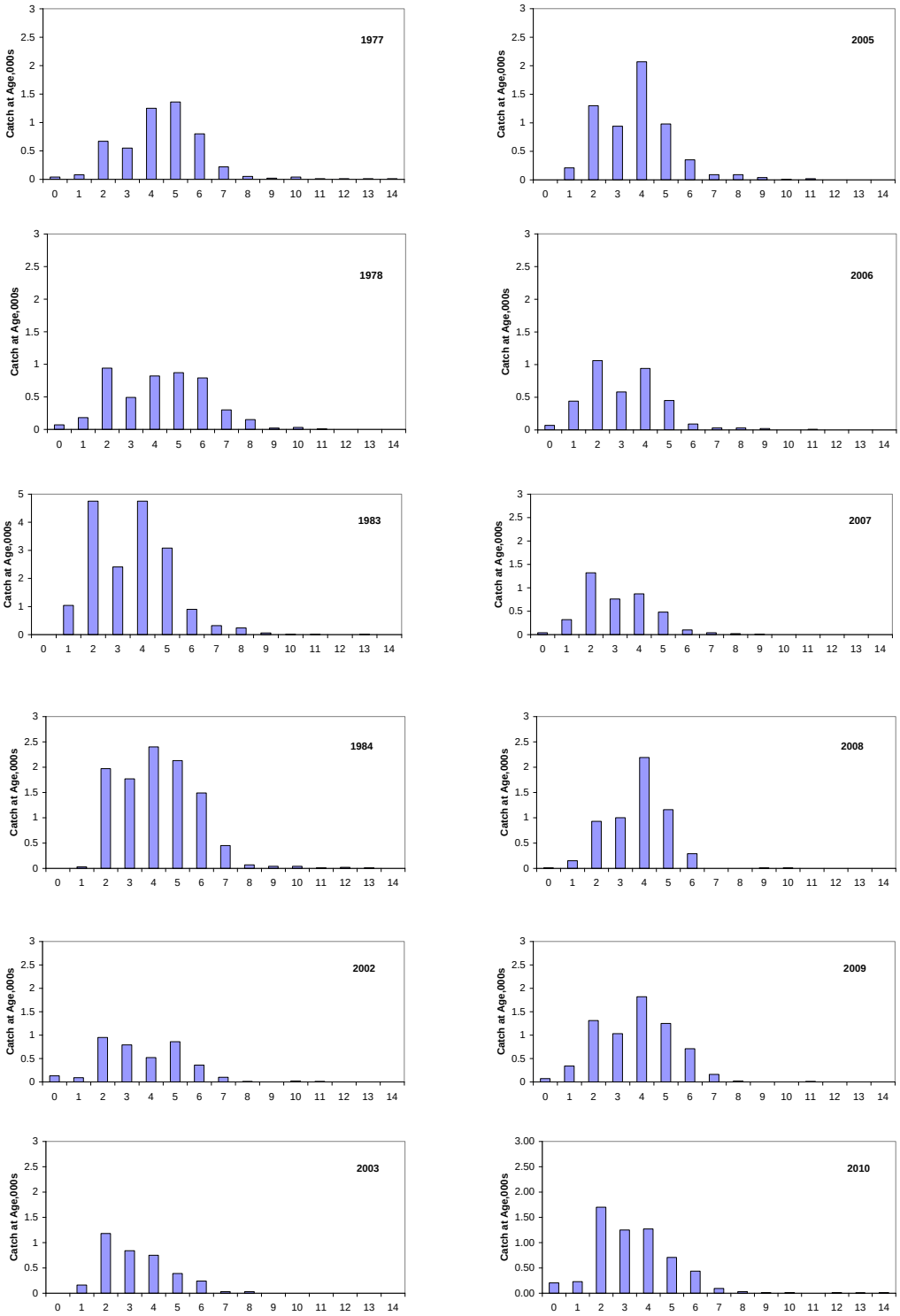

Figure 11. Catch at age (number of fish X 1000) of white hake from the summer RV survey by year when available, 1977 to 2010).

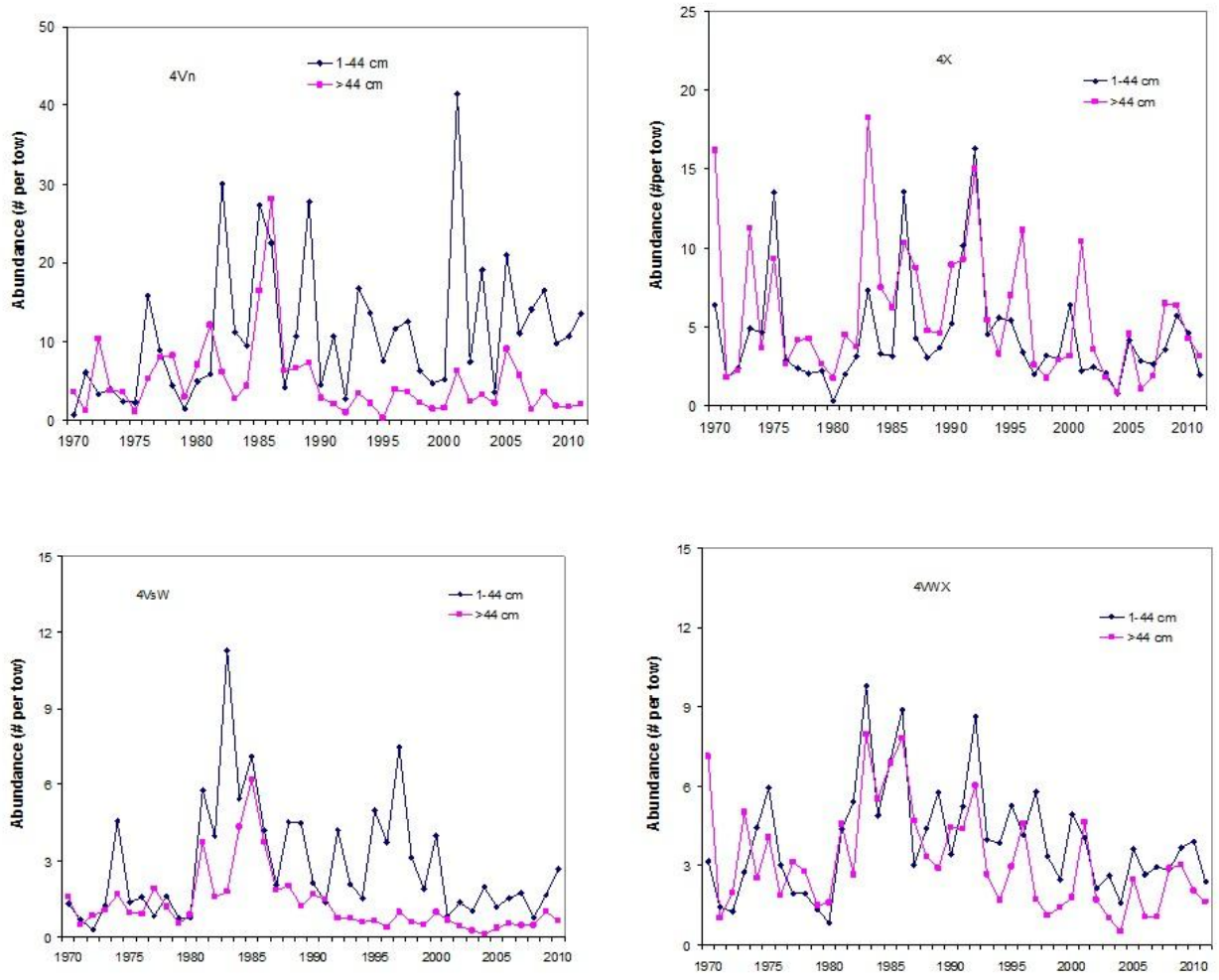

Figure 12. Annual abundance (number per tow) of white hake, 1-44 cm (immature) and >44 cm (mature) as indicated by the summer RV survey, 1970-2011, from NAFO Subdiv. 4Vn, Div. 4VsW, 4X and 4VWX.

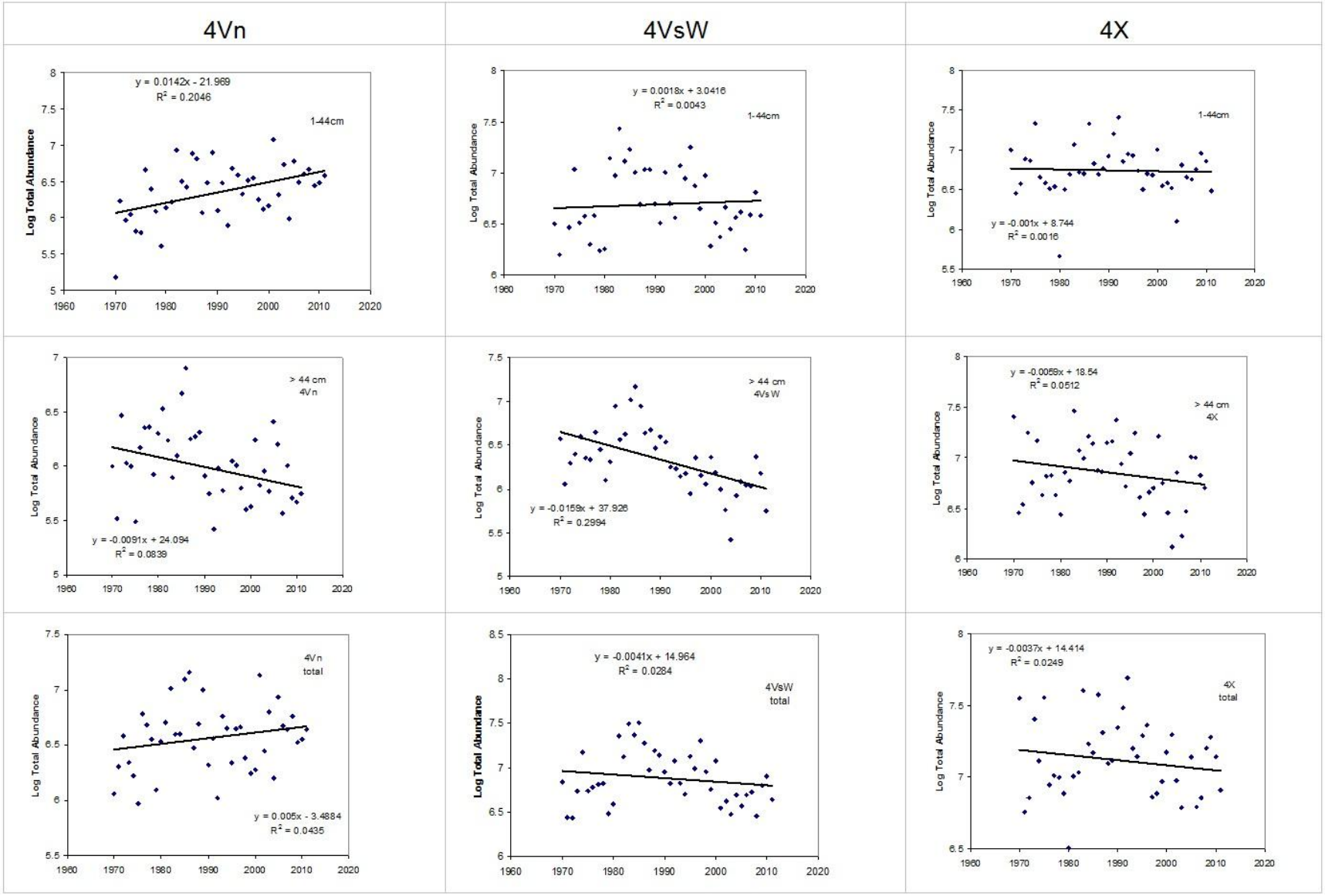

Figure 13. Log transformed catch rate (number per tow) of immature (1-44 cm; top row), mature (>44 cm; middle row) and all length groups combined (bottom row) of white hake during the summer RV survey, 1970-2011 (42 years) from NAFO Subdiv. 4Vn (left column panels), Div. 4VsW (middle column panels), and Div. 4X (right column panels).

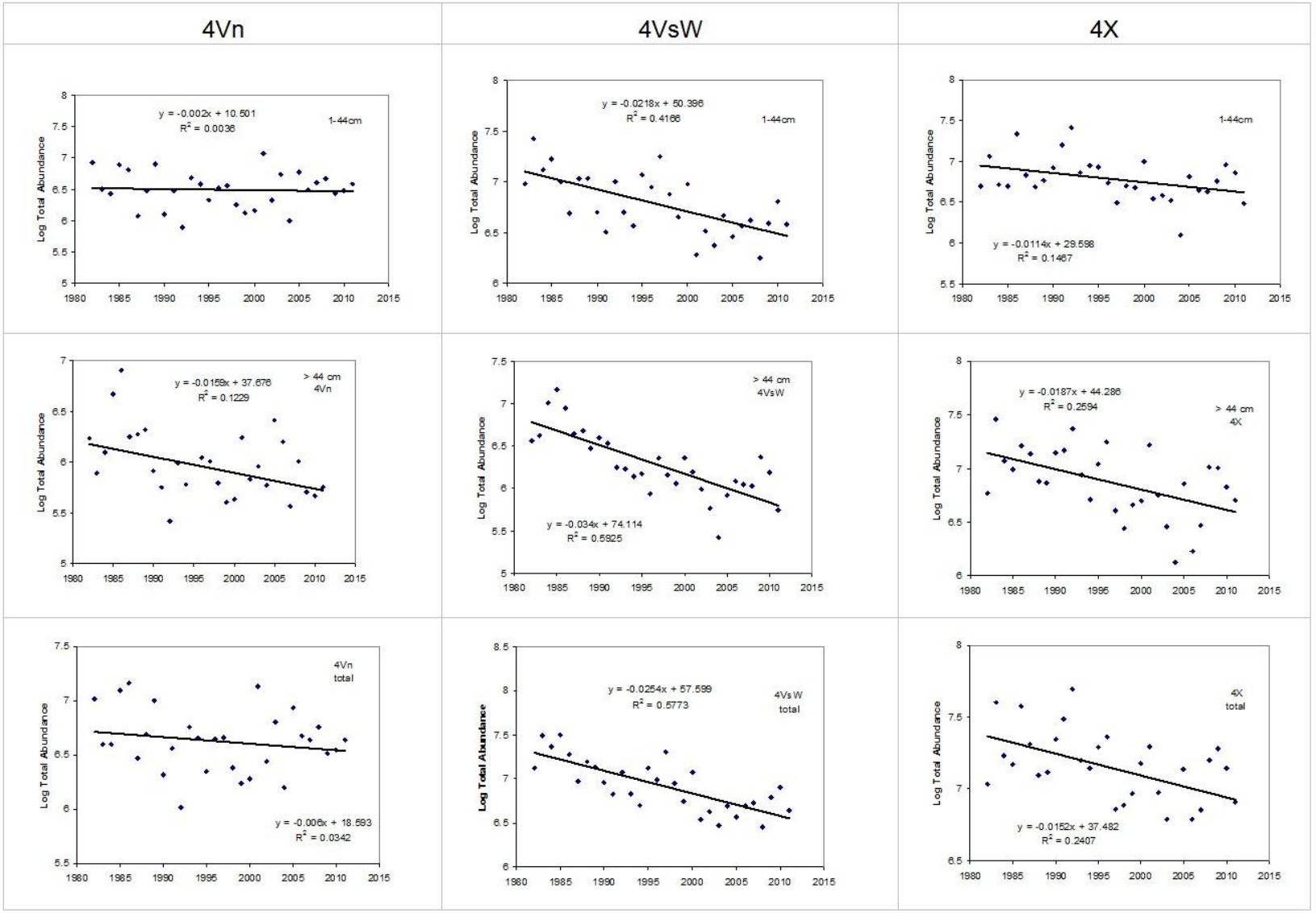

Figure 14. Log transformed catch rate (number per tow) of immature (1-44 cm; top row), mature (>44 cm; middle row) and all length groups combined (bottom row) of white hake during the summer RV survey, 1982-2011 (30 years) from NAFO Subdiv. 4Vn (left column panels), Div. 4VsW (middle column panels), and Div. 4X (right column panels).

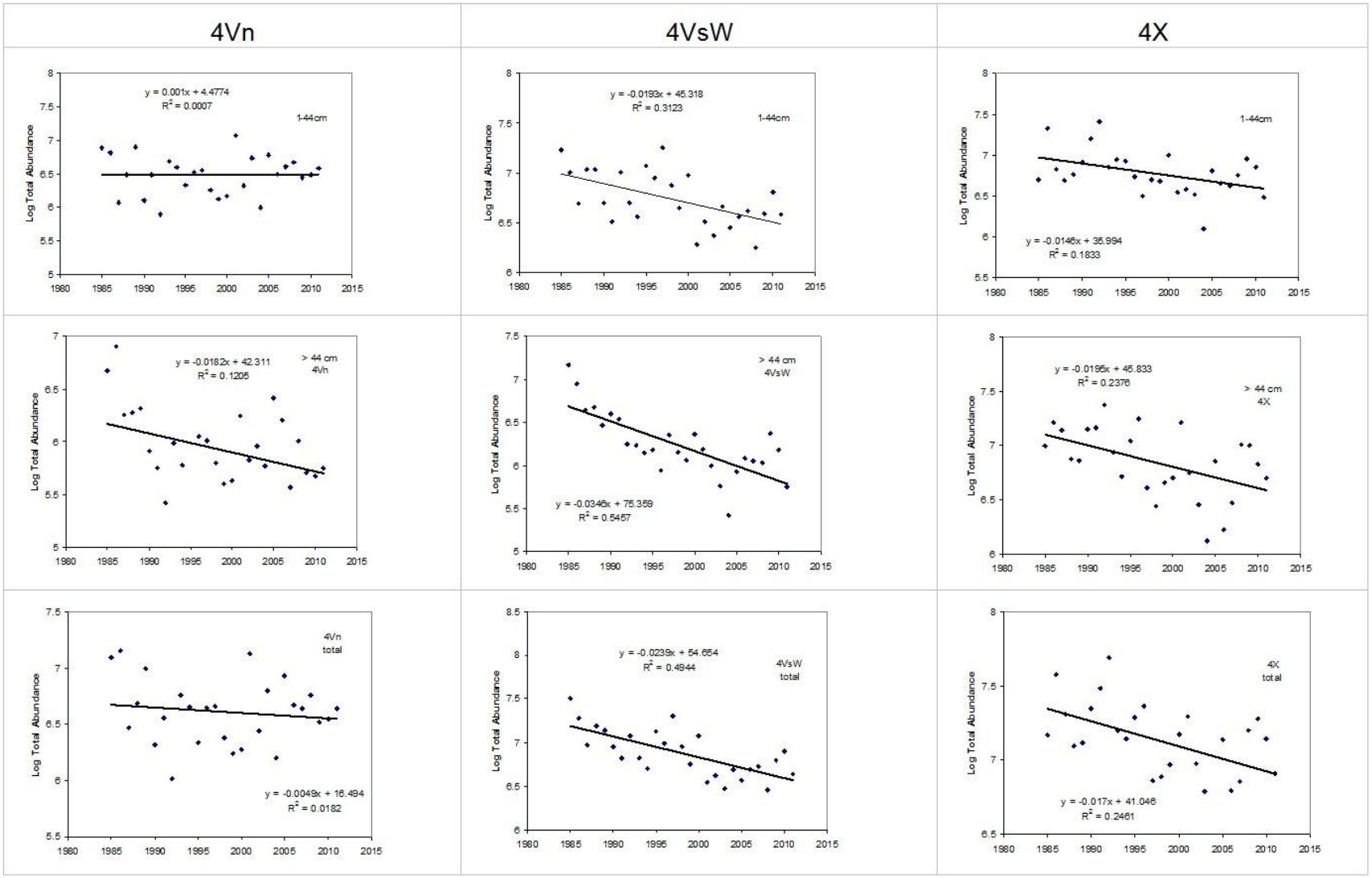

Figure 15. Log transformed catch rate (number per tow) of immature (1-44 cm; top row), mature (>44 cm; middle row) and all length groups combined (bottom row) of white hake during the summer RV survey, 1985-2011 (27 years or three generations) from NAFO Subdiv. 4Vn (left column panels), Div. 4VsW (middle column panels), and Div. 4X (right column panels).

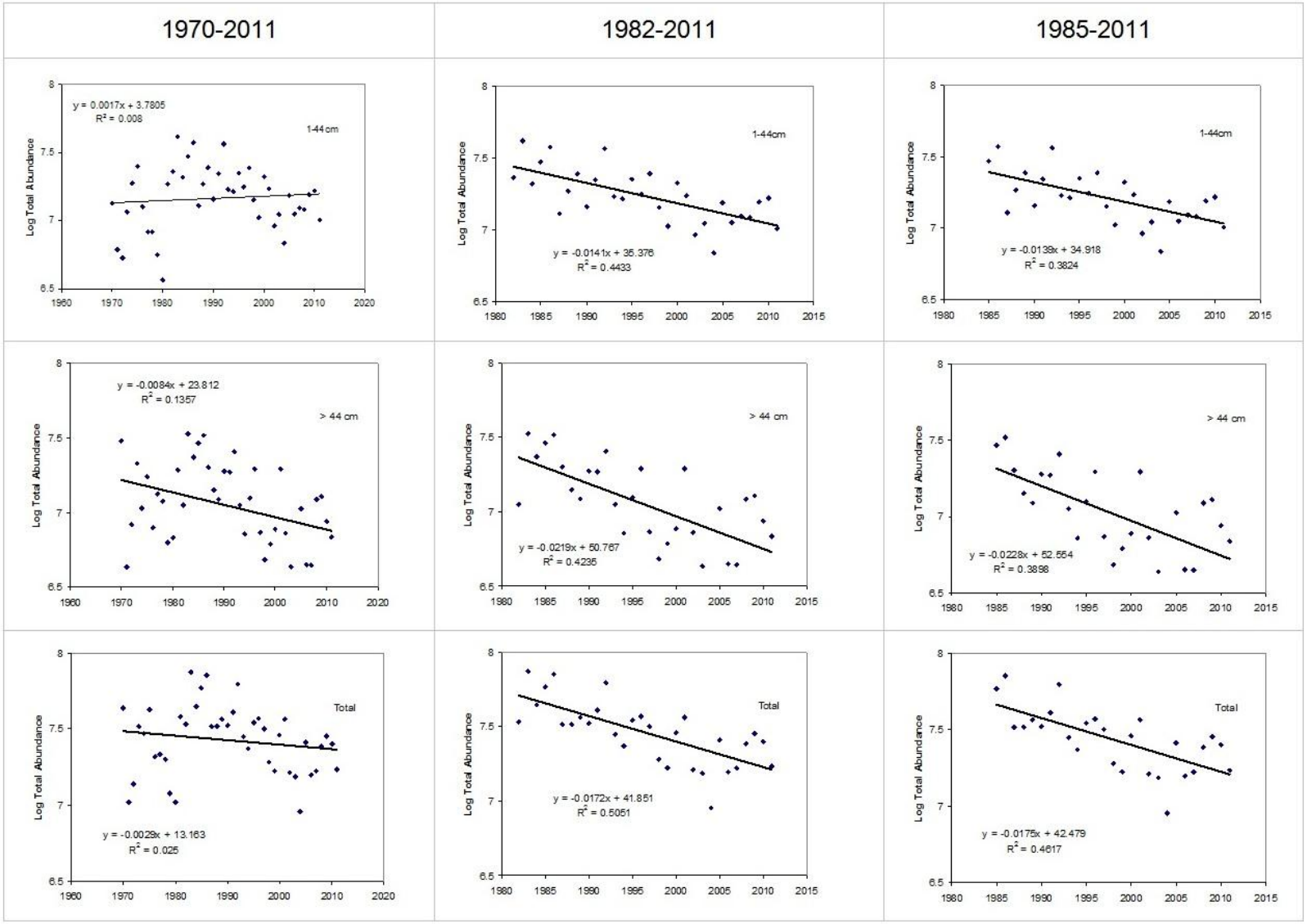

Figure 16. Log transformed catch rate (number per tow) of immature (1-44 cm; top row), mature (>44 cm; middle row) and all length groups combined (bottom row) of white hake during the summer RV survey from NAFO Div. 4VWX for three time periods; 1970-2011 (left column panels), 1982-2011 (middle column panels), and 1985-2011(right column panels).

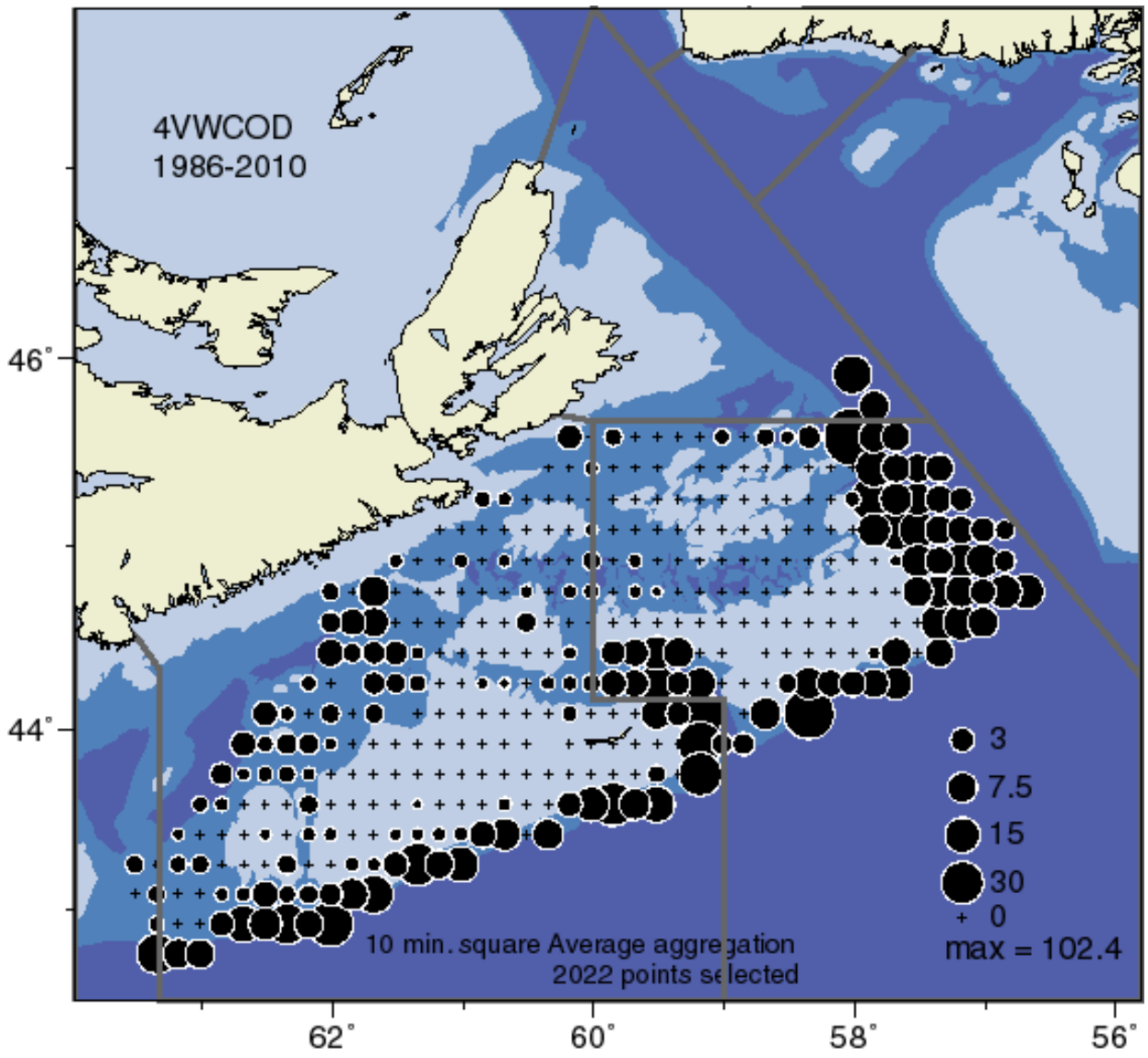

Figure 17. Distribution of white hake from the Spring 4VsW (4VWCOD) RV Survey on the eastern Scotian Shelf, 1986-2010. During some years, coverage was incomplete and the 1998, 2004 surveys are missing.

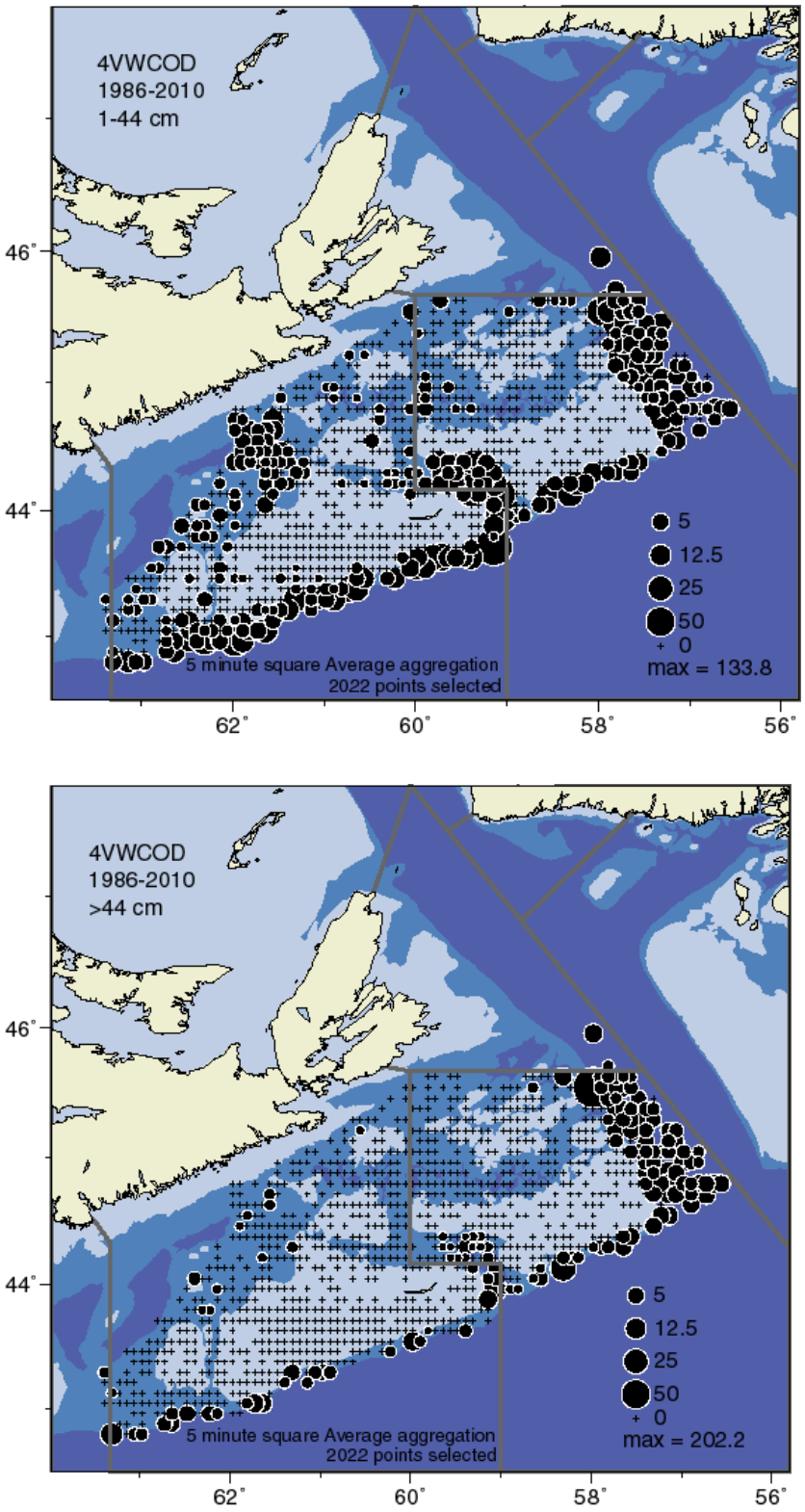

Figure 18. Distribution of immature (1-44 cm; top panel) and mature (>44 cm; bottom panel) white hake from the Spring 4VsW (4VWCOD) RV Survey on the eastern Scotian Shelf, 1986-2010. During some years, coverage was incomplete and the 1998, 2004 surveys are missing.

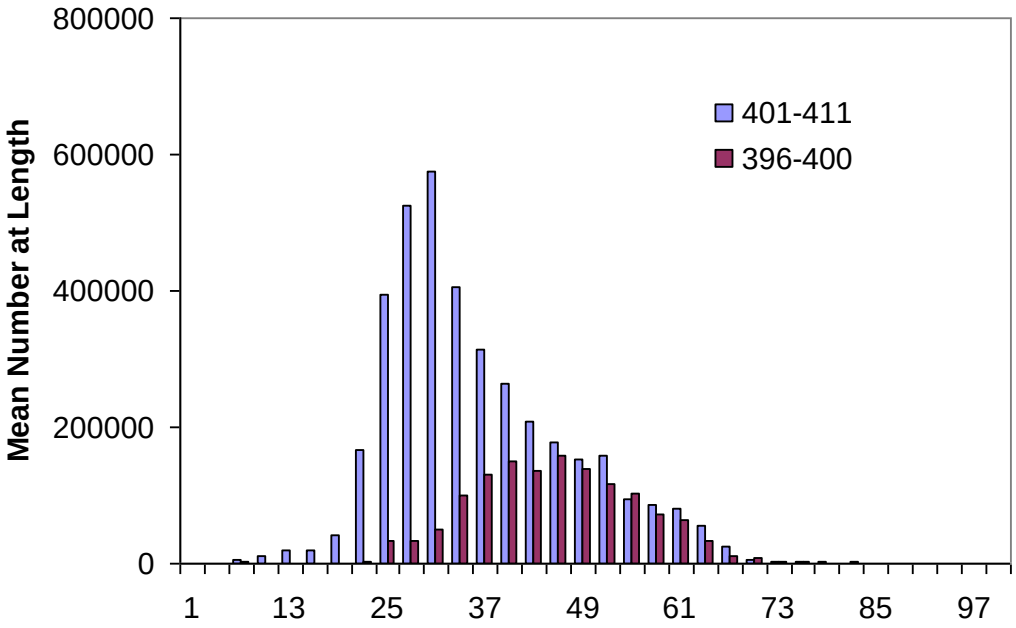

Figure 19. Total number at length (cm) per year of white hake from the core (401-411), as well as deepwater strata (396-400) in the Laurentian Channel of the Spring 4VsW (4VWCOD) RV Survey, 1986-2010.

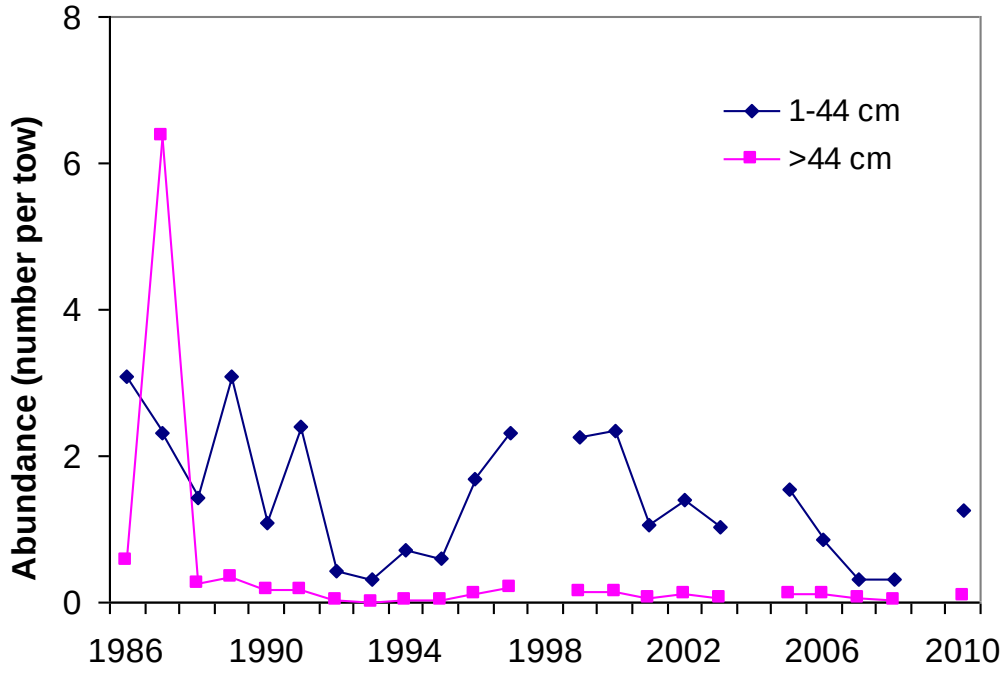

Figure 20. Abundance (number per tow) of immature (1-44 cm) and mature (>44 cm) white hake during the Spring 4VsW (4VWCOD) RV Survey, 1986-2010. Note that the 1998, 2004, and 2009 surveys are missing or incomplete.

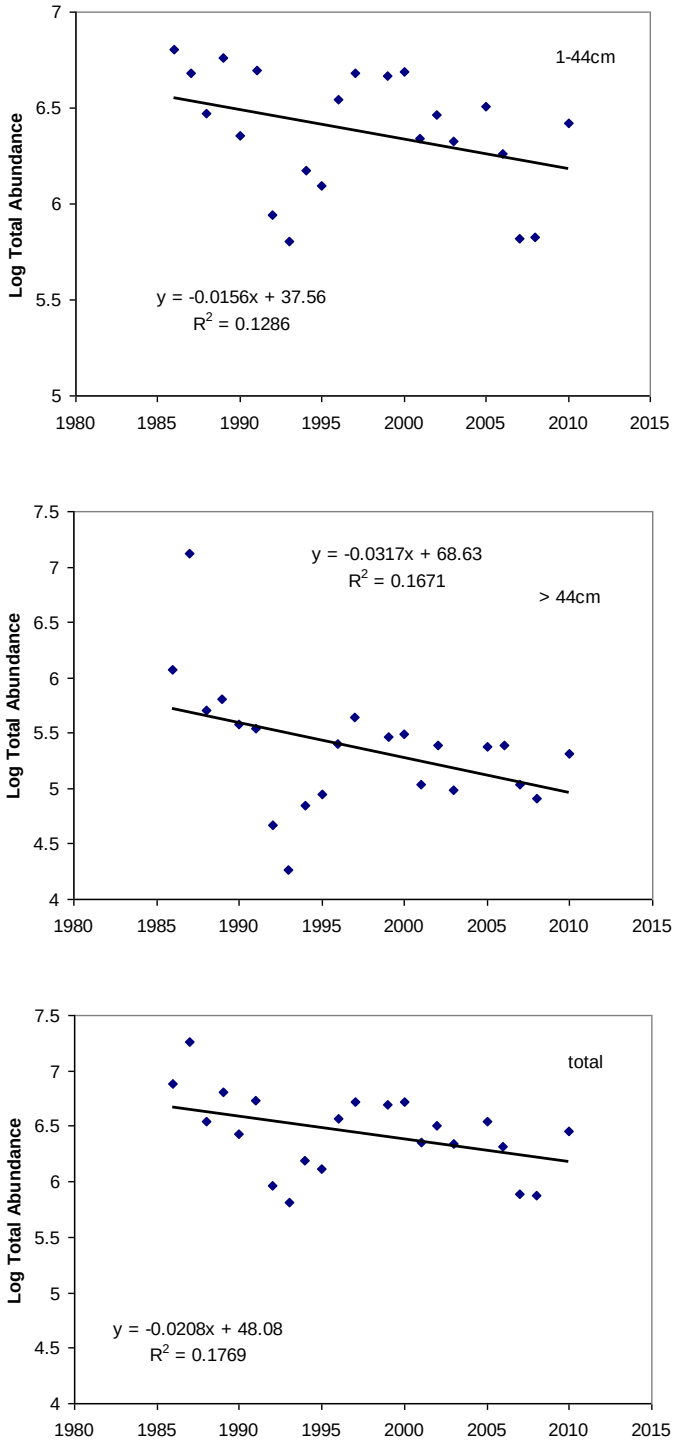

Figure 21. Log transformed catch rate (total number) of immature (upper panel), mature (middle panel) and all sizes (bottom panel) of white hake during the Spring 4VsW (4VWCOD) RV Survey, 1986-2010. Note that the 1998, 2004, and 2009 surveys are missing or incomplete.

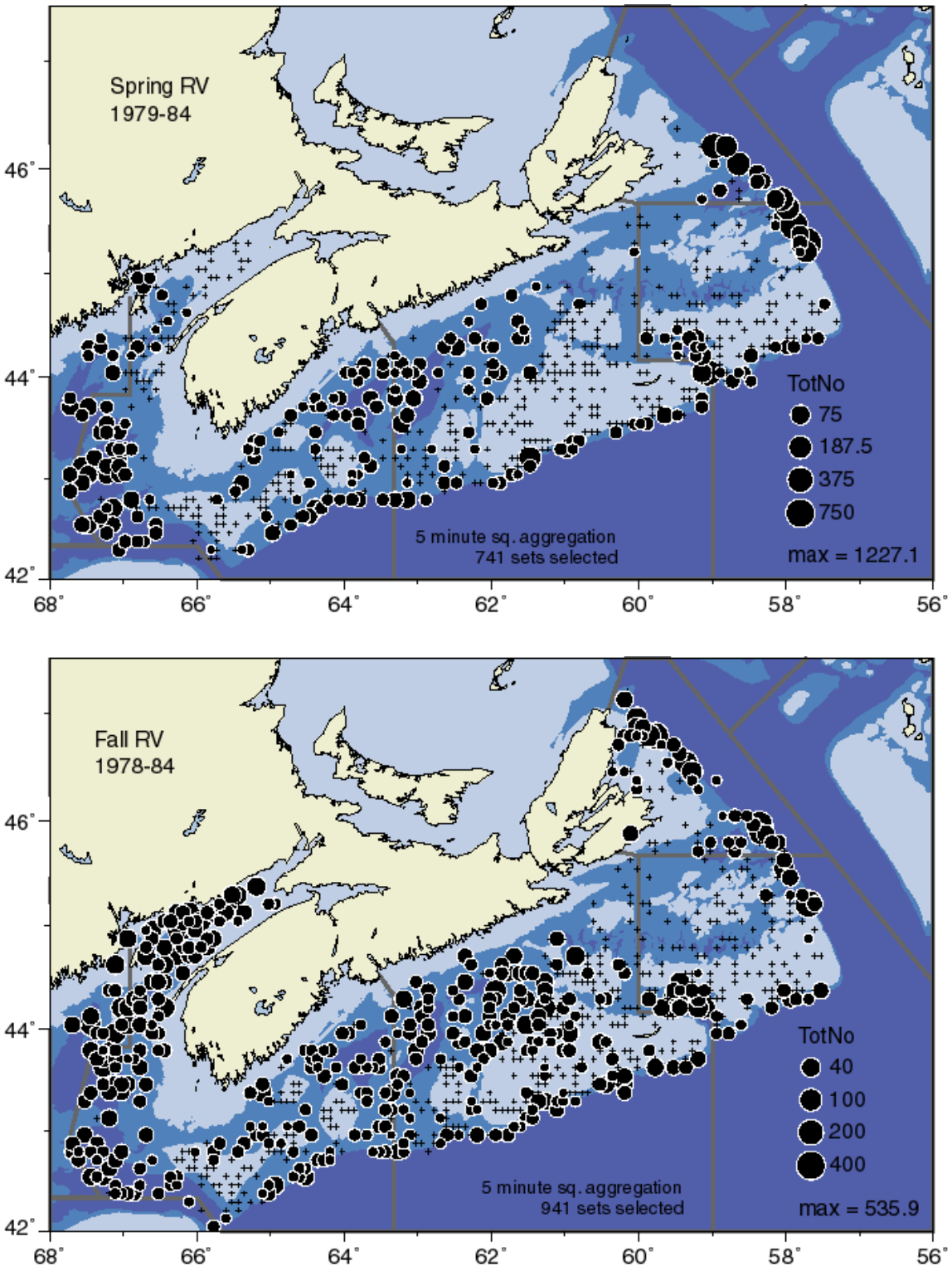

Figure 22. Distribution of white hake as indicated by the spring (top panel) and fall (bottom panel) RV surveys of the Scotian Shelf.

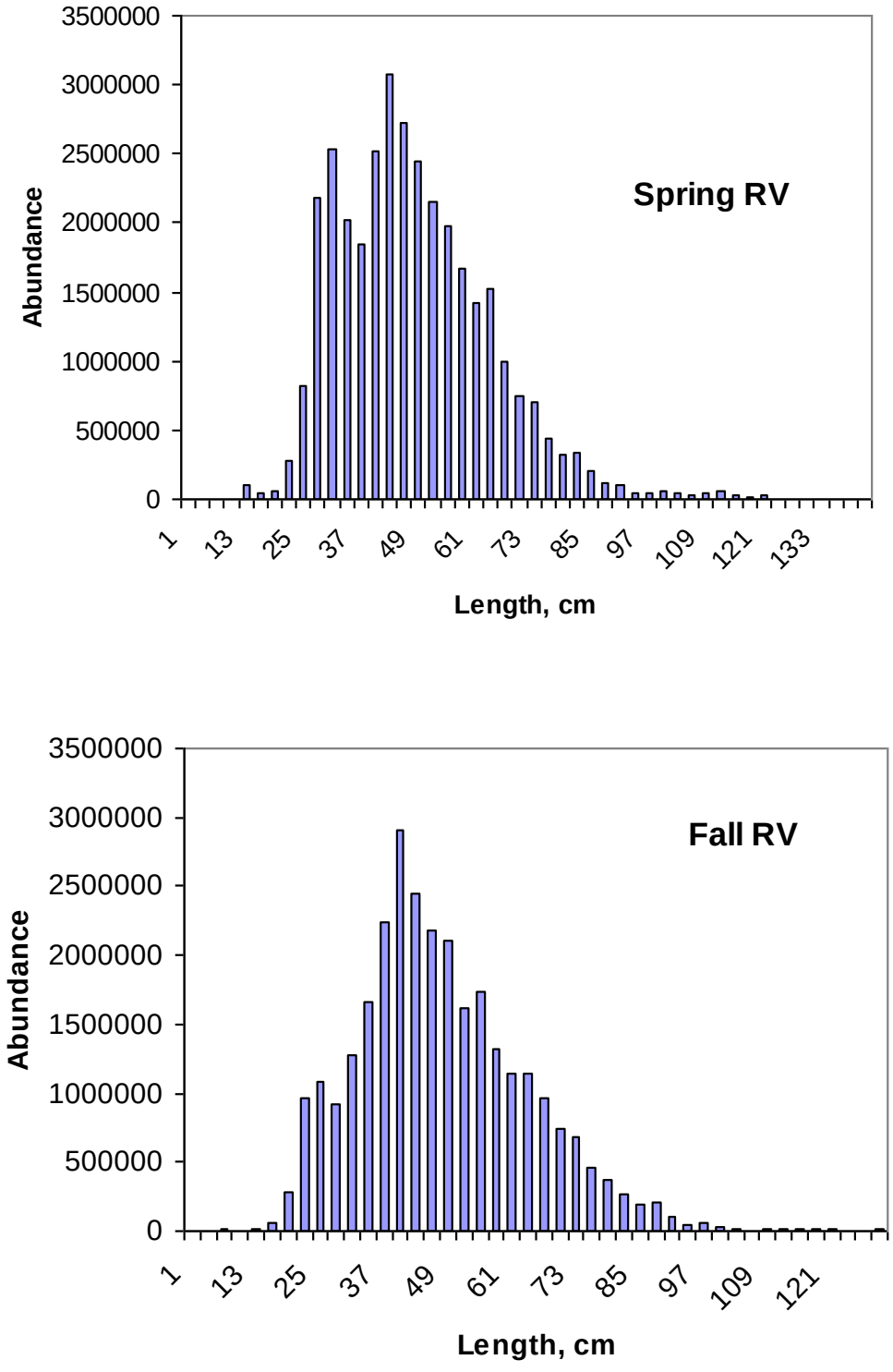

Figure 23. Total number at length (cm) per year of white hake from the spring (top panel) and fall (bottom panel) RV surveys of the Scotian Shelf, 1978-1984.

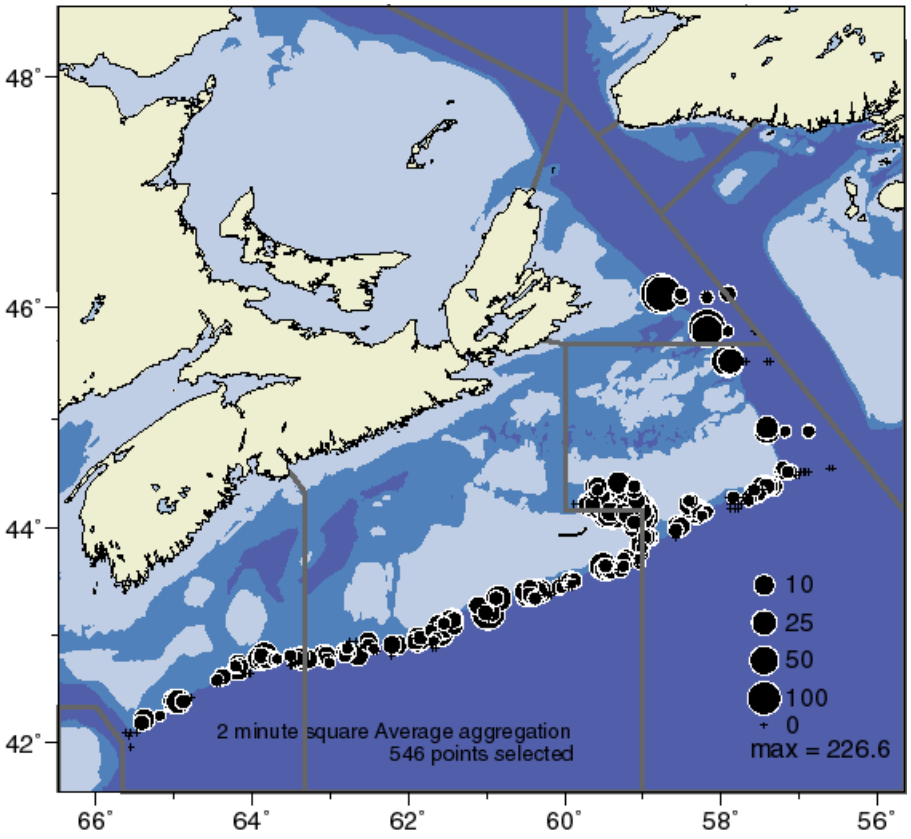

Figure 24. Distribution of white hake as indicated by the DFO Redfish RV Survey, 1982-1988.

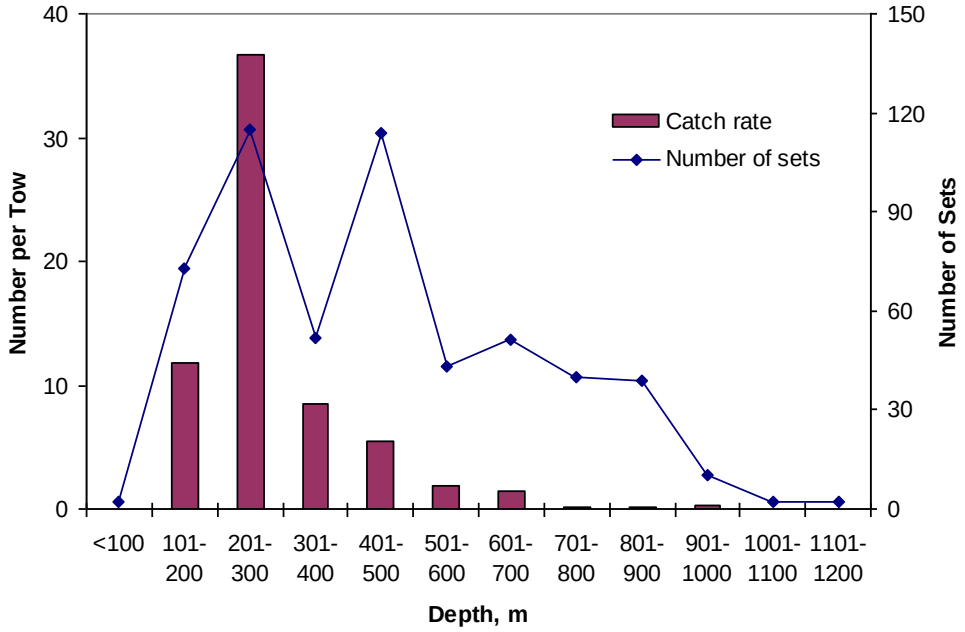

Figure 25. Abundance (number per tow) of white hake and number of sets per depth bin (m) from the DFO Redfish RV Surveys, 1982-1988 in Div. 4VWX.

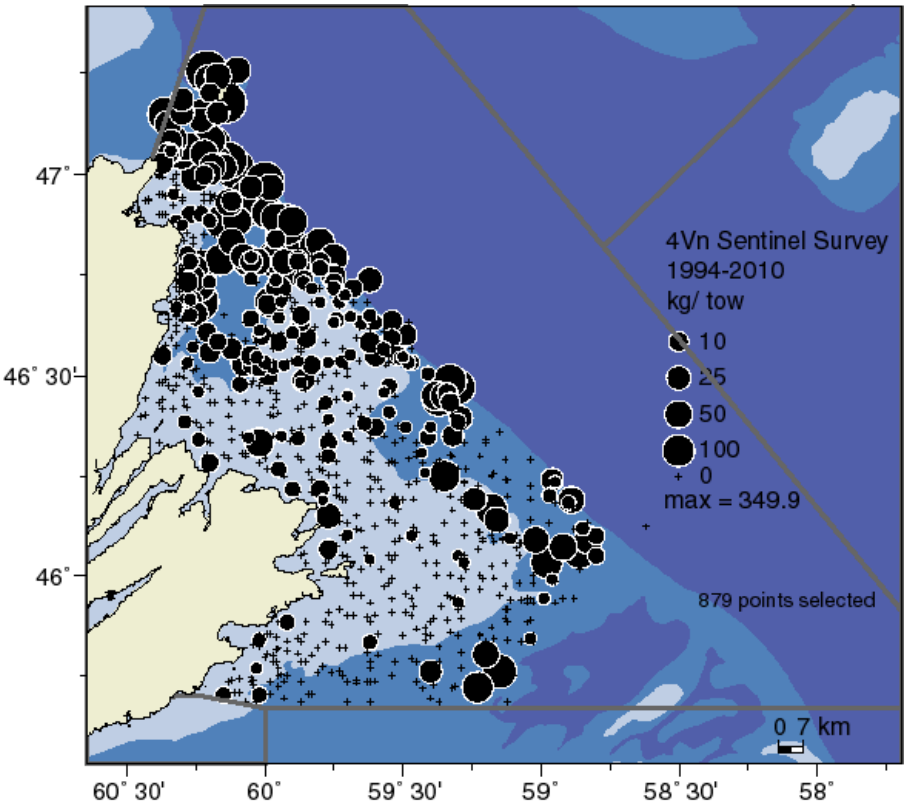

Figure 26. Distribution of white hake as indicated by the September, 4Vn Sentinel Longline Survey, 1994-2010.

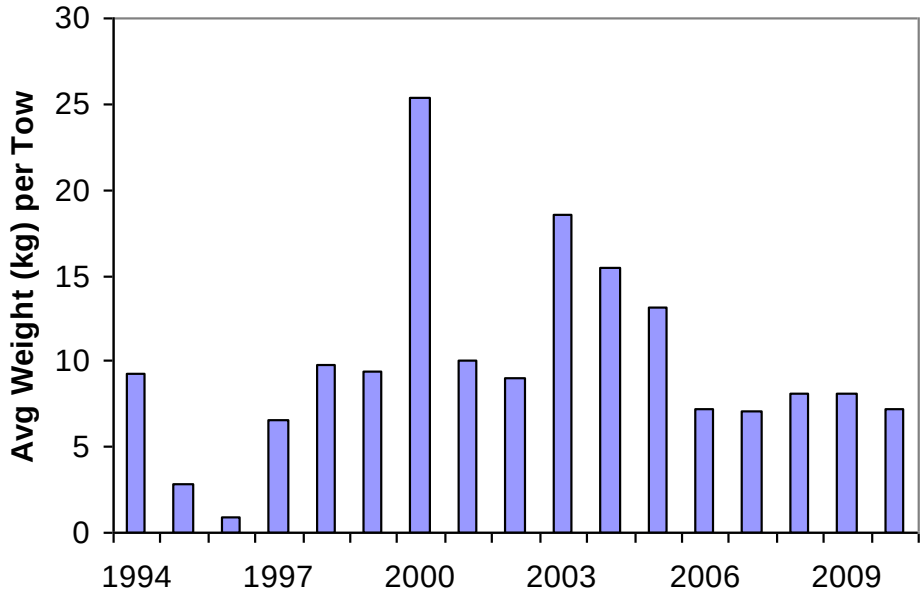

Figure 27. Abundance (weight (kg) per tow) of white hake as indicated by the 4Vn Sentinel Survey in Subdiv. 4Vn, 1994 to 2010.

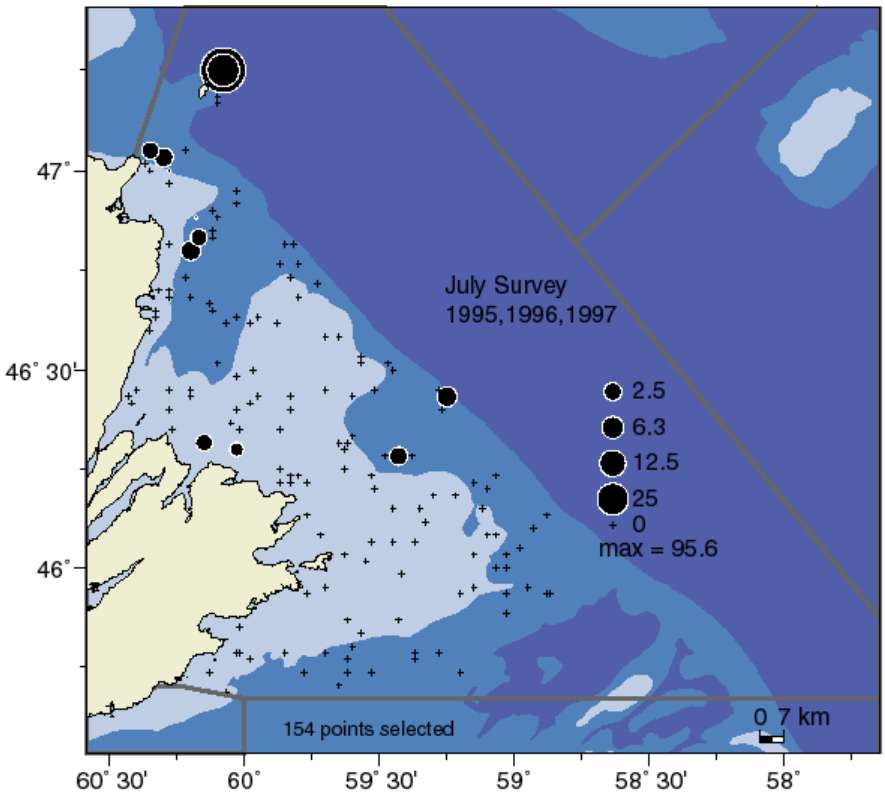

Figure 28. Distribution of white hake as indicated by the July 4Vn Sentinel Longline Survey, 1995-1997.

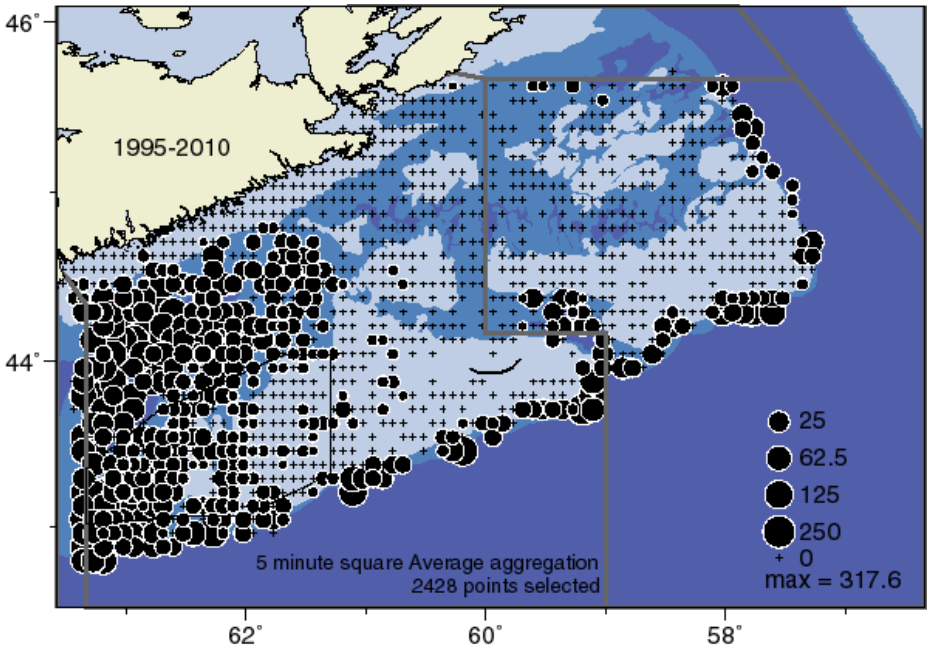

Figure 29. Distribution of white hake as indicated by the 4VsW Sentinel Industry Longline Survey, 1996-2010. The survey has been restricted to the two inshore strata along the eastern shore of Nova Scotia and the four offshore strata that extend out to the Haddock Box since 2004.

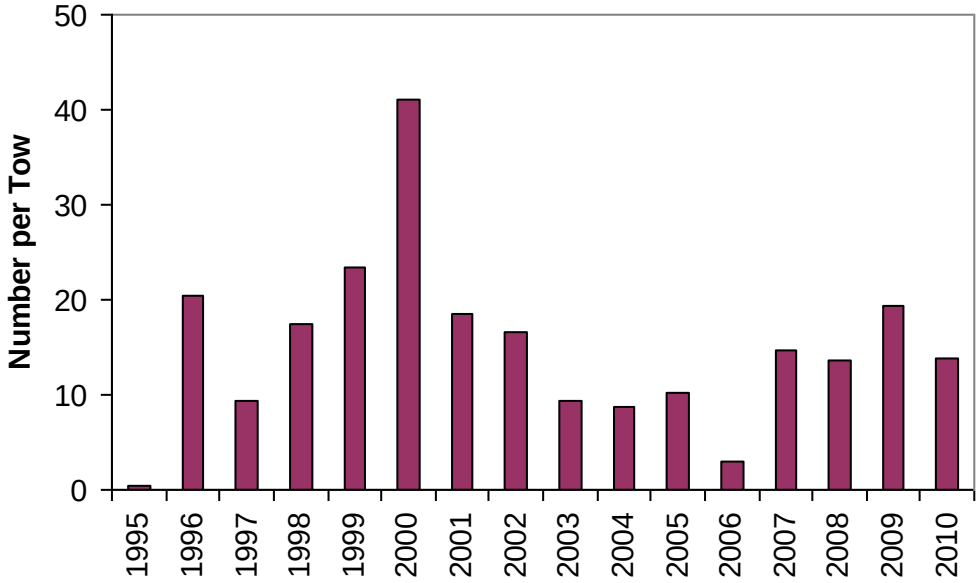

Figure 30. Stratified mean number per tow of white hake from strata 462-465 as indicated by the 4VsW Sentinel Survey, 1995-2010.

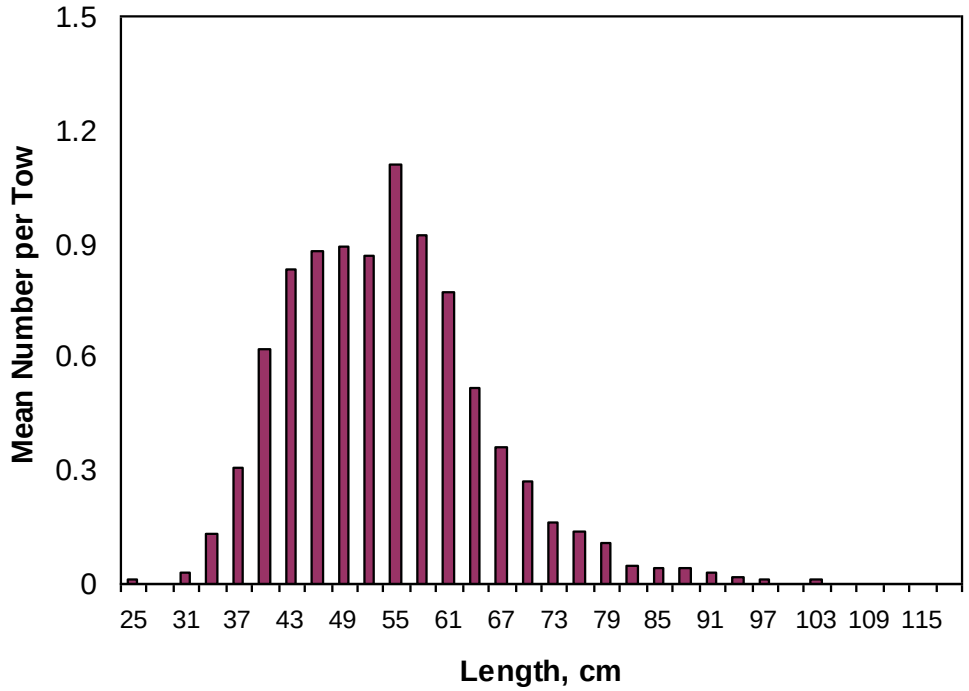

Figure 31. Number per tow at length (3 cm groupings) of white hake from the 4VsW Sentinel Industry Longline Survey, 1996-2010.

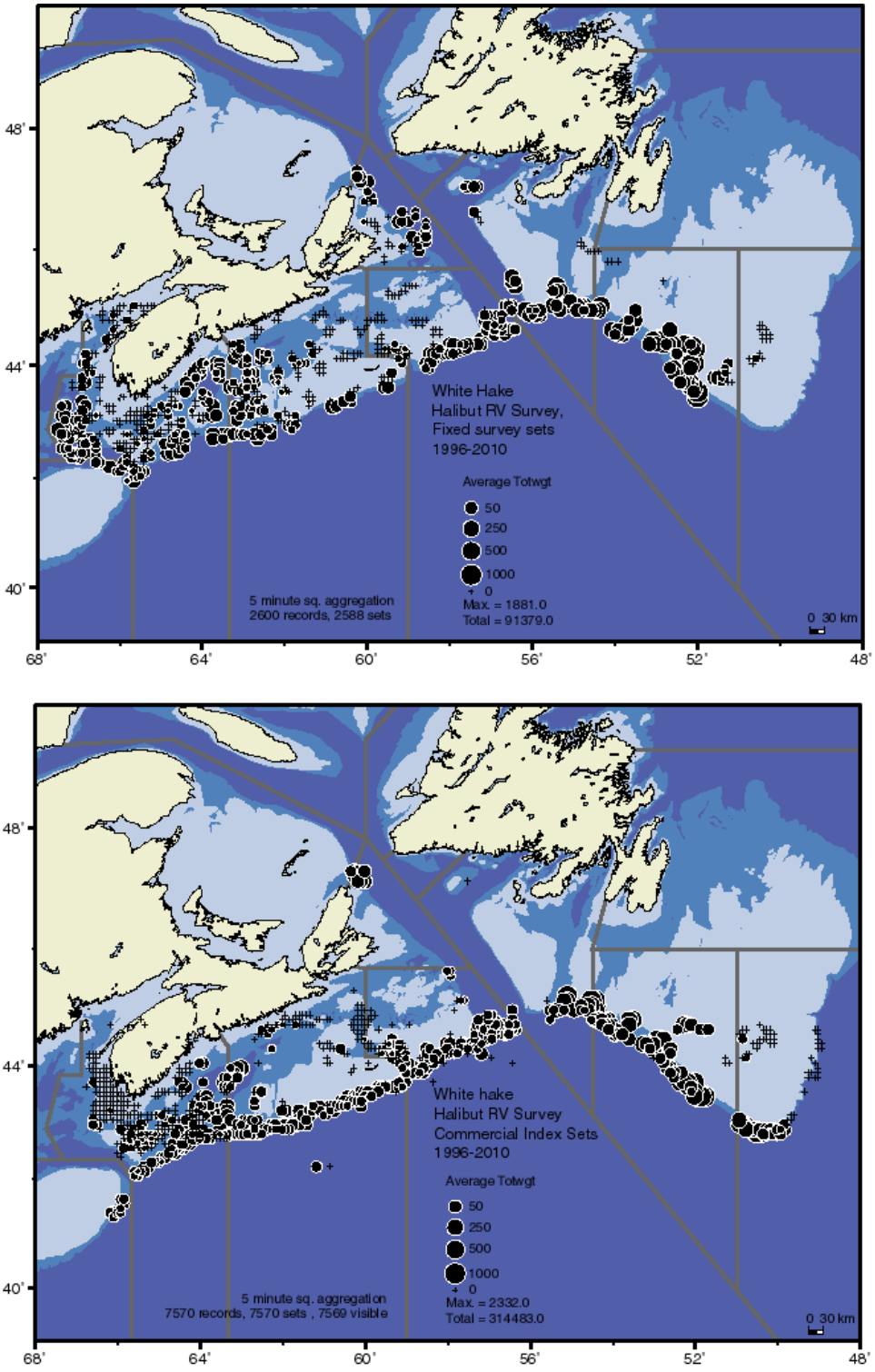

Figure 32. Distribution of white hake as indicated by the fixed station (upper panel) and commercial index stations (lower panel) of the Halibut Industry Longline Survey, 1998-2010.

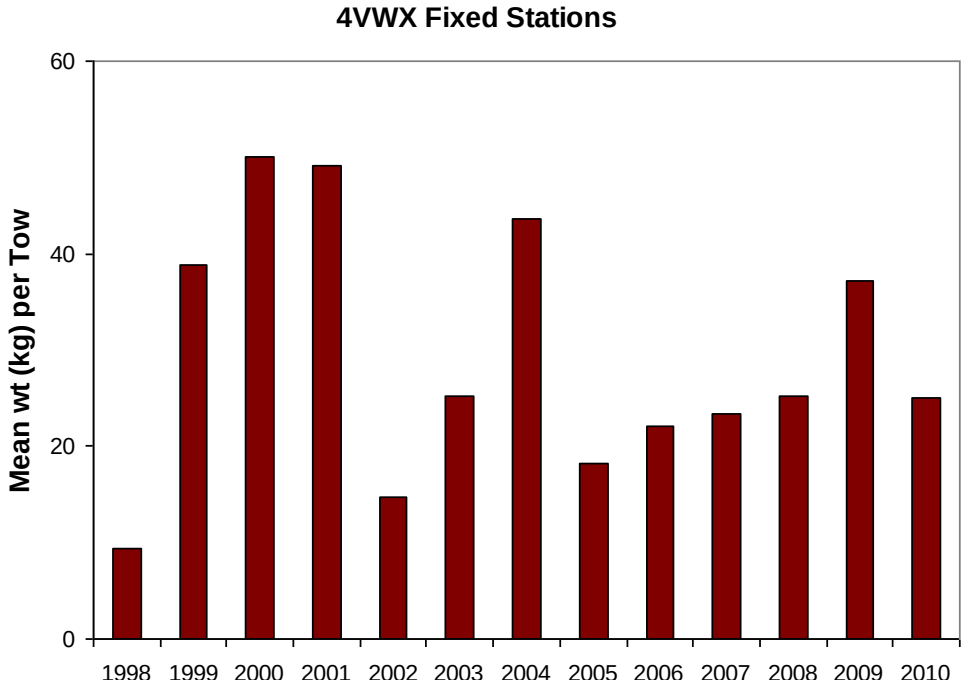

Figure 33. Mean weight (kg) per tow of white hake from Div. 4VWX of the fixed station portion of the Halibut Industry Longline Survey, 1998-2010.

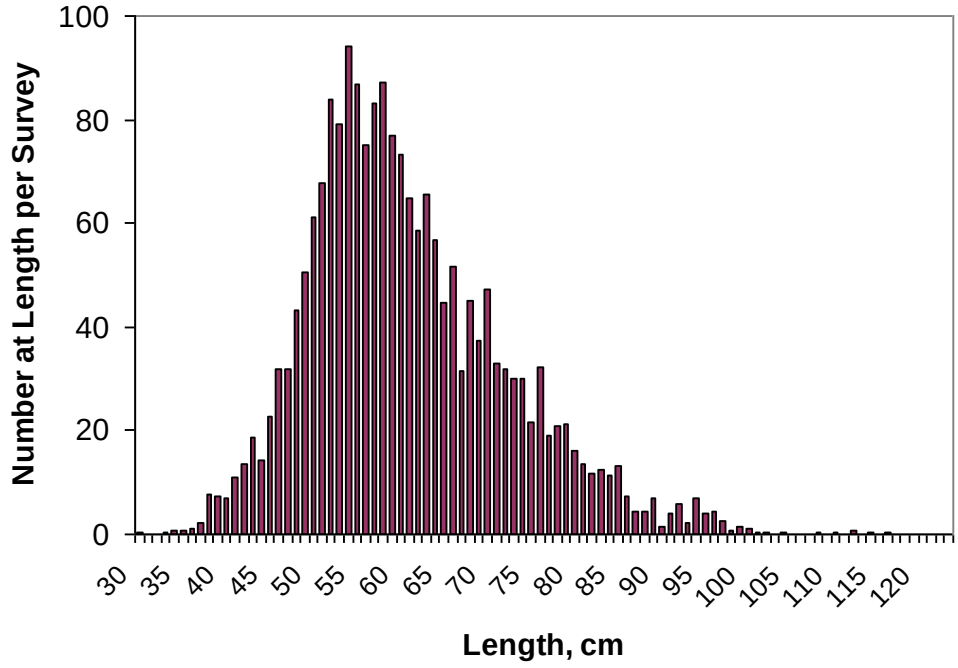

Figure 34. Length (cm) frequency distribution of white hake from Div. 4VWX of the fixed station portion of the Halibut Industry Longline Survey, 1998-2010.

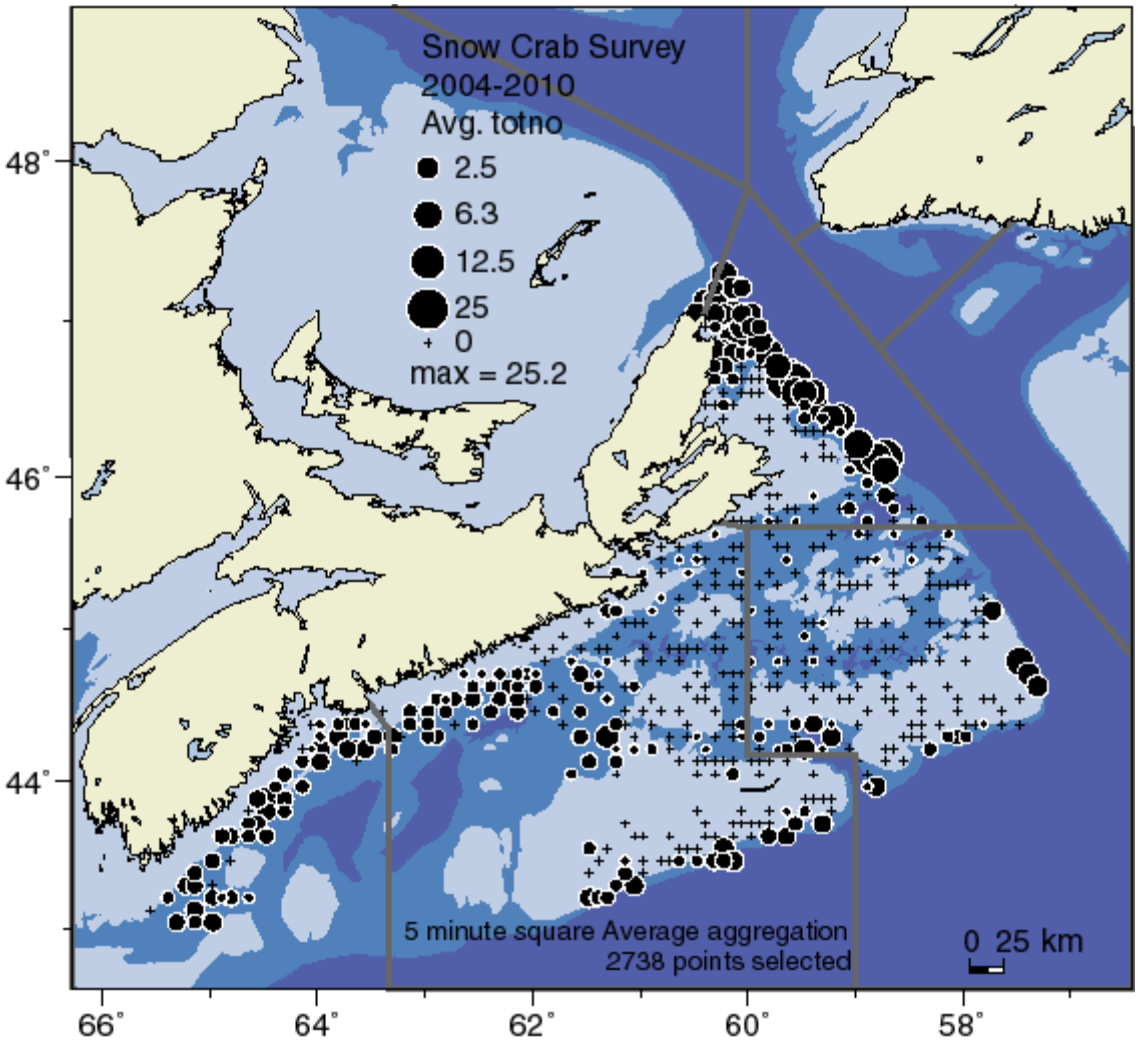

Figure 35. Distribution of white hake as indicated by the Industry Snow Crab Trawl Survey in Div. 4VWX, 2004-2010. Number per tow was expanded to a square kilometer and then multiplied by 10^{-3}.

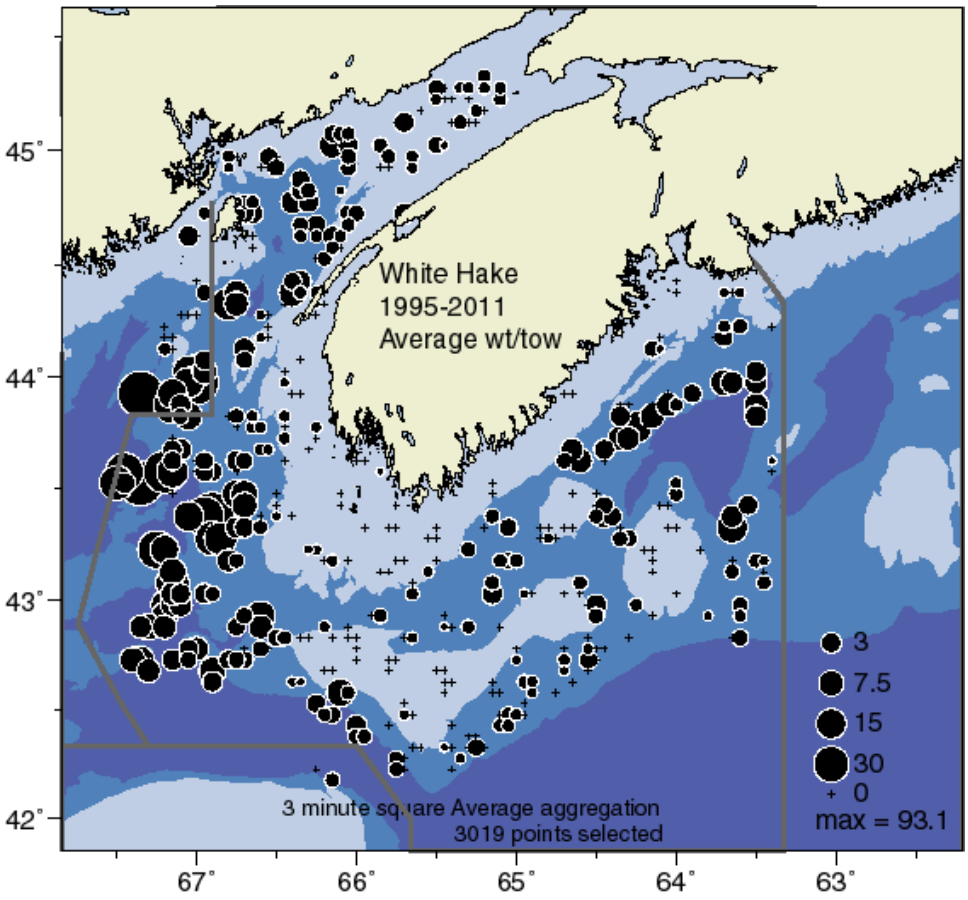

Figure 36. Distribution of white hake as indicated by the ITQ industry Trawl survey, 1995-2011.

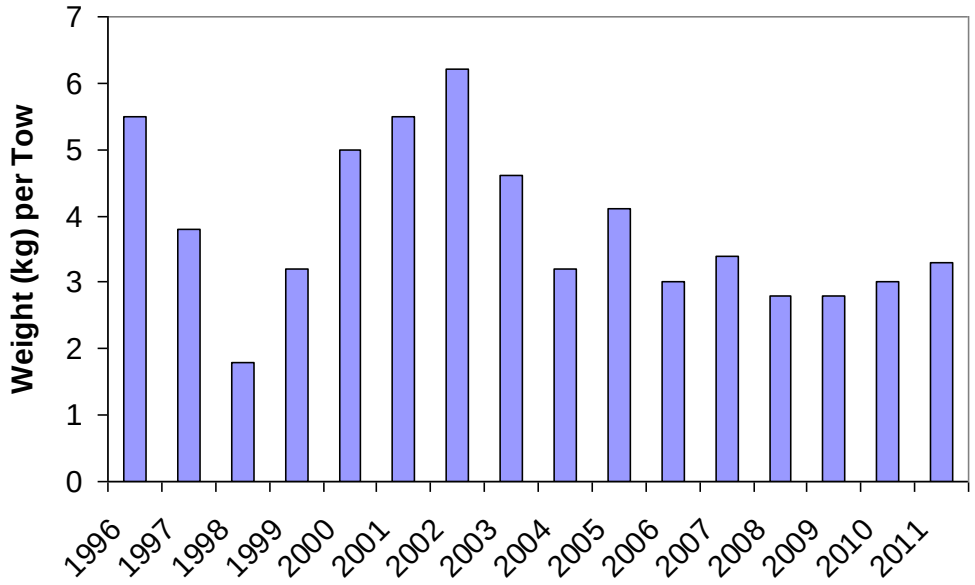

Figure 37. Abundance (weight (kg) per tow) of white hake as indicated by the ITQ Industry Trawl Survey, 1996-2011.

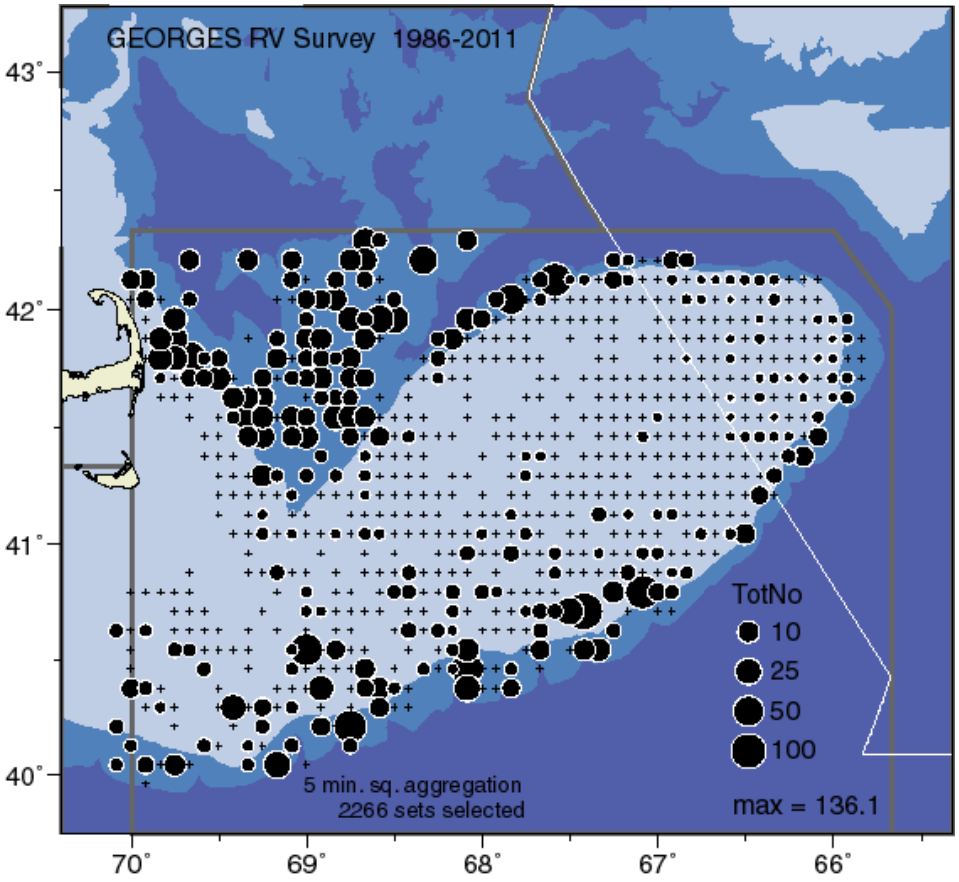

Figure 38. Distribution of white hake as indicated by the Georges Bank RV Survey, 1986-2011.

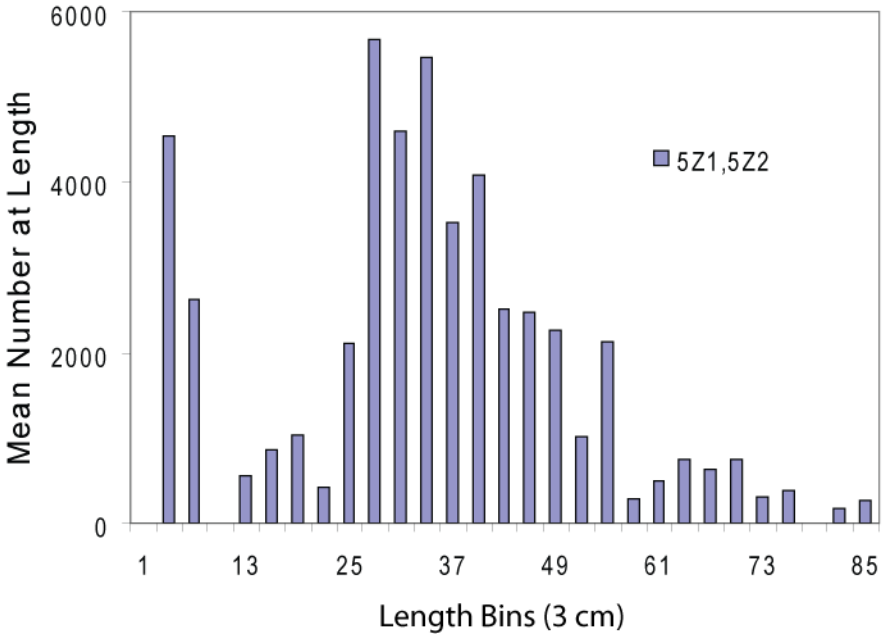

Figure 39. Mean number at length of white hake from the Georges Bank RV Survey on the Canadian side of Div. 5Z, 1986-2010.

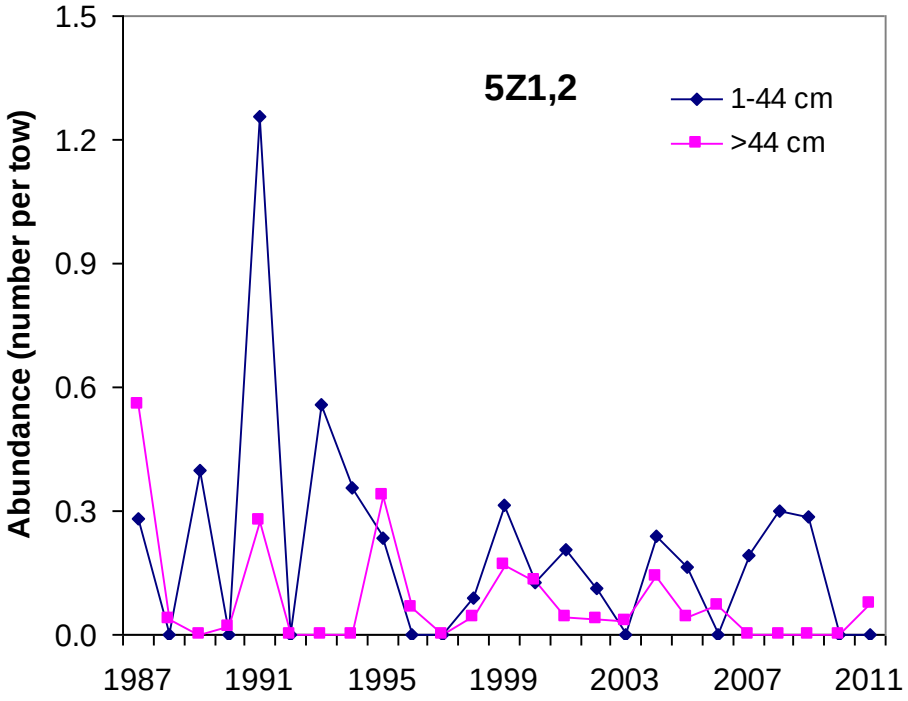

Figure 40. Abundance (total number per tow) of 1-44 cm (immature) and >44 cm (mature) length groups of white hake from the Canadian strata of the Georges Bank RV Survey in Div. 5Z, 1987 to 2011.

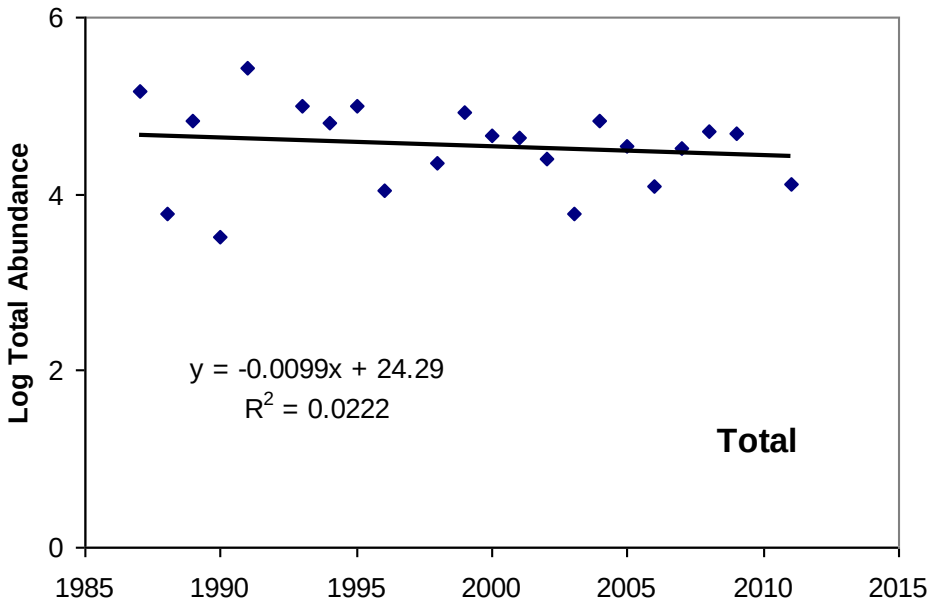

Figure 41. Log transformed catch rate (total number per tow) of all length groups of white hake from the Georges Bank RV Survey, Canadian strata only. The trend line is below the majority of points due to the zero estimates in 1992, 1997, and 2010.

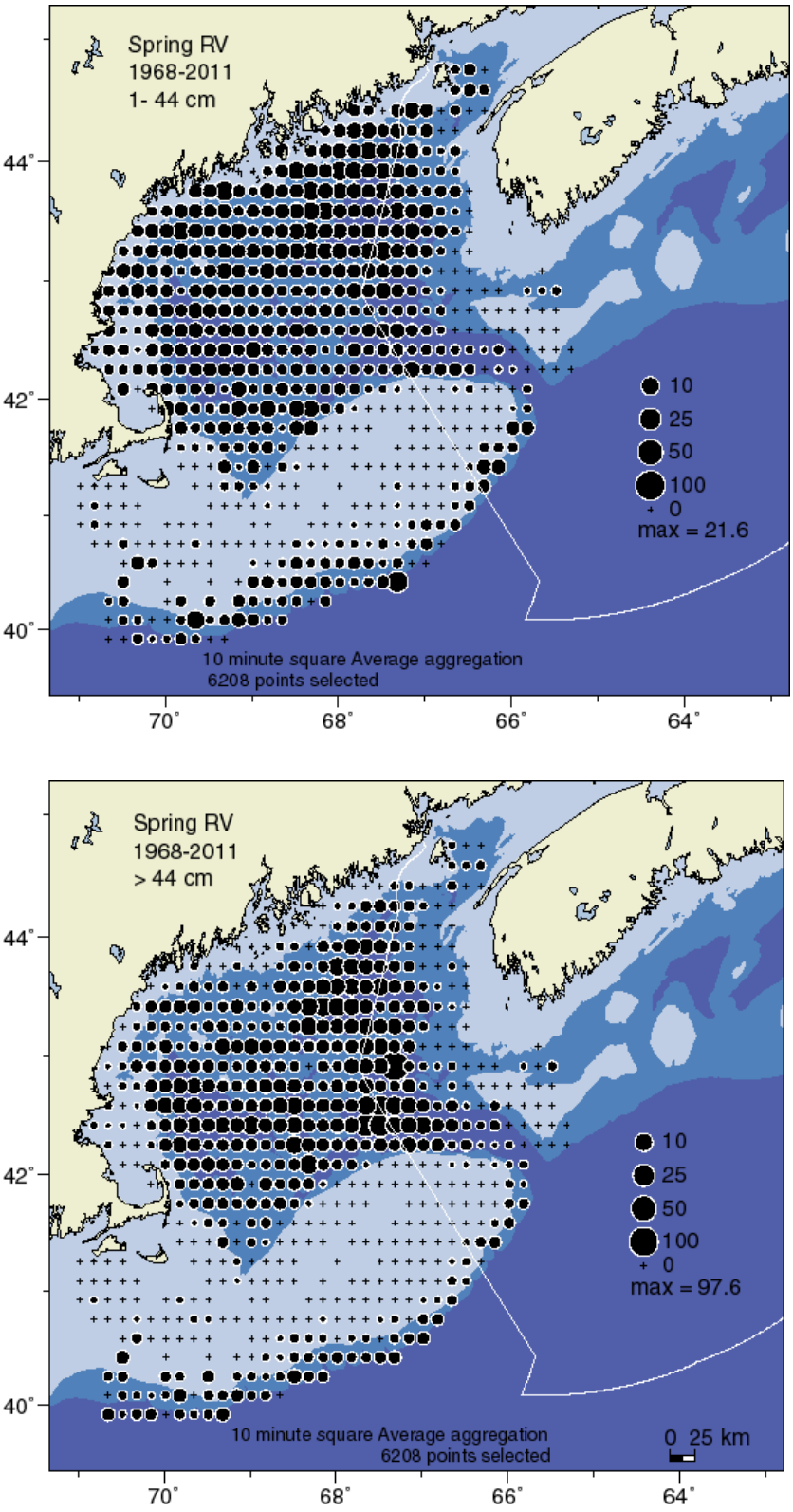

Figure 42. Distribution of white hake as indicated by the USA Spring RV Survey, 1968-2011.

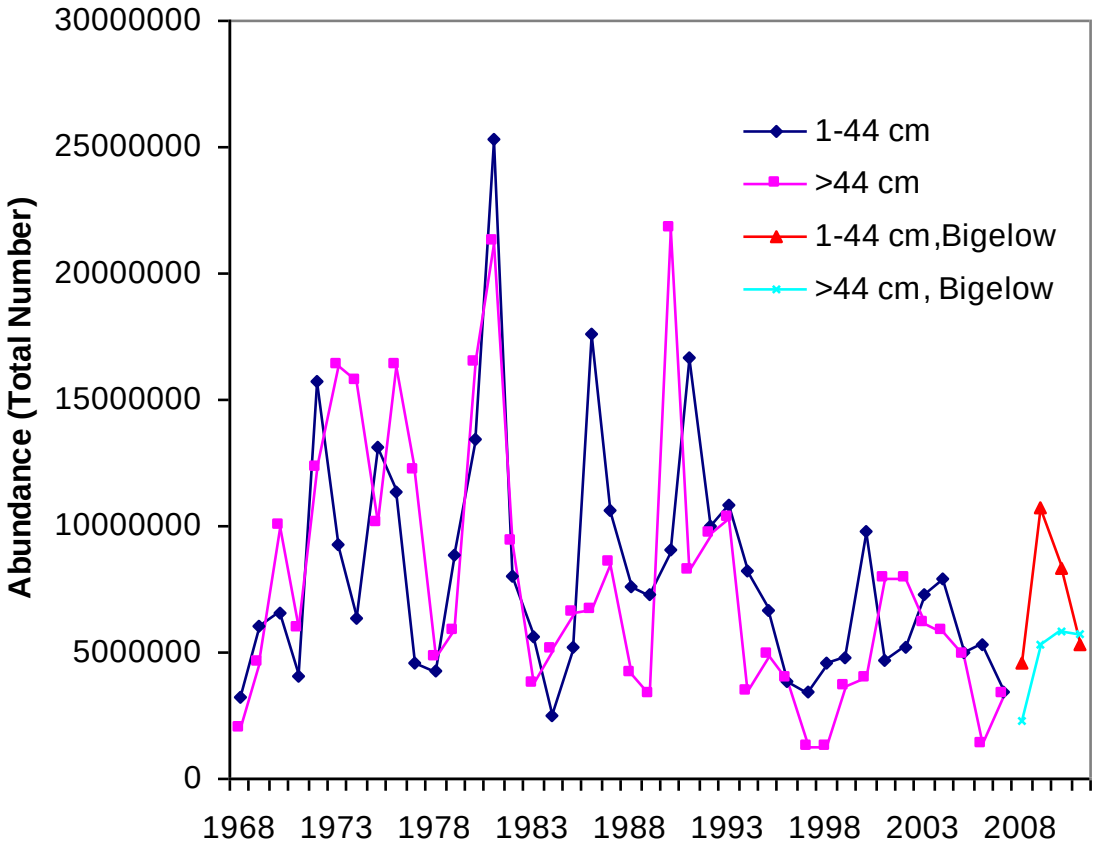

Figure 43. Stratified total number of white hake, 1-44 cm and >44 cm for Div. 4X5YZ, as indicated by the USA Spring RV Survey, 1968 to 2011.

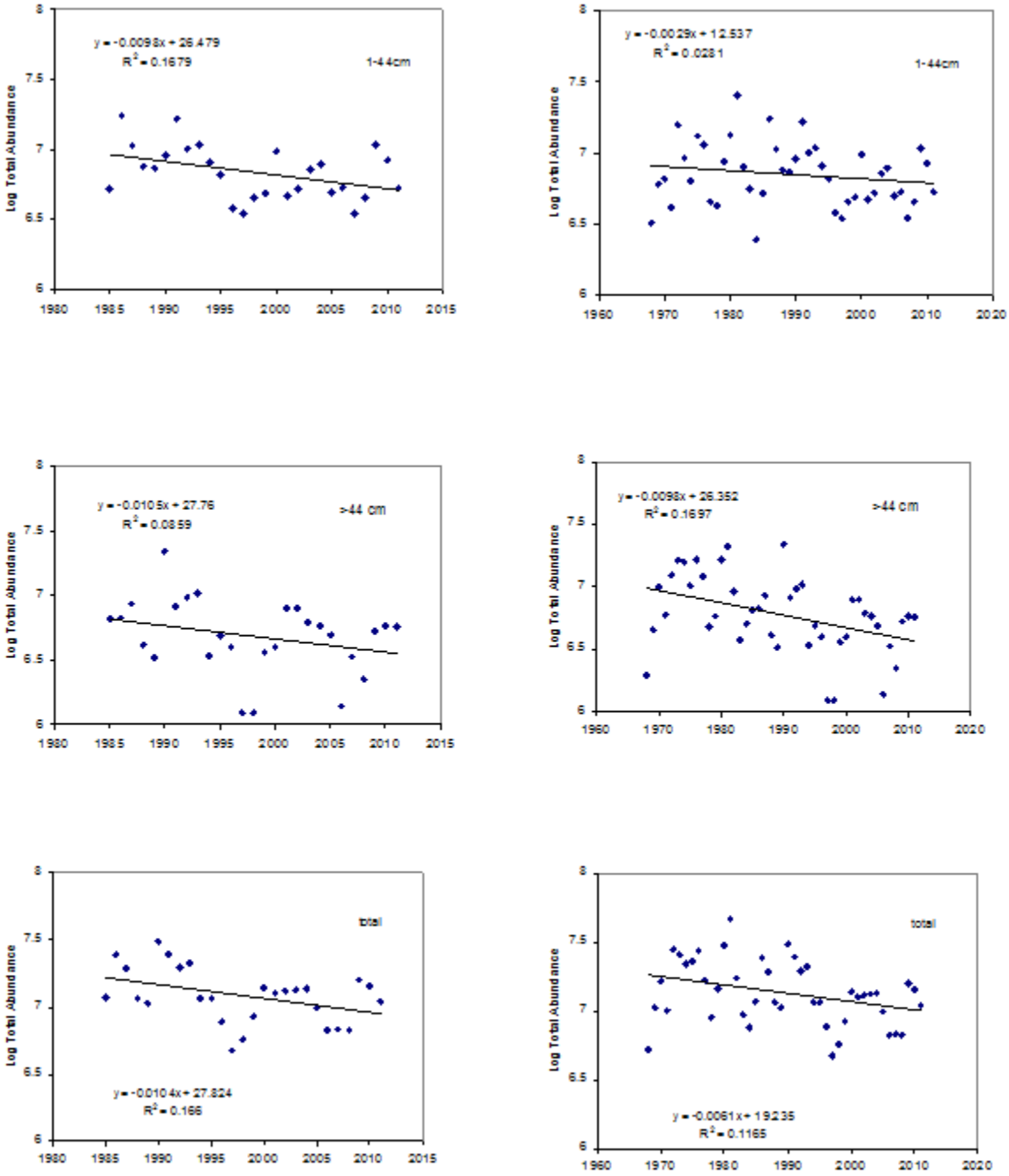

Figure 44. Log transformed catch rate (total number) of white hake, 1-44 cm (top row), >44 cm (middle row), and all length groups combined (bottom row) from all strata of the USA Spring RV Survey for three generations (1985-2011) (left column panels) and the survey series (1968-2011) (right column panels). The 2008 to 2011 surveys were adjusted using correction factor by Miller et.al. (2010).

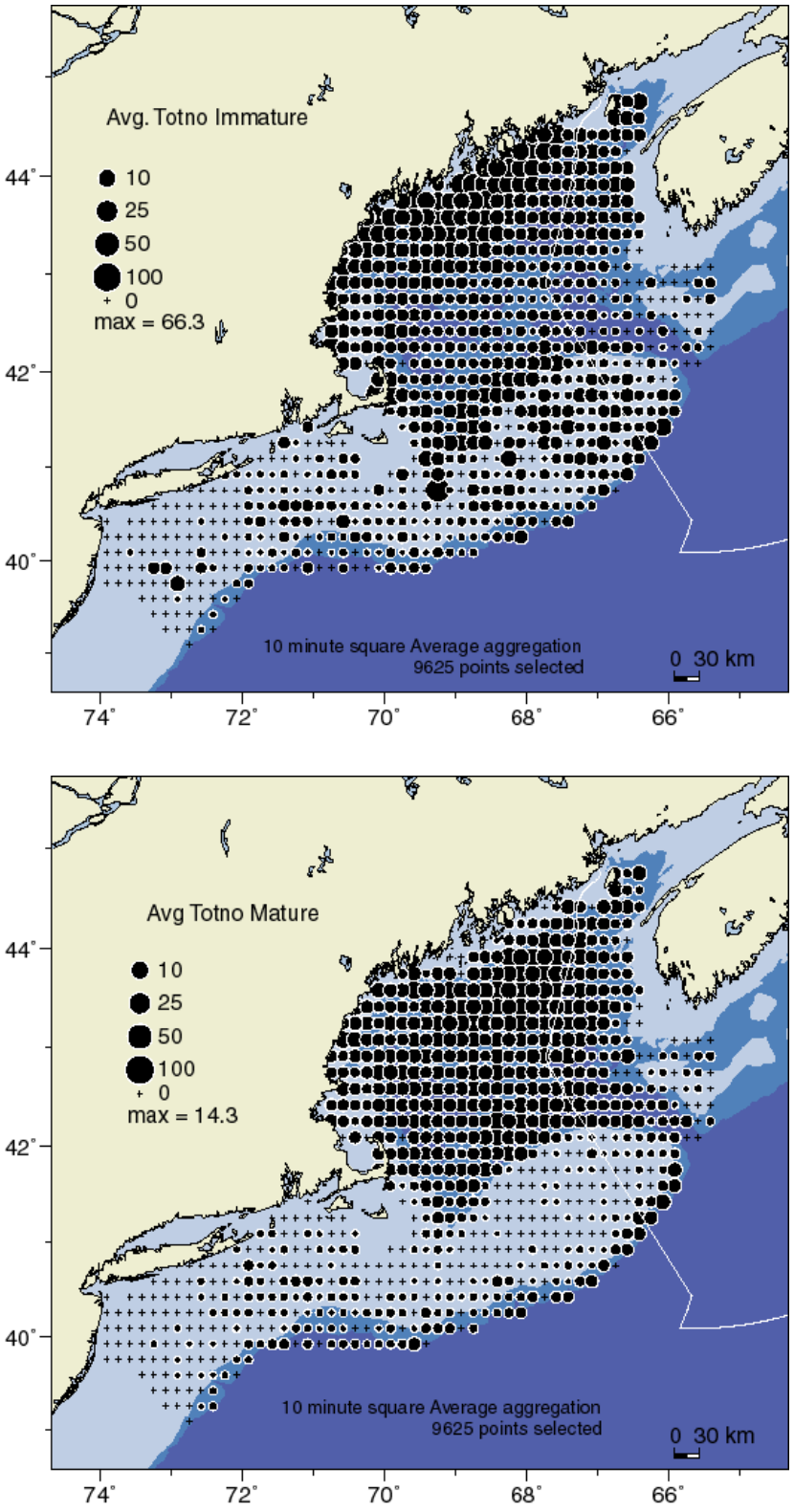

Figure 45. Distribution of white hake, 1-44 cm (top panel) and >44 cm (bottom panel) as indicated by the USA Fall RV Survey, 1963-2010.

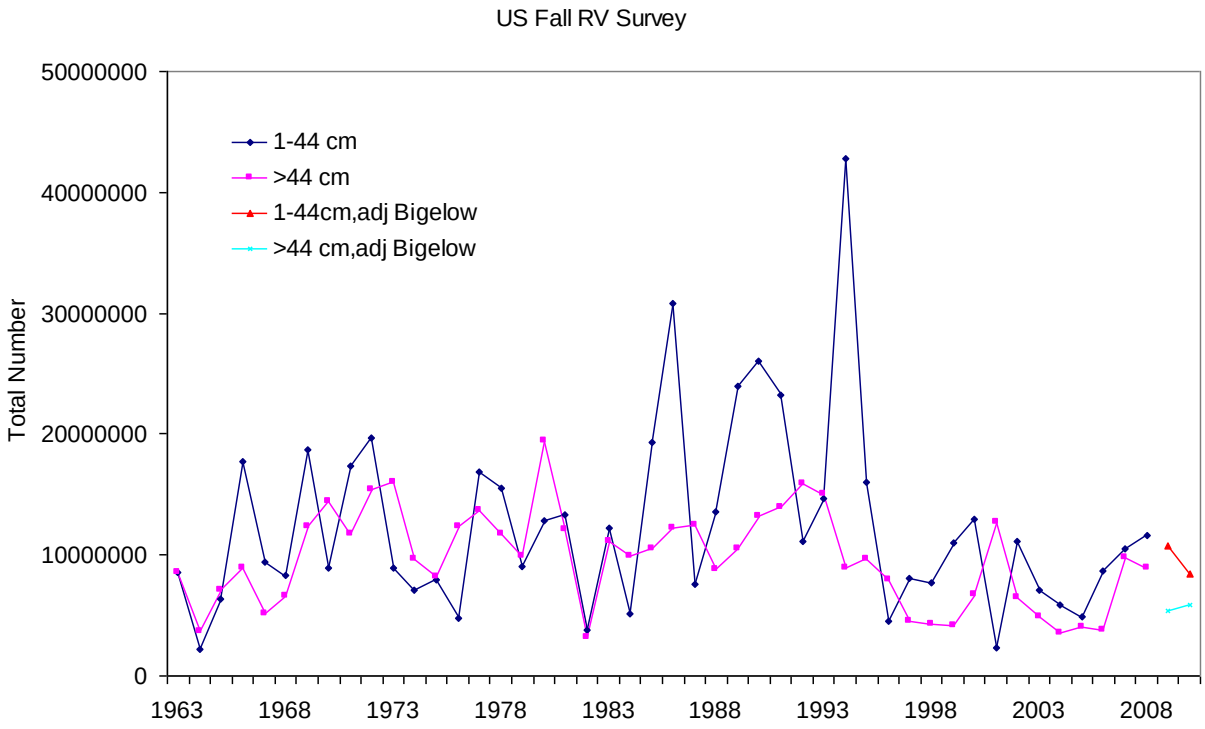

Figure 46. Stratified total number of white hake, 1-44 cm and >44 cm, as indicated by the USA Fall RV Survey, 1963-2010. The 2009 and 2010 surveys by the Bigelow have been adjusted using correction values estimated by Miller et al. (2010).

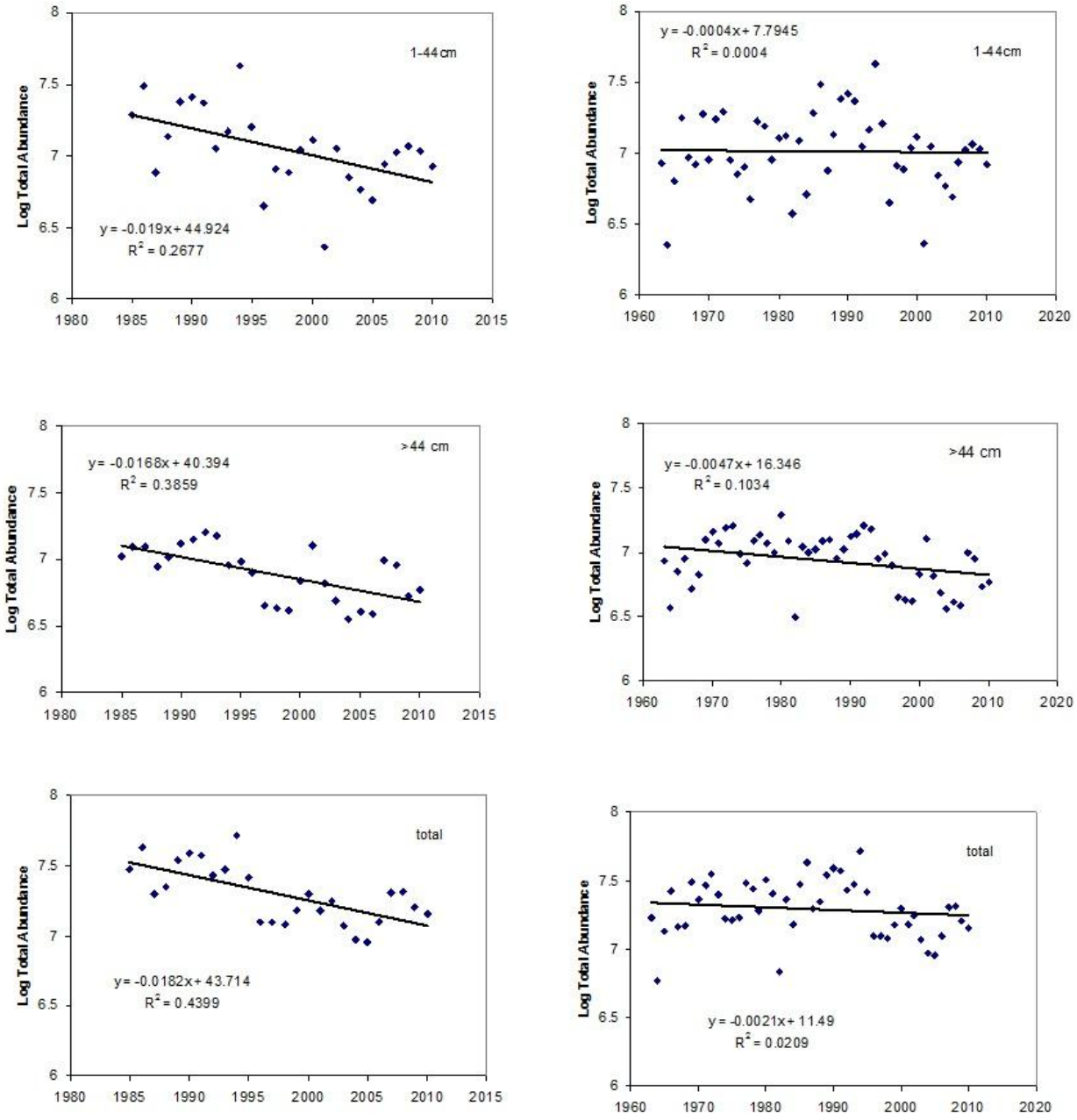

Figure 47. Log transformed catch rate (total number at length) of white hake immature (1-44 cm; top row), mature (>44 cm; middle row) and all length groups combined (bottom row) from all strata of the USA Fall RV Survey for three generations (1985-2010) (left column panels) and the survey series (1963-2010) (right column panels). The 2009 to 2010 surveys were adjusted using correction factor by Miller et al. (2010).

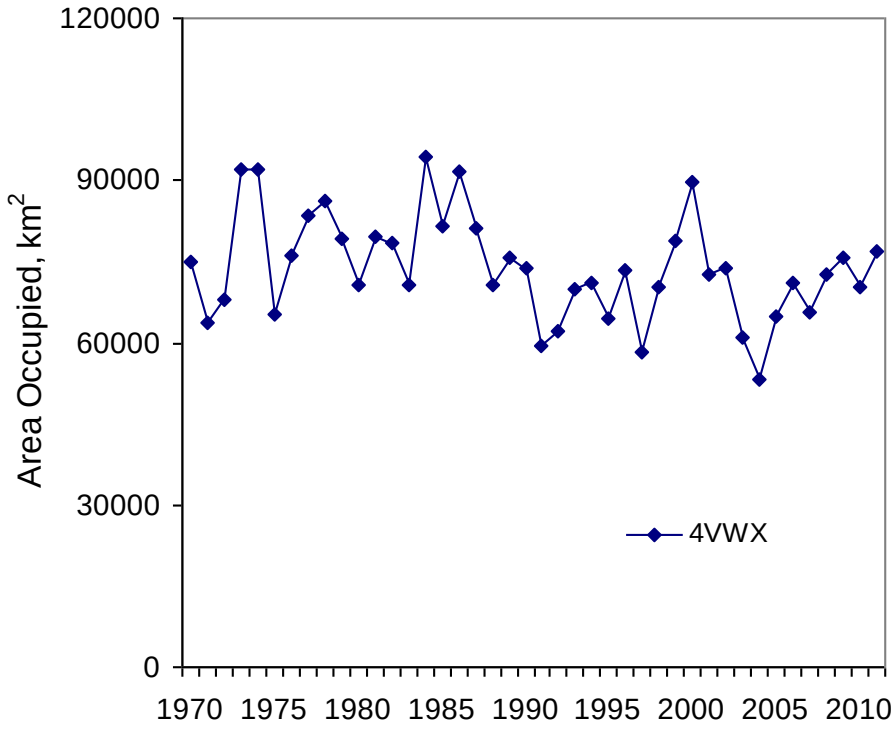

Figure 48. Depth Weighted Area Occupied (km²) of white hake as indicated by the summer RV survey, 1970-2011.

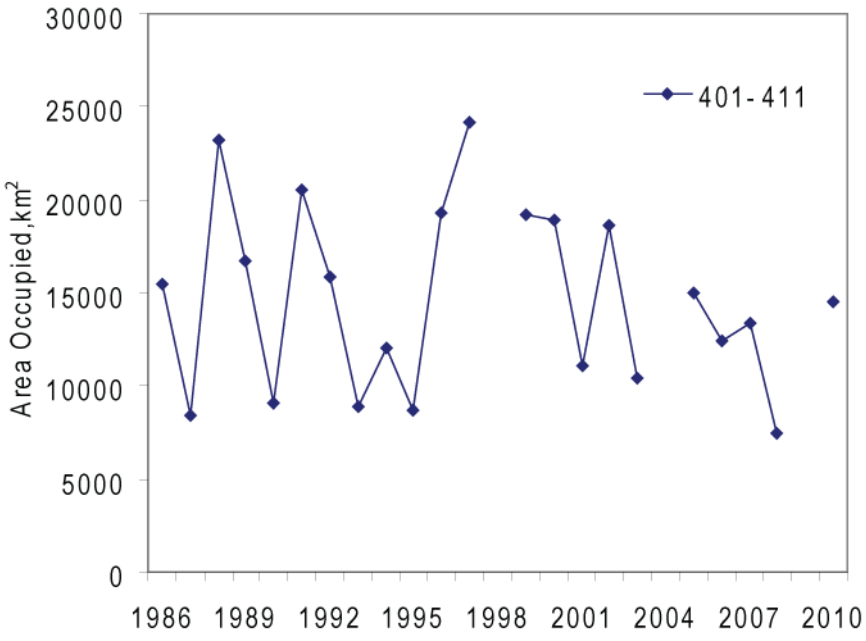

Figure 49. Depth Weighted Area Occupied (km²) of white hake as indicated by the Spring 4VsW (4VWCOD) RV Survey, 1986-2010. Note that the 1998, 2004, and 2009 surveys are missing or incomplete.

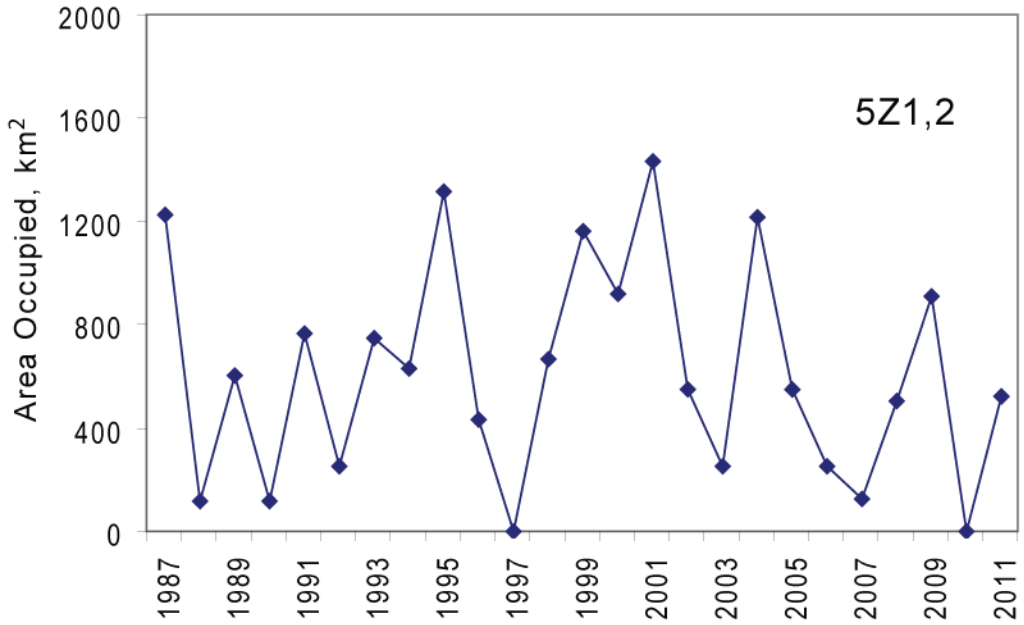

Figure 50. Depth Weighted Area Occupied (km²) of white hake as indicated by the Georges Bank RV Survey in Div. 5Zc, 1987-2011.

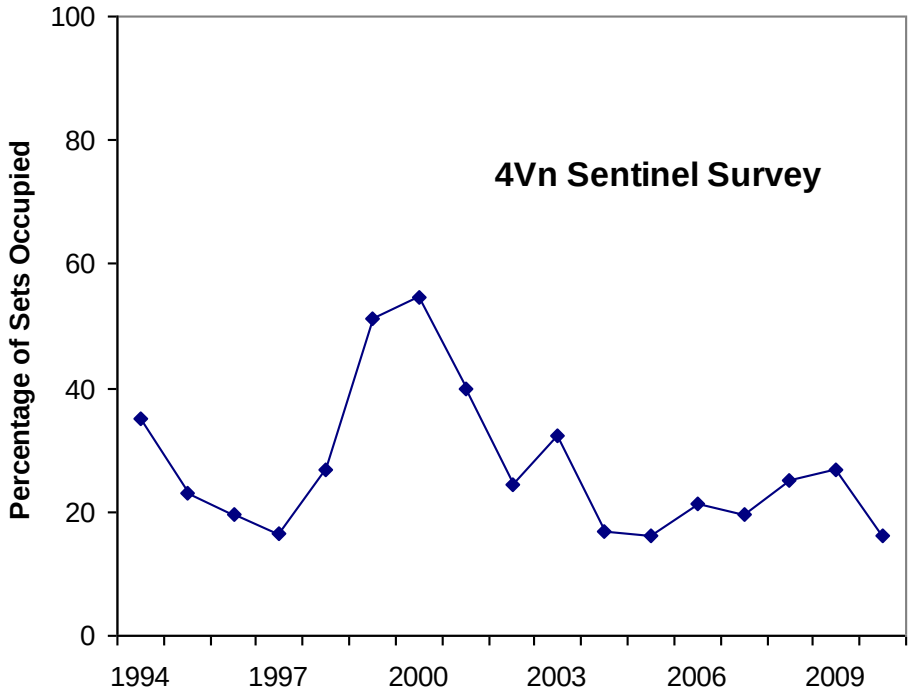

Figure 51. Percentage of sets containing white hake from the 4Vn Sentinel Survey, 1994-2010.

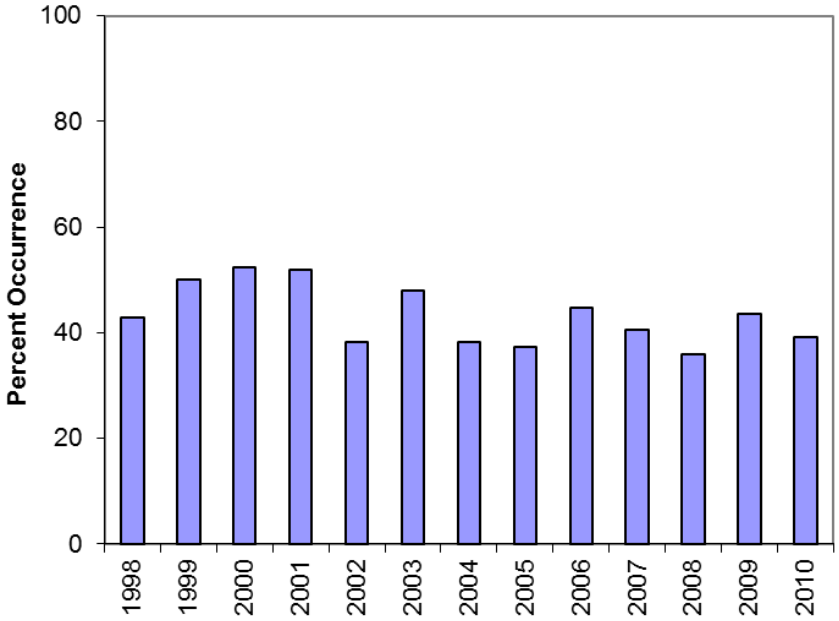

Figure 52. Percentage of sets containing white hake from the fixed survey sets from Halibut Industry Longline Survey in Div. 4VWX, 1998-2010.

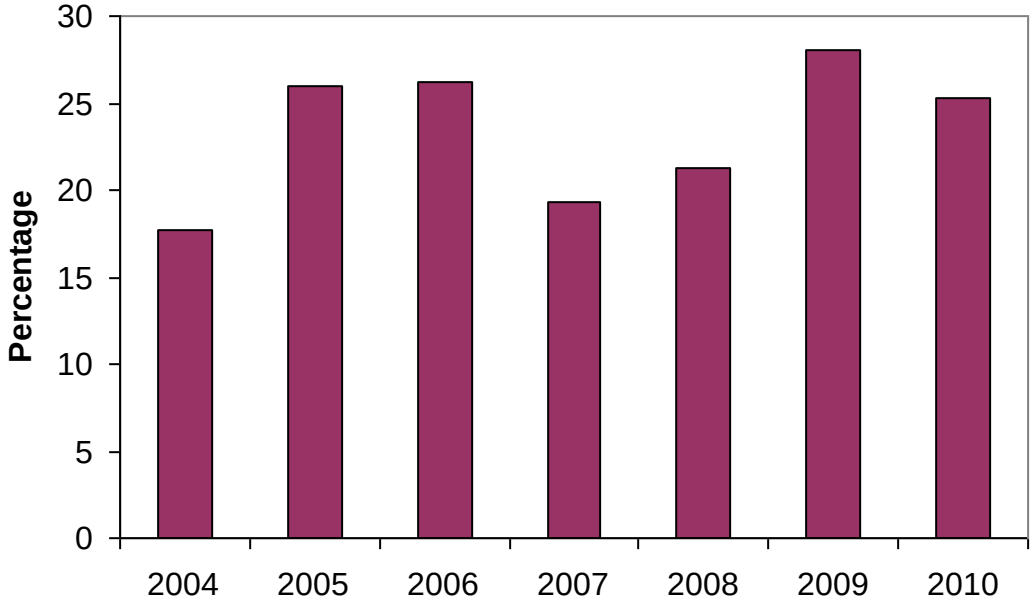

Figure 53. Percentage of sets containing white hake from the Industry Snow Crab Survey in Div. 4VWX, 2004-2010.

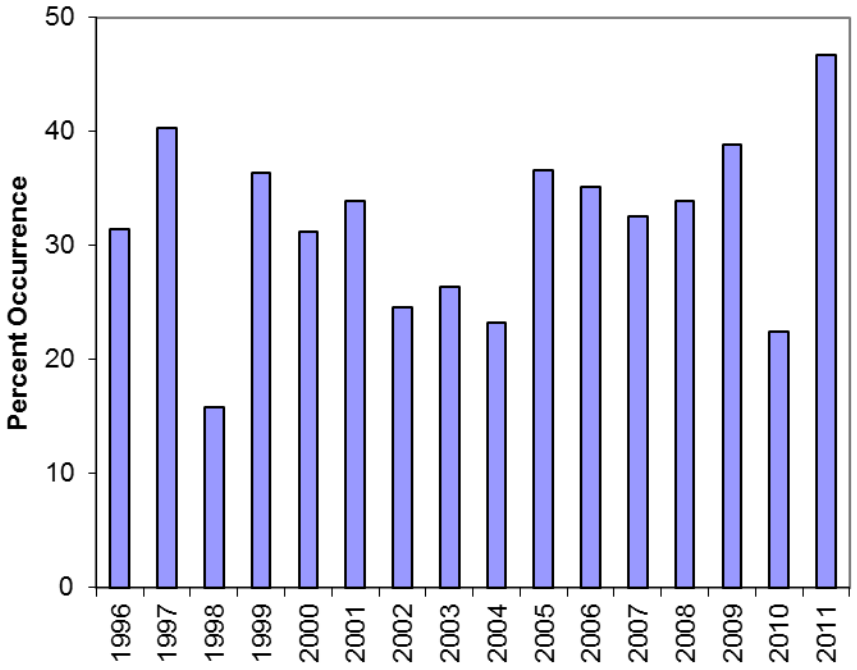

Figure 54. Percentages of sets containing of white hake in the ITQ Industry Otter Trawl Survey in Div. 4X, 1996-2011.

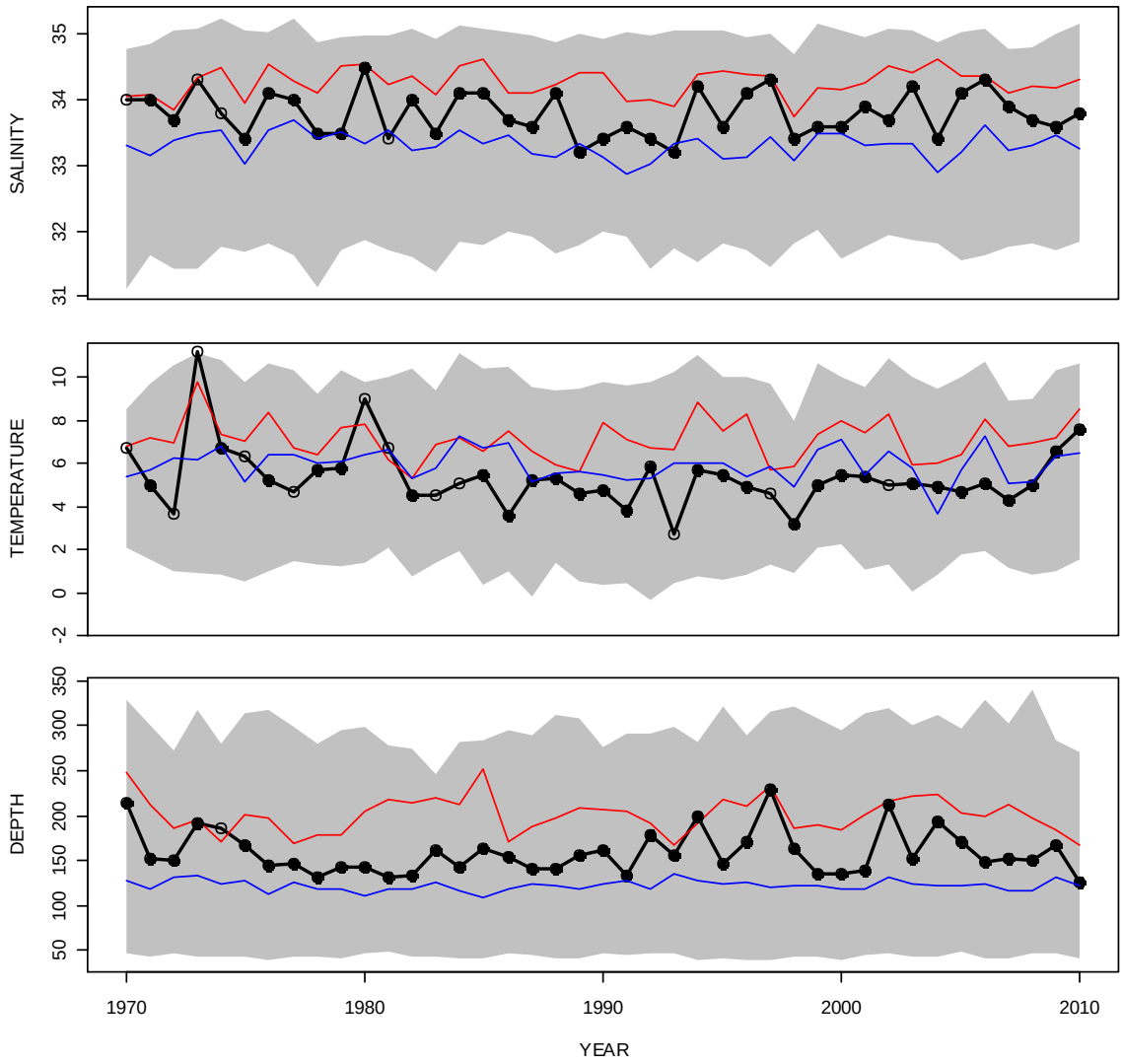

Figure 55. Time series of habitat preferences of white hake in Div. 4VWX as obtained from the summer RV survey between 1970 and 2010. Circles represent the location of maximum deviation of cumulative distributions from catch and effort. Filled circles represent statistically significant habitat associations and open circles represent non-significant associations. Red line indicates the median habitat occupied by white hake. Blue line is median of sampled habitat. Shaded polygon in background is the 95th percentile for range of sampling habitat.

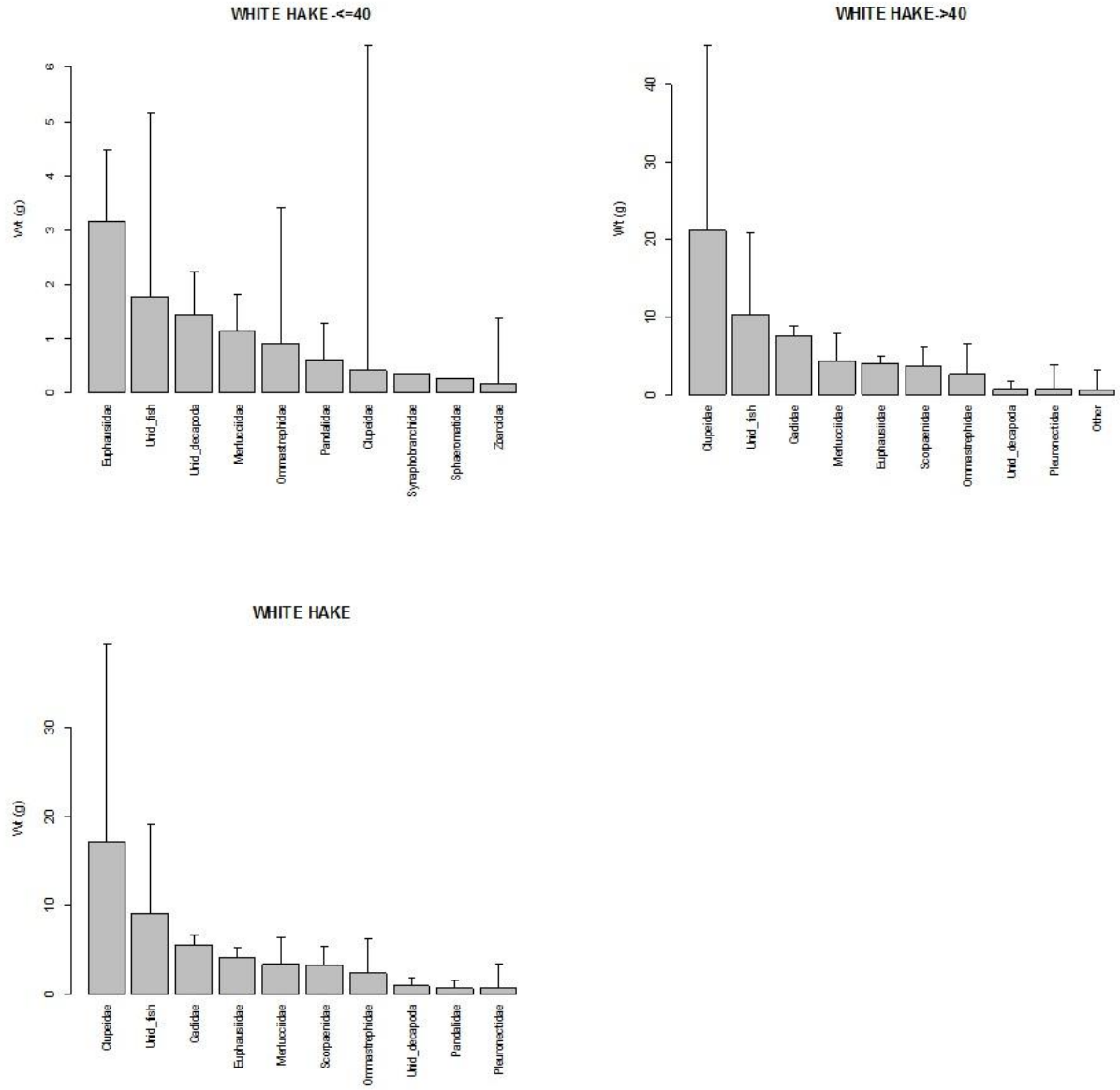

Figure 56. Prey composition of white hake <=40 cm (top left panel), >40 cm (top right panel) and total combined (bottom panel) based on 1,140 stomach from the 1999 to 2009 summer RV survey.

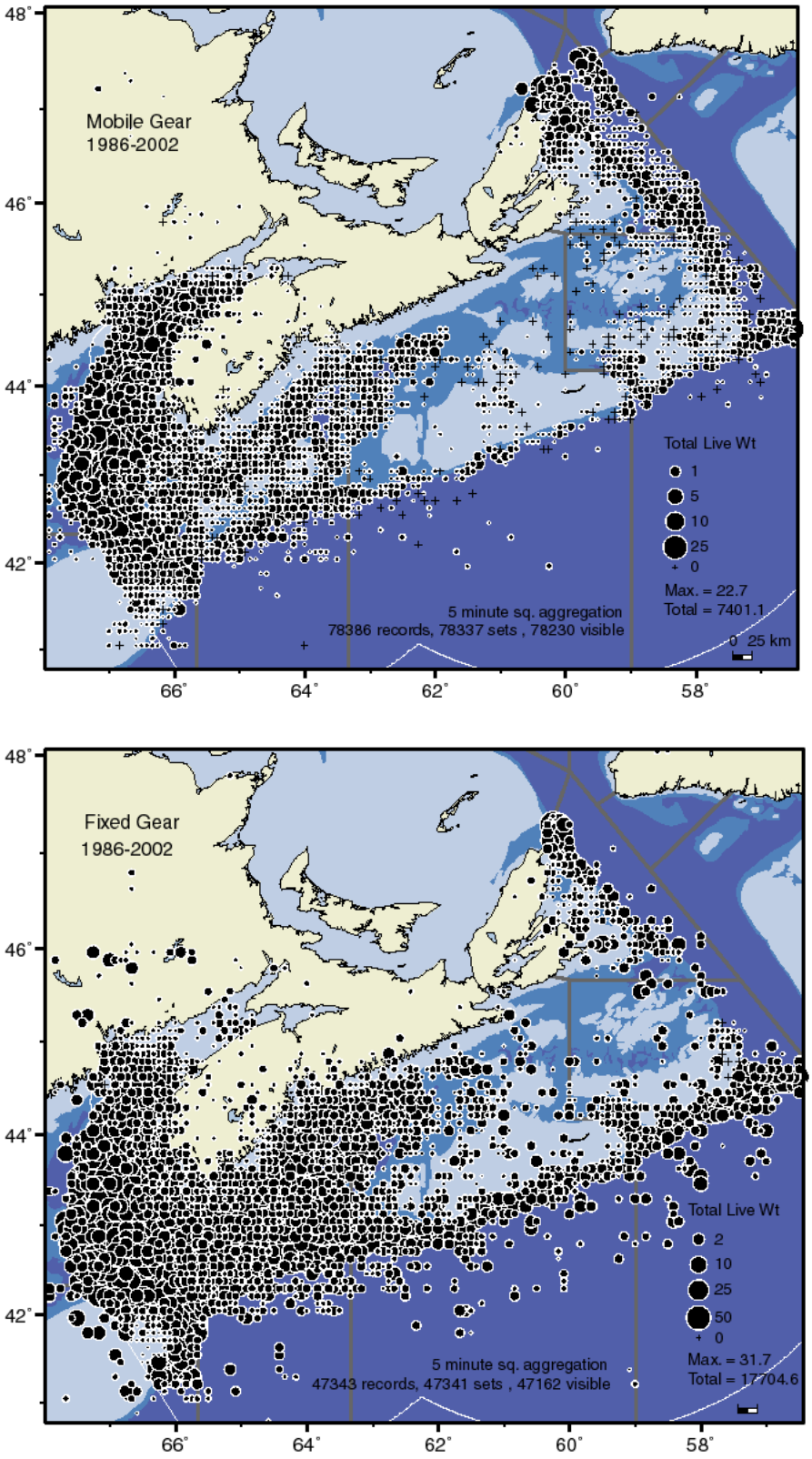

Figure 57. Location of commercial landings of white hake from the Maritimes Region, 1986-2002, separated into mobile (top) and fixed (bottom) gear sectors.

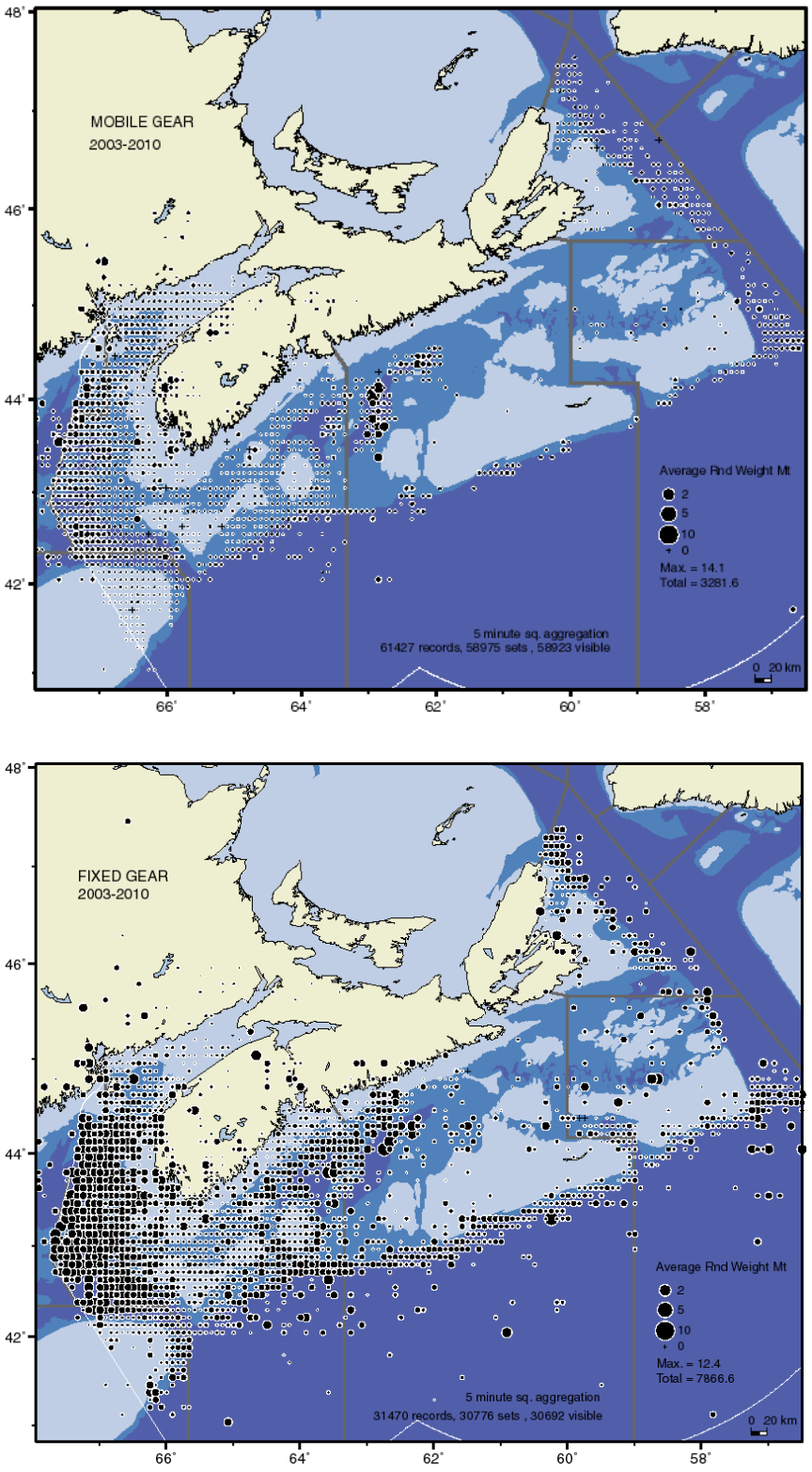

Figure 58. Location of commercial landings of white hake from the Maritimes Region, 2003-2010, separated into mobile (top) and fixed (bottom) gear sectors.

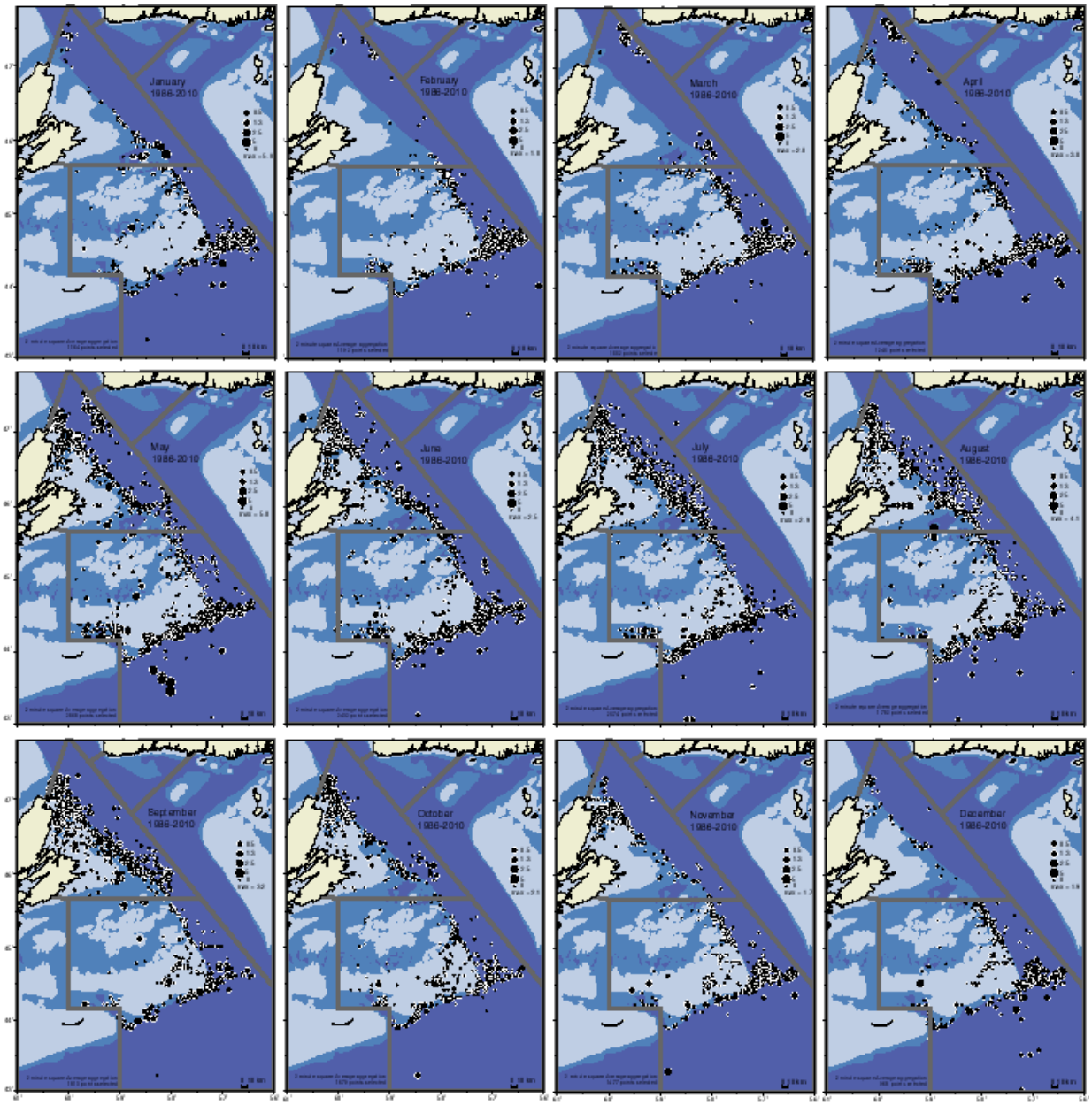

Figure 59. Monthly distribution of white hake by mobile gear from 1986-2010, as indicated by the commercial fisheries in Div. 4V.

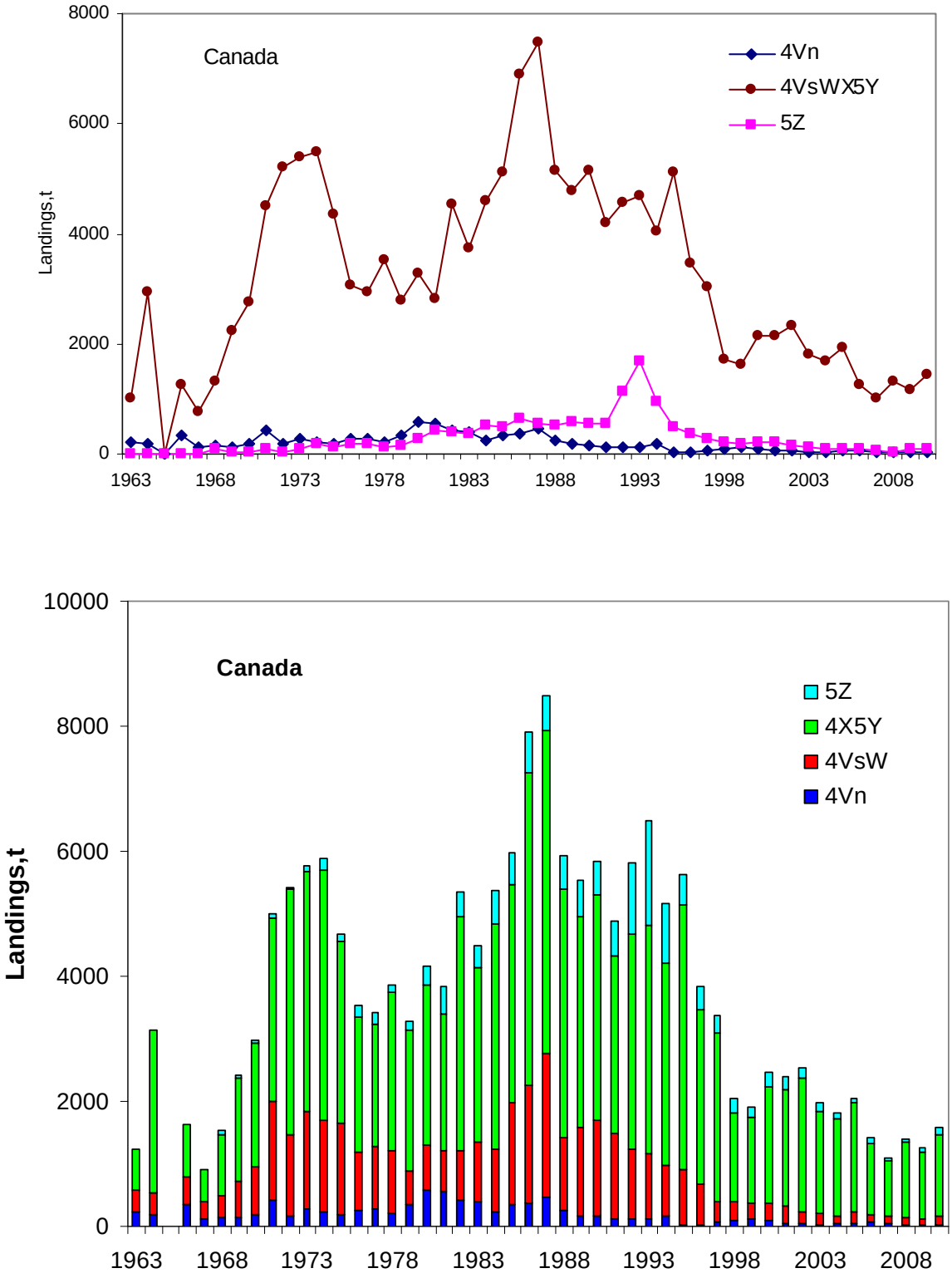

Figure 60. Commercial landings (t) of white hake by Canada from Div. 4VW, 4X5Y, and 5Z from all gears combined, 1963-2010, by division/group (top) and by yearly totals (bottom).

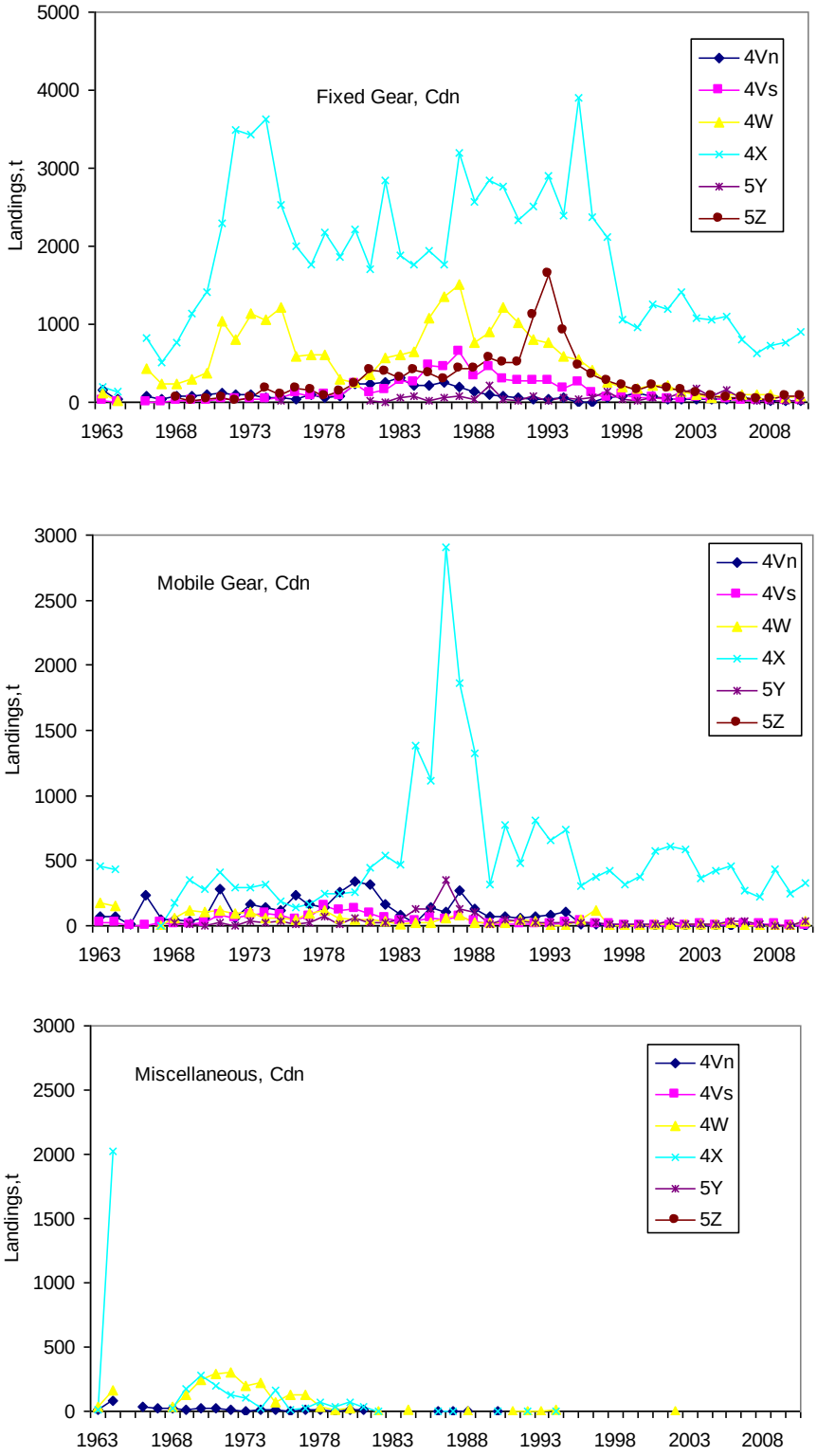

Figure 61. Commercial landings (t) of white hake by Canada by gear sector from Subdiv. 4Vn, 4Vs, Div. 4W, 4X, 5Y, and 5Z for1963-2010. (Top: fixed gear; middle: mobile gear; bottom, miscellaneous).

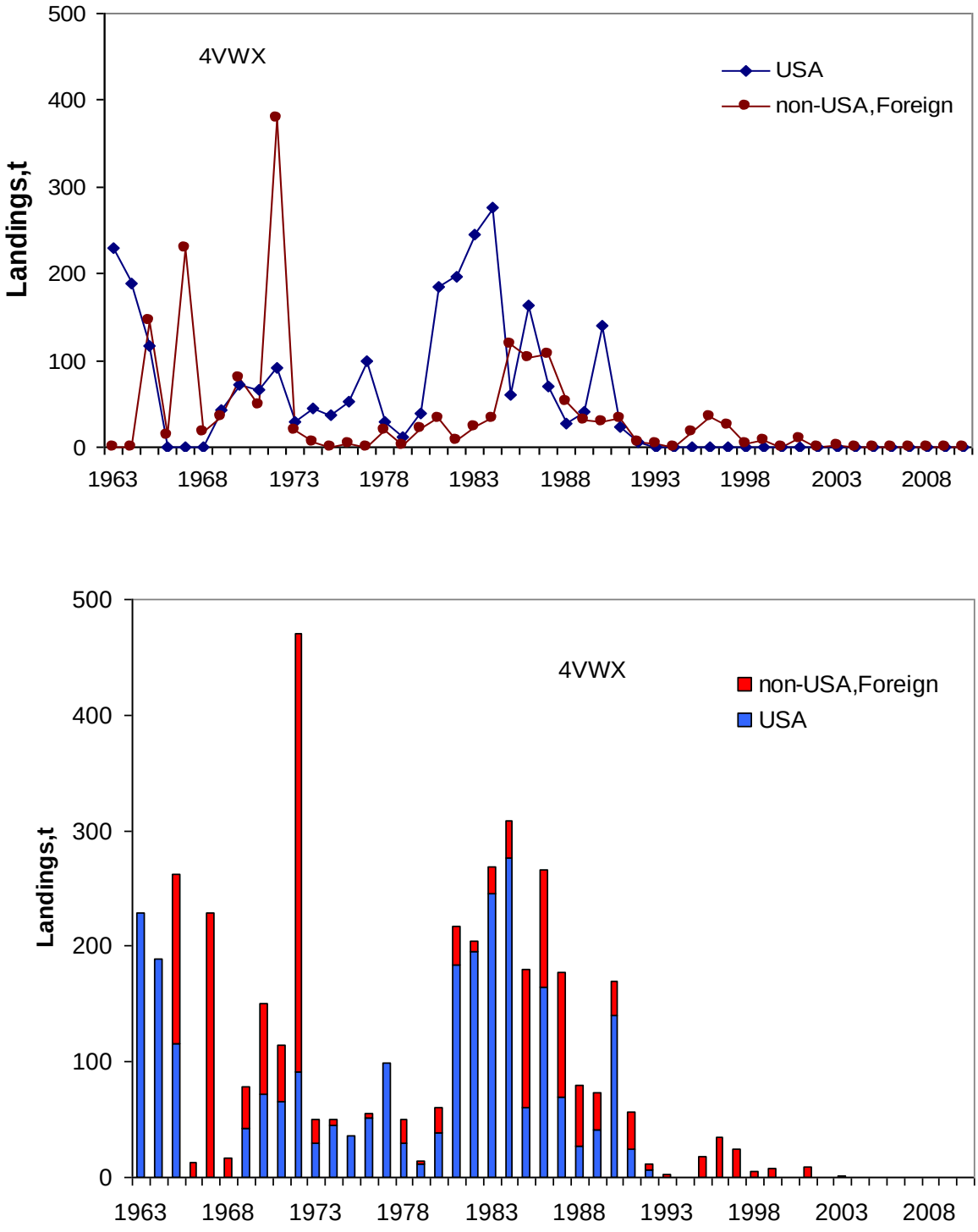

Figure 62. Commercial landings (t) of white hake by the United States and other foreign countries in Div. 4VWX, 1963-2010, by division/group (top) and by yearly totals (bottom).

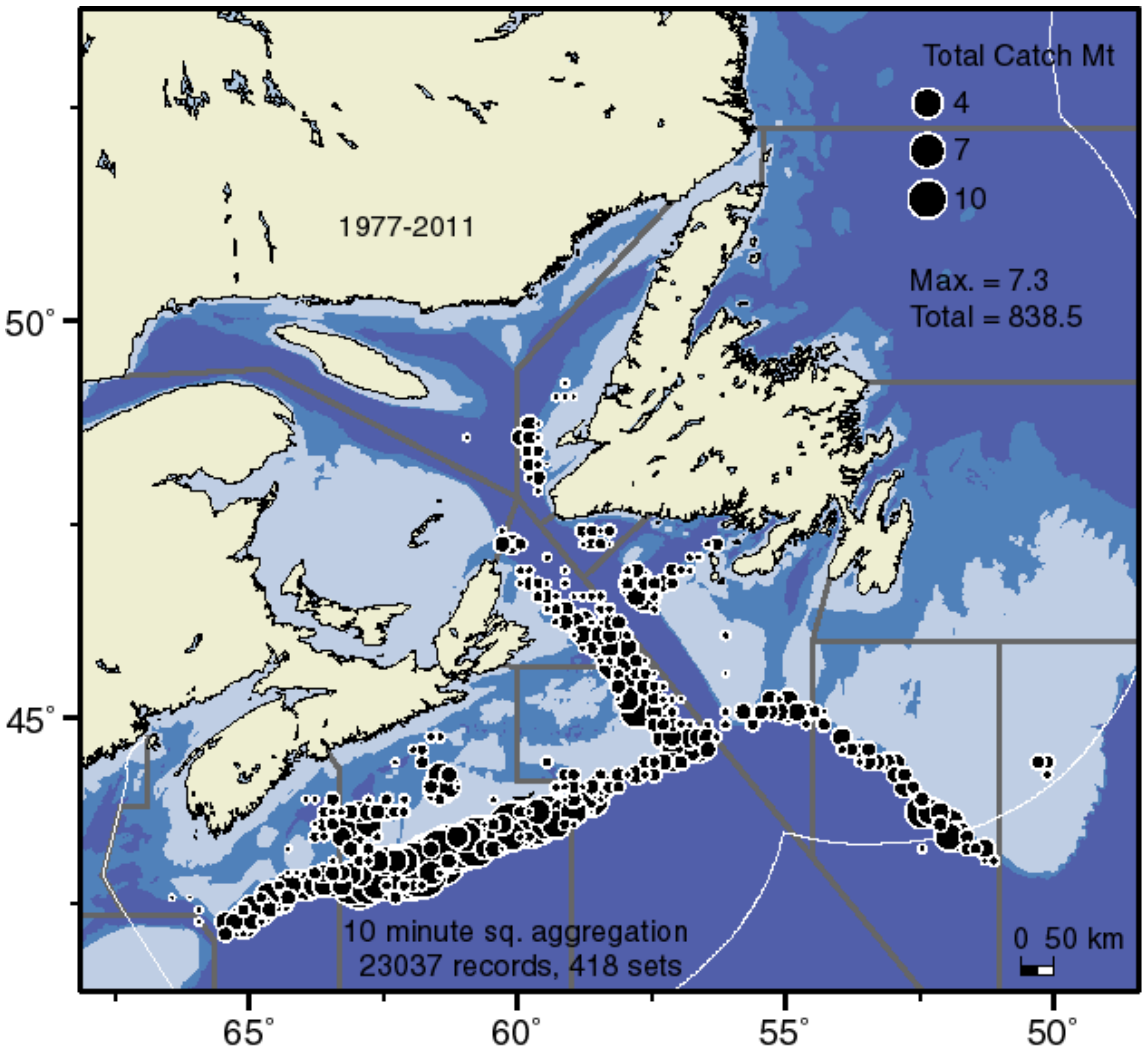

Figure 63. Reports of white hake by the observers from the Maritimes Region on non-Canadian vessels, 1977-2011.

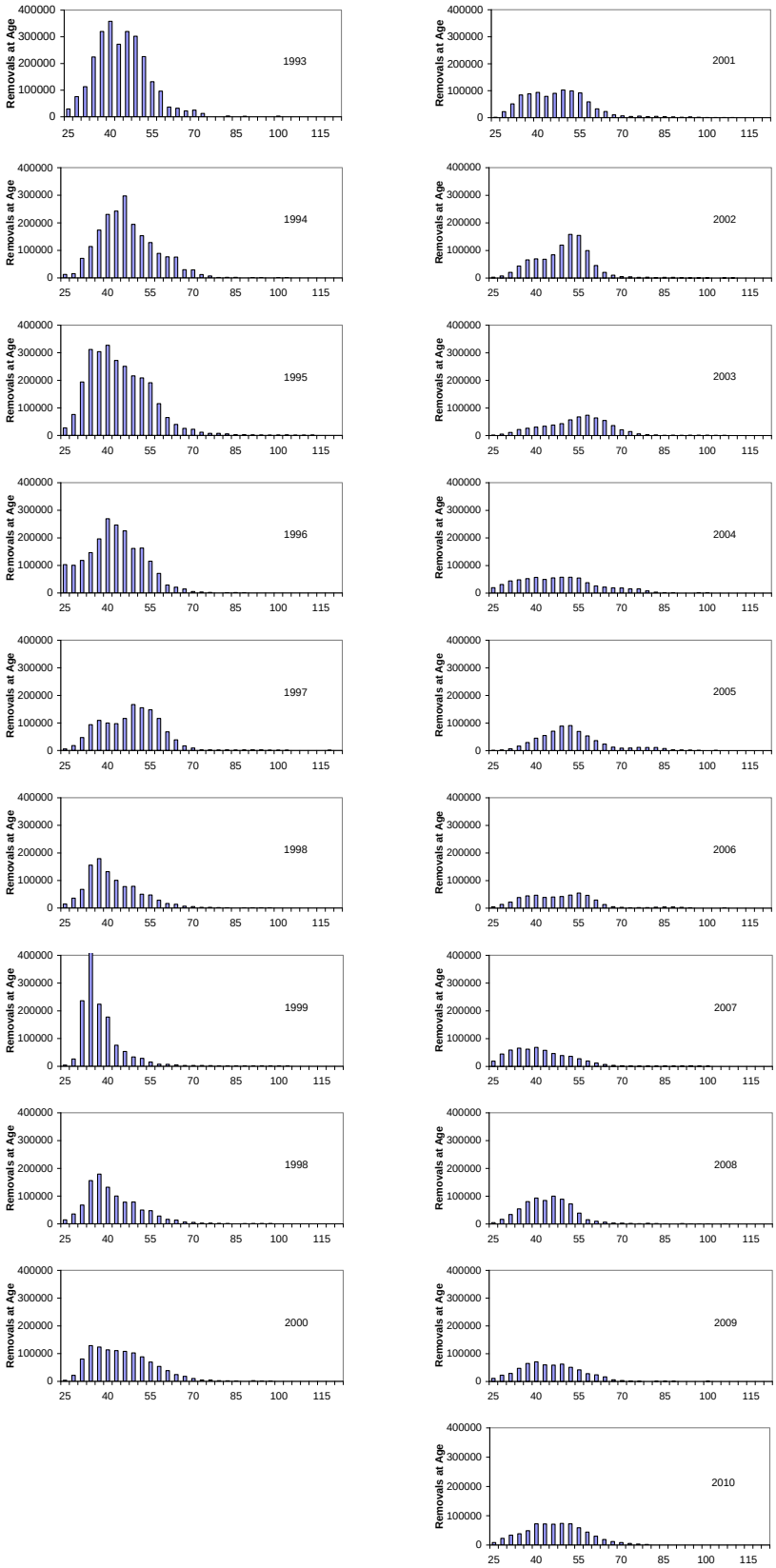

Figure 64. Removals (number of fish) at length of white hake from the commercial fishery in Div. 4VWX, 1993-2010.

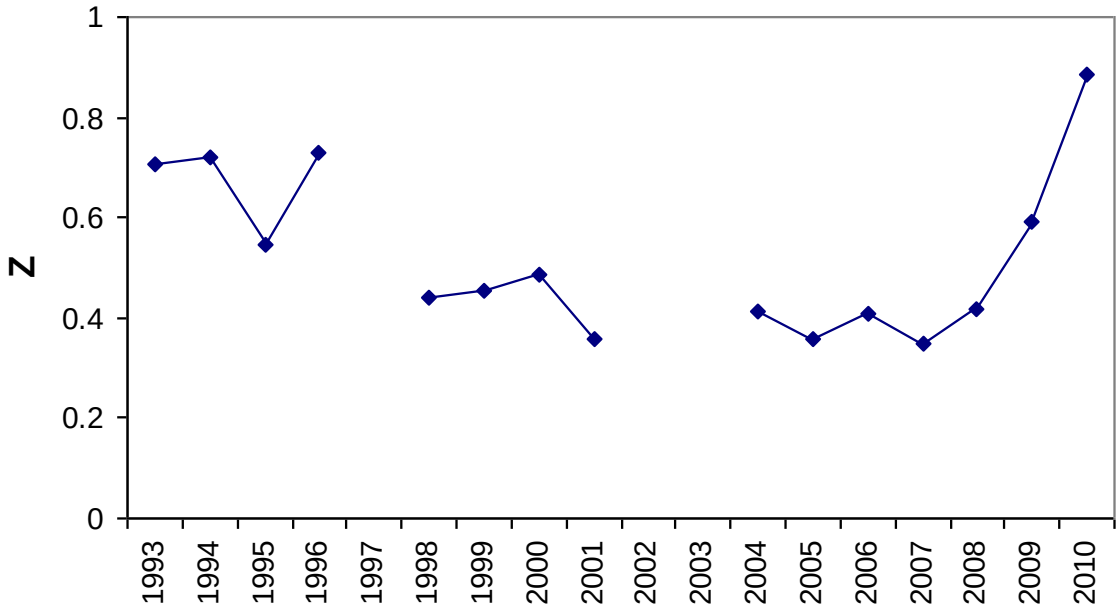

Figure 65. Estimates of Z from the descending limb of the commercial length frequencies from Div. 4VWX, 1993-2010. The model was not able to estimate Z in 1997, 2002 and 2003.

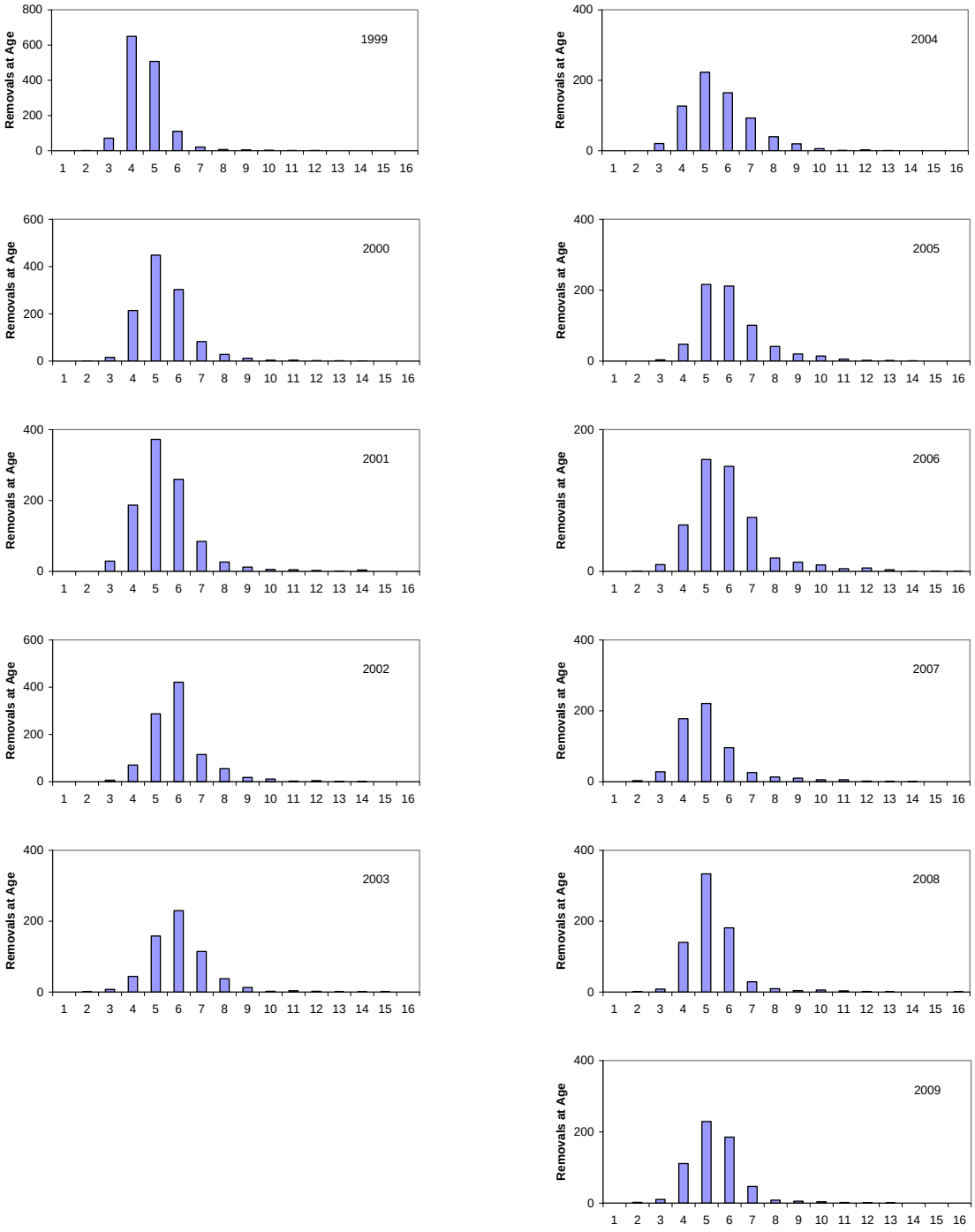

Figure 66. Removals at age (number of fish, X1000) of white hake from the commercial fishery in Div. 4VWX, 1999-2009.

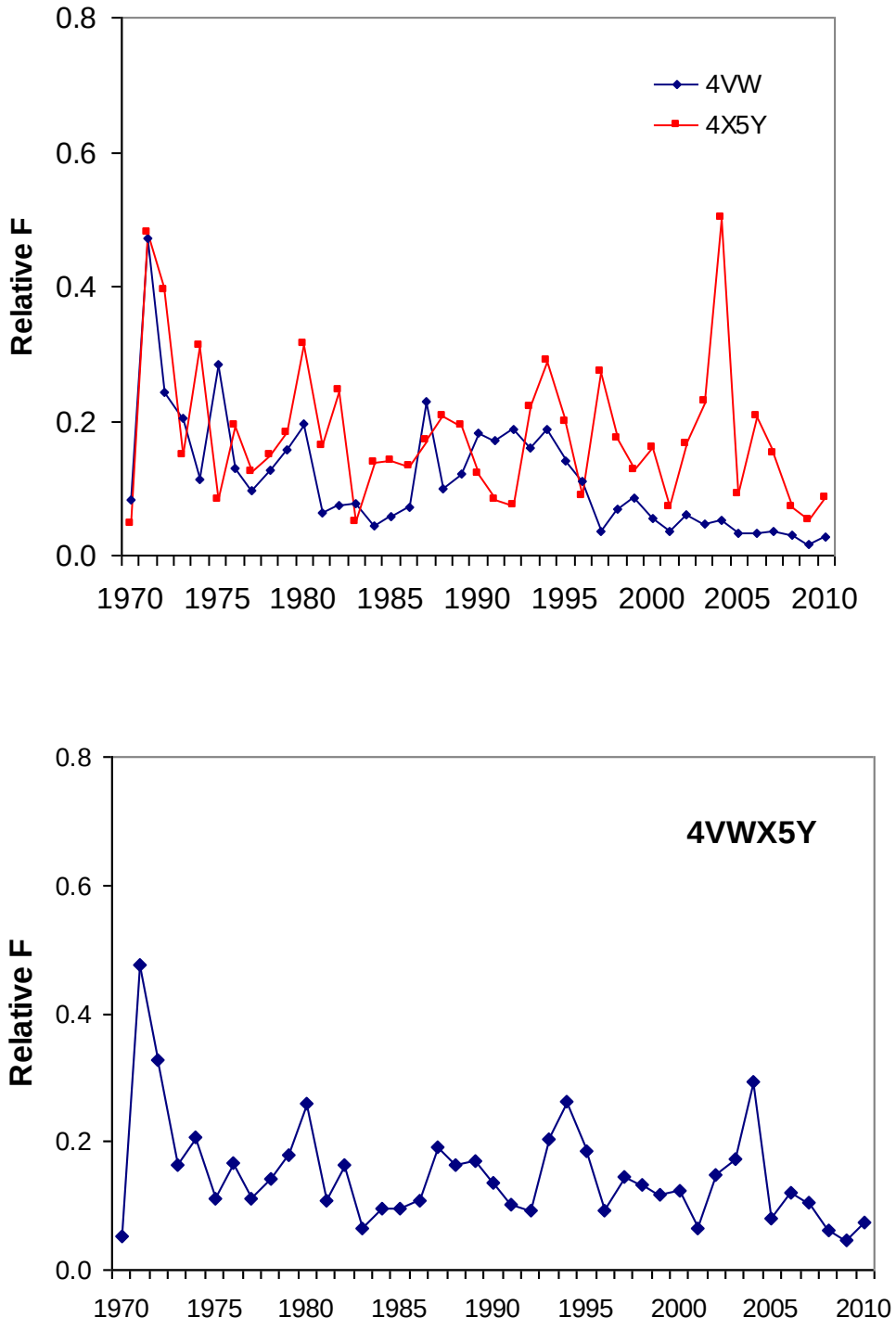

Figure 67. Relative F for white hake based on landings and summer RV biomass for Div. 4VW and 4X (top panel) and the entire survey area combined (Div. 4VWX5Y) in the bottom panel, 1970-2011.