The 4Vn Sentinel Survey: 1994-2015

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ABSTRACT

Lambert, T.C. 2019. The 4Vn Sentinel Survey:1994-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3319: iv + 55 p.

Initiated after the 1993 declaration of a moratorium on cod fishing in NAFO statistical subdivision 4Vn (Sydney Bight), this survey is conducted annually in September by commercial longliners under the supervision of the Department of Fisheries and Oceans. The key product of this survey is an abundance index for 4Vn cod. Although cod are targeted, data on other groundfish bycatch are also collected. A subsample of cod are taken ashore for processing where they are weighed and measured, otoliths removed and organ weights recorded along with identification of stomach contents. Thus, in addition to age, length and weight data, information on condition and diet are provided. Also as well as the abundance survey conducted in September, other fishing operations included the monitoring of the outward winter migration of cod from the Gulf of St. Lawrence and a monthly monitoring of cod in Sydney Bight from April to December.

RÉSUMÉ

Lambert, T.C. 2019. The 4Vn Sentinel Survey:1994-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3319: iv + 55 p.

Lancé après le moratoire de 1993 sur la pêche à la morue dans la sous-division statistique 4Vn de l’OPANO (Sydney Bight), ce relevé est réalisé en septembre de chaque année par les palangriers commerciaux sous la supervision du ministère des Pêches et des Océans. Le principal produit issu de ce relevé est un indice de l’abondance de la morue dans la sous-division 4Vn. Bien que le relevé cible la morue, des données sur d’autres poissons de fond constituant des prises accessoires sont également recueillies. Un sous-échantillon de morue est ramené à terre aux fins de traitement. Les spécimens sont alors pesés et mesurés; les otolithes sont retirés; et le poids des organes est noté, tout comme le contenu de l’estomac du poisson. Ainsi, en plus de l’âge, de la longueur et du poids, on obtient des données concernant l’état et l’alimentation du poisson. En plus du relevé d’abondance réalisé en septembre, d’autres opérations de pêche comprenaient la surveillance de la morue pendant sa migration hivernale depuis le golfe du Saint-Laurent ainsi qu’une surveillance mensuelle de la morue de Sydney Bight d’avril à décembre.

INTRODUCTION

Due to a rapid decline in cod stocks on the Eastern Scotian Shelf, the federal Minister of Fisheries closed the fishery in September of 1993. As a result of pressure by inshore fishermen, who fished in Sydney Bight (NAFO subdivision 4Vn) a so-called “test fishery” was organized by the Department of Fisheries and Oceans (DFO). This survey was conducted by six inshore longliners over a period of 6 weeks from October 15 to November 30 (Lambert 1994). The 4Vn subdivision was divided into 5 areas from north to south with one boat assigned to each area. The sixth boat fished area 4Vsb on the southern boundary of 4Vn. The boats were permitted to fish at any location of their choosing within the sector assigned to them. Other than all boats using the same amount and type of gear and allocation to a specific region of 4Vn, there was no other sampling protocol. Due to the lateness of the year, little was learned of the 4Vn cod stock, for the data clearly showed the entry of 4T cod during their winter migration out of the Gulf of St. Lawrence and into Sydney Bight and their subsequent south-easterly movement. Determining catch rates for the resident stock was obviously compromised. If nothing else though, the monitored fishing showed that good data could be obtained from commercial boats and in many ways the exercise was a success.

The following year the inshore industry expressed a desire to conduct an annual survey during the moratorium to get an accurate reading of the stock status. There was merit to this suggestion due to the fact that the annual DFO Scotian Shelf groundfish survey made only about 10 sets in 4Vn, although in recent years that has been increased to 16. The stock abundance index generated from the information gleaned from these sets showed considerable annual variability, no doubt due to the low sample number. The DFO agreed to inshore longliners conducting a survey so long as the survey following accepted sampling protocols and was carried out over a short time period in order to get a synoptic representation of cod distribution.

ORGANISATION

PRELIMINARY

During the summer of 1994 a team made up of personnel from the Department of Fisheries and Oceans (DFO) Operations and Science Branches and Human Resources and Development (HRD) worked out the details of a sentinel fishing program for the 4Vn area off Cape Breton. There was a wide disparity in the amount of fishing wanted by the industry and the amount required by Science to do an adequate assessment of the abundance of the fish stock. By August a compromise plan had been formulated which would have good scientific value and adhere to conservation principals while allowing sufficient fishing to qualify for assistance under the Atlantic Groundfish Strategy (TAGS) program of the HRD. In addition, an education and training component was required for eligibility under the TAGS program.

A number of fishermen's organisations were interested in participating in the sentinel survey; therefore, to facilitate the operation of the venture, an umbrella organisation, the 4Vn Sentinel Fishery Association was formed. This association included all eligible longline operators comprising representation from five industry groups; the North of Smokey Fishermen's Association, the Glace Bay Fishermen's Association, Maritime Fishermen's Union - Local #6, the Port Morien Fishermen's Association, and the 4Vn Hook and Line Association. The 4Vn Sentinel Fishery Association (4VnSFA) was duly incorporated and registered with the N.S. Registrar of Joint Stock Companies.

SELECTION OF PARTICIPANTS

Applicants for participation in the survey had to meet the following criteria:

* be a single groundfish only licence holder
* be eligible for HRD Income Assistance through TAGS
* be the head of an active fishing enterprise
* have fished full-time for seven years
* have earned 75% of income or annual revenues of $20,000 from fishing.

In addition, the applicants had to be prepared to make a multi-year (3-5) commitment to the project. Also the Board decided to make it mandatory that boats must be decked over, have good navigational equipment and carry lifeboats.

FUNDING

Initially, funding for the project was secured from four sources. HRD provided wages and monies toward overhead under the TAGS program; DFO paid for boat charters, fuel and bait from the Atlantic Fisheries Adjustment Program (AFAP); DFO Science funded training, equipment and operating expenses, and Enterprise Cape Breton Corporation (ECBC) also provided funding on a cost shared basis. Later, as sunset programs (TAGS and AFAP) were concluded, DFO took over the sole responsibility for funding and the total amount available was cut considerably. With this decrease in funding a number of ancillary activities conducted by the 4VnSFA were cancelled. At present, only an abundance survey is carried out annually in September.

TRAINING

Under the terms for TAGS eligibility, participants were required to undergo training. Accordingly, instruction was provided in two sessions; the first was given prior to the survey and consisted of practical data collection training, and the second, conducted after the survey, was a course of instruction on basic fisheries science.

Pre survey

The participants of the Sentinel Survey were divided into two groups for this first session. Each of the groups received one and a half days instruction on the correct procedures for weighing and measuring fish, removing otoliths, and recording these data. Each session was introduced with an overview of the intended project, which included an explanation of the function and design of a scientific survey.

Post survey

After the survey, the fishermen were given a two-week course on the basic elements of oceanography, marine ecology and fish biology. The topics were selected to be of particular interest and usefulness to fishermen. Videos, slides, overheads and other illustrative material were liberally used to make the course as interesting as possible. Each section of the course was followed by a short quiz. These were purely for self-testing and no marks were recorded. Specific topics covered were:

The scientific method.	Body Form and Swimming.
Presentation of data.	Feeding Behaviour and Adaptations.
Physical Oceanography.	Growth.
Migration and Movement of fishes.	Reproduction and Maturation.
Marine Ecology.	Stock Assessment.
Spawning and Early Life History.	Elements of Marine Weather.

SAMPLING PROTOCOL

SURVEY DESIGN

A stratified random sampling scheme was used, similar to that used by DFO groundfish surveys. The sampling area was approximately 4000 sq. nautical miles (13,750 km2), comprising all of 4Vn within the 100 fathom (183m) contour and with the omission of about 650 sq. miles in the south-east corner of the subdivision. This last area ranged from about 50 miles from shore at its nearest point to about 80 miles at its furthest which was considered an impractical distance to travel. The sampling area was divided into three strata on the basis of depth. Initially, 60 set locations were selected randomly and assigned proportionally among the three strata; these were fished by 5 boats. Later due to reduction in funding and less money from diminishing cod catch sales the number of boats was reduced to 4 and sets to 56 (Table 1).

Table 1. Three depth strata for the 4Vn Sentinel Survey.

Depth (fathom)	Depth (metres)	Area (nm^2)	Area (km^2)	% of Total	# of Sets
<31	<56	1,070	3,674	25	14
31 – 50	56 - 91	1,320	4,532	32	18
>50	>91	1,780	6,112	43	24

The sample grid consisted of 463 blocks of approximately 9 sq. naut. mi. (31sq. km.) each 5 minutes by 3 minutes lat. and would fit most longline strings starting the set from the centre of the block (Fig. 1). The number of sets for each stratum was proportional to the area of that particular stratum. This had two benefits; more cod are caught in the deeper waters, and a simple mean of all sets could be calculated without having to calculate separate means for each stratum and weighting these to determine an overall unbiased mean.

For the first year, the boats were supplied with measuring equipment to determine individual length and weight of cod as well as materials for collecting and storing otoliths for later age determination. However, it quickly became clear that this was impractical. Trying to secure quality data on the unstable deck of a small boat in often rough weather was extremely difficult. Therefore, the protocol was changed in order to obtain more and better data. The first 50 cod to come aboard were reserved for shore analysis. Here, otoliths were collected and the fish measured and weighed. Then stomachs, gonads and livers were extracted and weighed. Gonads were assigned a maturity stage and stomach fullness estimated. A subsample of stomachs were opened and contents weighed and identified.

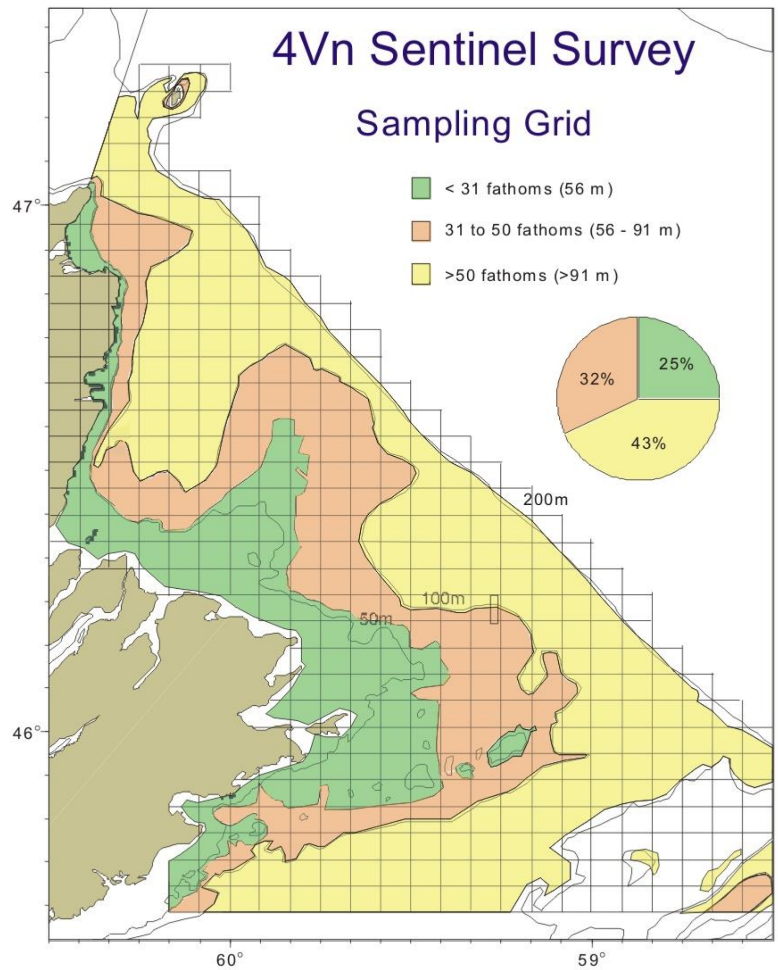


Figure 1. 4Vn Survey sampling grid design.

Initially, boats were allowed to make two sets per trip. However, with the elimination of at sea sampling three and sometimes (if station locations were particularly close) four sets were allowed.

FISHING GEAR

Fishing effort in the survey was standardized. Fishing sets, gear specifications and methods of deployment were standardized in consultation with industry.

- One set consisted of 5 tubs of gear.
- A tub of gear contained 450-500 hooks.
- Hooks - #12 circle.
- Gangions - 18 in. long, made of 150-200 lb. test (3-4 lb. linear weight) braided nylon set 6 ft. apart along the ground line.
- Bait - mackerel.
- As far as is practical captains should aim for a soak time of 3 to 6 hours.

- A preprogramed temperature recorder to be attached to the anchor at an end of one of the set strings.

An additional standardization was added to recognize a tactic common in the Cape Breton area; the ground line had floating line spliced to it at intervals to raise hooks off the bottom. The floating line is added every 60 hooks; thus from the anchor, by groups of hooks: 30-normal back line; 60-floating line spliced in; 60-normal; 60-float; 60-normal; 60-float etc. The majority of sets, 88% were made at night.

Statistics collected after the survey to monitor the degree of conformity to standards showed the following gear values for the original six boats:

	Minimum	Average	Maximum	Stan.Dev.
Soak Time (hours)	2.6	6.2	12.1	2.0
Hooks (total)	2,225	2,295	2,550	60
Hooks per tub	445	460	510	12
Length of set (km)	3.5	3.9	4.5	0.3

All the gear variables listed above appeared to be well within limits of tolerance with perhaps the exception of soak time. It was not possible to be more consistent with set duration due to the positioning of set locations. The travel time between the two sets on each trip was quite variable but unavoidable due to the random positioning of the set locations. However, although there tended to be a drop off in catch over time, good catches were made at the average soak time (Fig. 2).

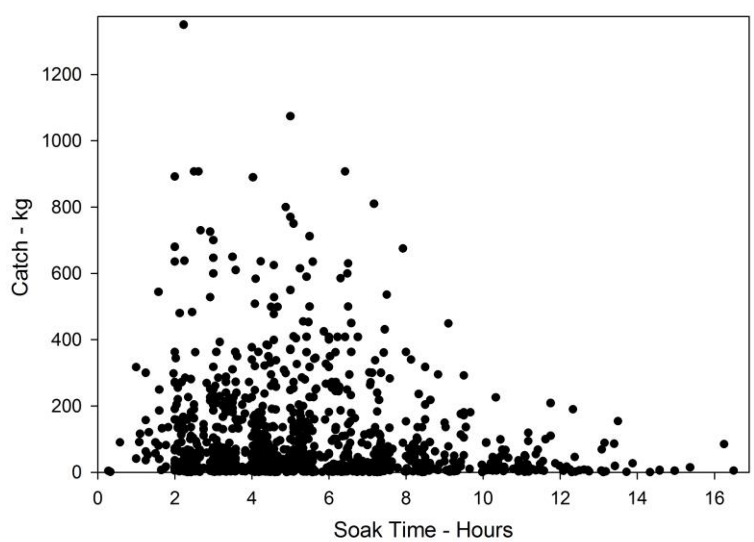


Figure 2. Relation of catch to soak time.

The duration of most sets was between two and ten hours. Good catches could be made in less than two hours. The largest catch of 1350 kg occurred after not much more than two hours. If anything this graph tells us that there is little, if any, advantage in leaving the gear in the water longer than about 8 hours.

SUPPLEMENTARY ACTIVITIES

Unless specified otherwise all figures and tables refer to the annual September abundance survey. However, in addition a number of auxiliary studies or experiments were conducted by the Sentinel longliners.

July abundance index

Participants felt that a survey in early September would give the best estimate of the resident 4Vn cod stock. However, it was felt that a survey conducted in July might be useful as a comparison to the regular DFO shelf wide trawl survey conducted at that time of year.

Cod migration monitoring

At the time Sentinel Survey activities began, the conventional DFO wisdom was that the Gulf of St. Lawrence cod stock (NAFO sub-division 4T) exited the Gulf and entered Sydney Bight in November on their annual overwintering migration. This was disputed by many inshore 4Vn fishermen who believed the date was much earlier; hence a number of fishing sets were organized to test this assumption.

Gear comparison study

When the Sentinel Survey first began the gear used was that used by the commercial fishermen at that time. However, later on, a newer gear was introduced which was felt to be superior to the older gear. This newer gear was tested against the older gear to see if it was indeed superior and if so, to quantify this catch advantage. It did indeed prove superior but for consistencies sake we continued to use the original, older gear for the survey.

Monthly monitoring

In order to investigate monthly changes in such things as catch, distribution and feeding an experiment was established whereby three fixed station sites were chosen by those fishermen tasked to fish them. One was located in each of the three depth strata.

Commercial index

Despite the moratorium on the cod fishery, inshore fishermen continually lobbied for a commercial index fishery; one in which more boats than those chosen for the science abundance survey could participate. These short term fisheries began in 1998 under strict quota conditions. However since stock abundance continued to decline, they were discontinued after 2004.

RESULTS

July Abundance Index

A July abundance survey was abandoned after three years for a number of reasons. Firstly, the species composition of the catch in July was different from September (Table 2) and the July catch rates of cod were much lower than those of the September survey (Table 3) and it was felt they were not representative of the 4Vn stock. It is possible that the 4Vn cod had not completely returned to their 'home' grounds after overwintering further offshore, particularly in 1995 and 1996. Also overwintering fish from 4Vs may still have been present for larger fish appeared to be present in July than later in September (Table 4 & Fig. 3).

Table 2. Total catch in the July and September surveys; 1995-1997.

JULY SURVEY		SEPTEMBER SURVEY	
SPECIES	**CATCH (KG)**	**SPECIES**	**CATCH (KG)**
Spiny Dogfish	29926	Cod	40576
Cod	12843	American plaice	6492
American Plaice	3443	Skate	3786
Thorny Skate	3157	Spiny Dogfish	2082
Striped Atl. Wolffish	1757	Striped Atl. Wolffish	1130
Sculpins	665	Greenland cod	797
Blue Shark	400	Blue shark	599
Yellowtail flounder	308	Sculpins	648
Silver Hake	307	White Hake	628
Northern Wolffish	253	Spotted wolffish	416
Greenland Cod	180	Halibut	274
Halibut	150	Crabs (unspecified)	165
White Hake	136	Yellowtail flounder	113
Haddock	111	Porbeagle shark	98
Spotted Wolffish	76	Eel	52
Eel	71	Haddock	31
Crabs (unspecified)	37	Shortfin Mako	30
Turbot	33	Pollock	22
Pollock	13	Northern wolfish	10
Winter flounder	7	Redfish	10
Other	21	Other	18

Table 3. Catch rate of cod from July and September surveys (CPUE – Catch per unit effort).

	CPUE (kg/1000 hooks)	
Year	**July**	**September**
1995	22.8	106.6
1996	19.2	86.9
1997	54.9	91.9

Table 4. Weighted mean length of cod from July and September surveys.

	Wt. Mean Length (cm)	
Year	**July**	**September**
1995	54.9	52.7
1996	53.2	53.2
1997	57.4	54.1

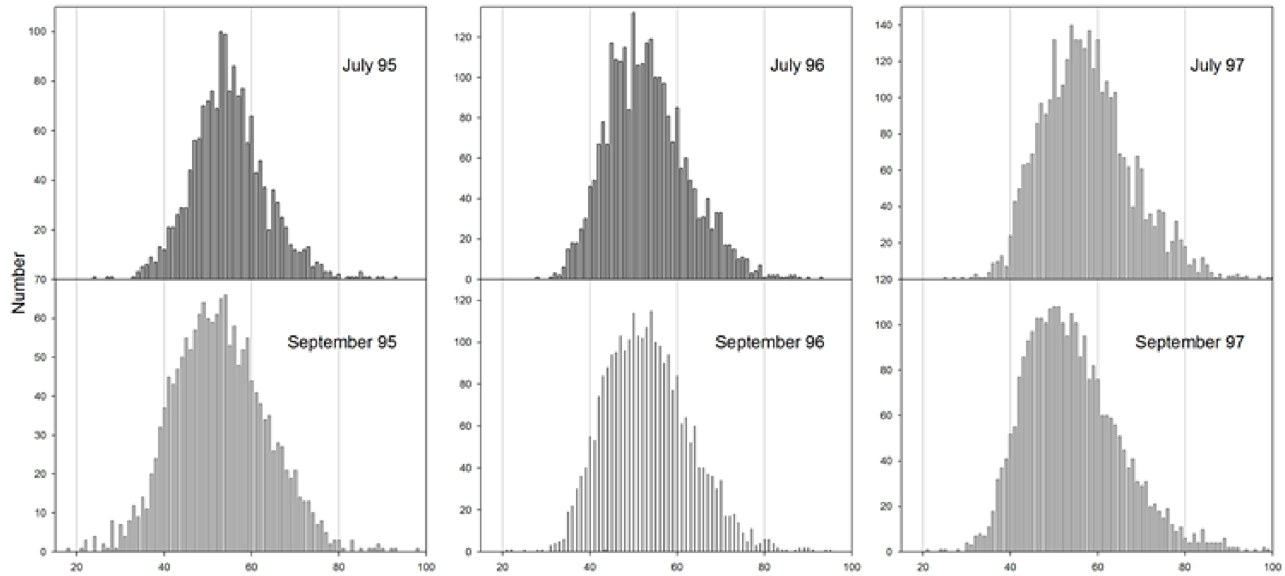


Figure 3. Length frequencies of cod taken during July and September surveys 1995 to 1997.

Furthermore, dogfish were the dominant species in the catch and apart from being hard to handle it is possible they, being quite voracious, took up much of the 'hook space' on the longline strings that would otherwise have captured cod, thus biasing the actually cod catch rate. Finally, it was agreed by participants that the money put toward this summer survey could be employed better in alternative projects.

Bottom temperature

Each boat was provided with a programmable temperature recorder which was attached to a gear anchor on one of the sets made during a trip. Annual shaded contour plots were constructed and can be found in Appendix I. Bottom temperature was plotted for the three sampling strata (Fig. 4).

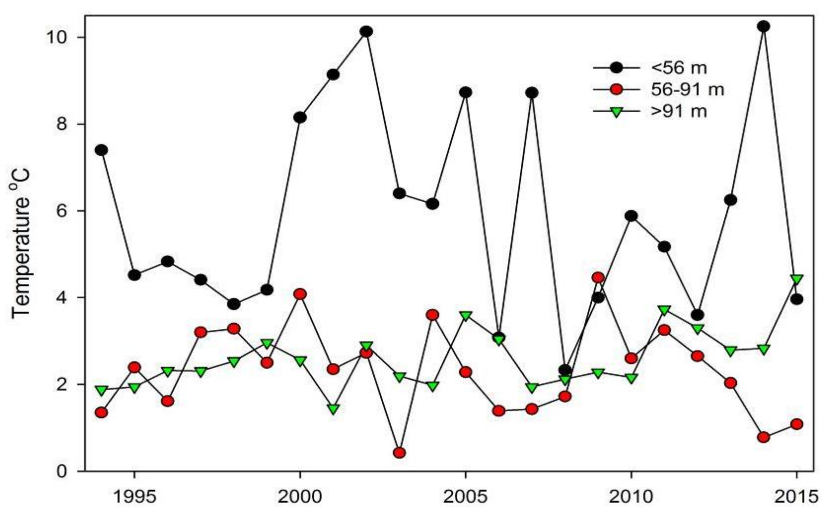


Figure 4. Bottom temperature by depth stratum 1994 to 2015.

Not surprisingly, temperatures varied the least at the deepest depth stratum and most at the shallow stratum. The high variability (ranging between 2.33 °C and 10.25 °C) in the shallow stratum is probably partially due to the low number of observations in some years. The number of temperature observations per year ranged from 10 to 44 with an average of 21. Due to various types of malfunctions the number in some strata was quite low, particularly in the shallow stratum where fewer fishing sets were conducted normally. Therefore, to determine a more accurate overall average bottom temperature for the 4Vn sample area, weighted means were calculated. One index used the number of sets per stratum to weight the mean and the other the stratum area. The overall average bottom temperature is shown in Fig. 5. There was little difference between the two.

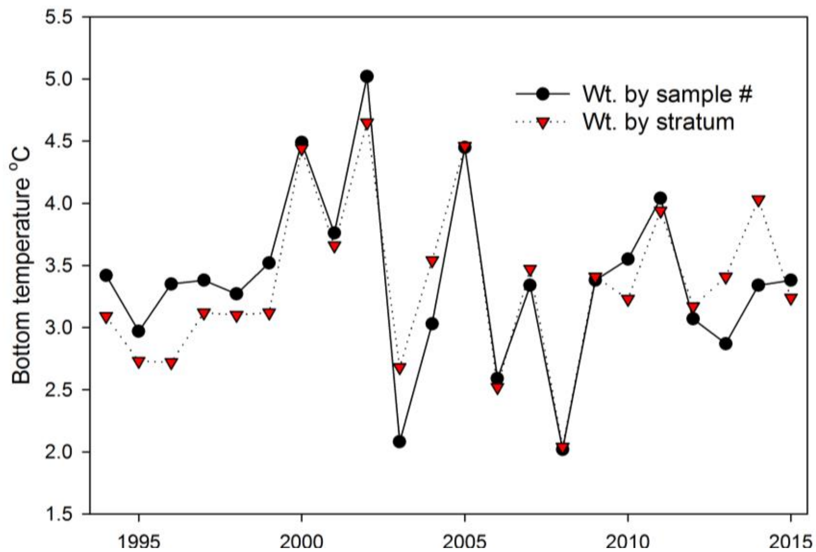


Figure 5. Weighted mean temperature for survey area.

Although bottom temperatures in shallow waters were highly variable, there were distinct trends in temperature at the intermediate and deep strata. Temperature at depth indicated a steady increase over the 22 year period at a rate of 0.06 °C per year (Fig. 6).

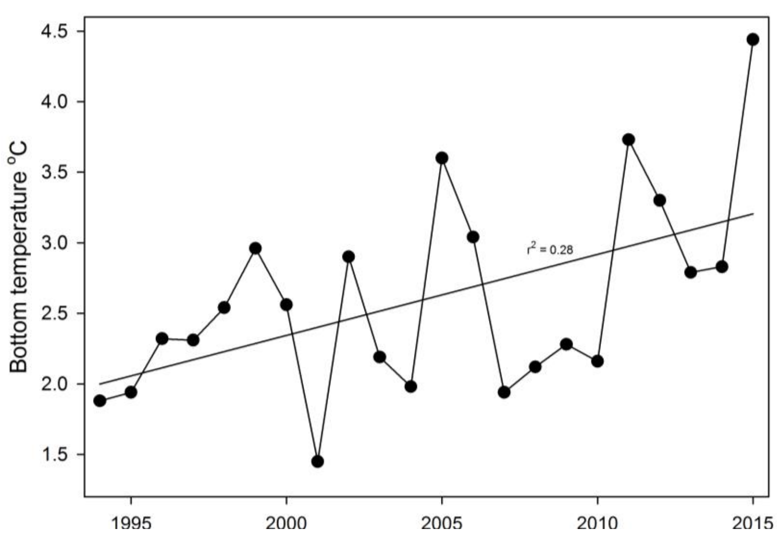


Figure 6. Bottom temperature at the deep stratum (>91m)

However, whereas bottom temperature at intermediate depth initially followed the same increasing trend as the deep layer; over the last 7 years, in contrast to deeper water, a steep cooling trend was evident (Fig. 7).

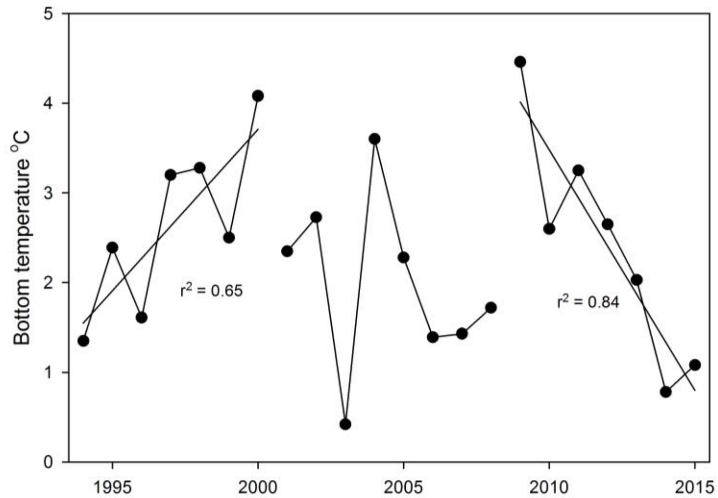


Figure 7. Bottom temperature at the intermediate stratum (56-91m).

Catch

The total catch by species over the 22 year span of the survey was divided into two periods (Table 5, Figures 8 & 9). A number of things stand out. The catch over the past decade was less than half of that of the earlier decade; most of which can be attributed to the drop in cod landings. Another noticeable feature is the huge increase in halibut catch, 21 times greater in the recent decade over the first decade.

Table 5. Total catch of all species from 1994 to 2015.

1994-2004		**2005-2015**	
Species	**kg**	**Species**	**kg**
Cod	91,126.31	Cod	32,525.17
Plaice	11,741.37	Halibut	9,157.80
Skate (unspecified)	7,812.76	White Hake	5,762.32
White Hake	6,656.41	Skate (unspecified)	3,378.06
Spiny Dogfish	5,546.50	Greenland Cod	1,875.02
Greenland Cod	2,755.89	Atlantic Wolffish	1,613.20
Atlantic Wolffish	3,060.68	Sculpin (unspecified)	1,522.48
Blue Shark	1,215.10	Plaice	1,010.62
Sculpins	1339.45	Blue Shark	822.76
Spotted Wolffish	527.81	Turbot	247.31
Halibut	432.74	Porbeagle Shark	199.50
Snow Crab	211.62	Snow Crab	189.05
Crabs (unspecified)	168.00	Shortfin Mako	104.61
Turbot	131.90	Black dogfish	90.00
Porbeagle Shark	127.00	Redfish (unspecified)	77.86
Yellowtail	113.00	Haddock	75.41
Pollock	81.36	Spotted Wolffish	52.37
Northern Wolffish	73.80	Pollock	10.45
Eel	58.00	Starfish	10.00
Redfish (marinus)	55.00	Spiny Dogfish	9.26
Shortfin Mako	55.00	Eel	6.91
Haddock	54.30	Crabs (unspecified)	3.20
Redfish(unspecified)	35.10	Winter flounder	3.00
Starfish	16.00	Witch flounder	3.00
Northern Hagfish	12.00	Northern hagfish	1.00
Cucumbers	4.00	Yellowtail	1.00
Silver Hake	1.00		
Total	133,412.1	Total	58,751.36

The catch of cod has declined in recent years to about a quarter of the catch rate at the start of the survey. This trend was closely matched by the remainder of the groundfish community (Fig.10). The only noticeable departure from this parallel was in 2015 when the catch rate, excluding cod, showed a large increase which was mainly due to high catches of halibut.

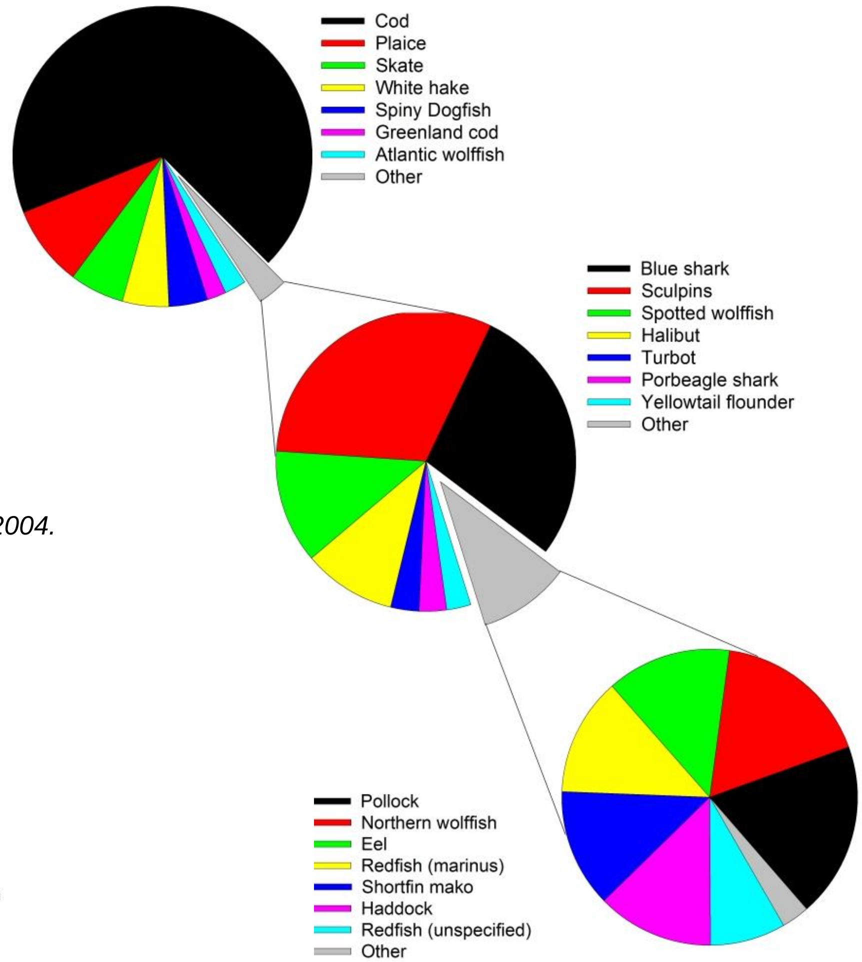


Figure 8. Total catch (kg) from 1994 to 2004.

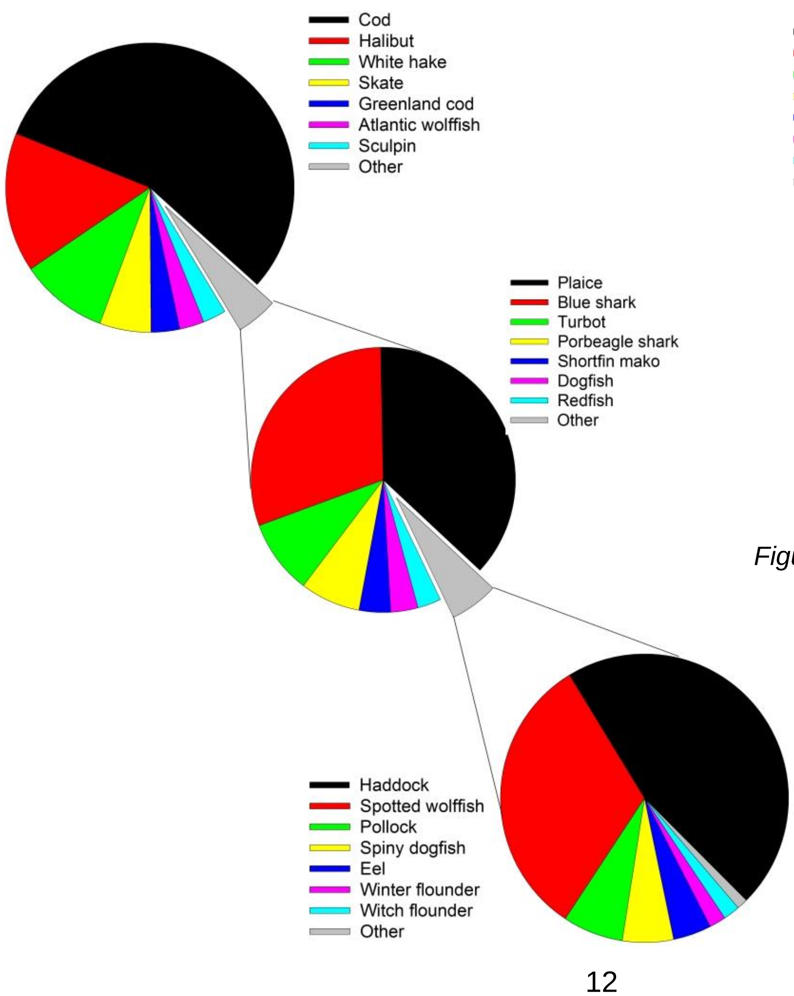


Figure 9. Total catch (kg) from 2005 to 2015.

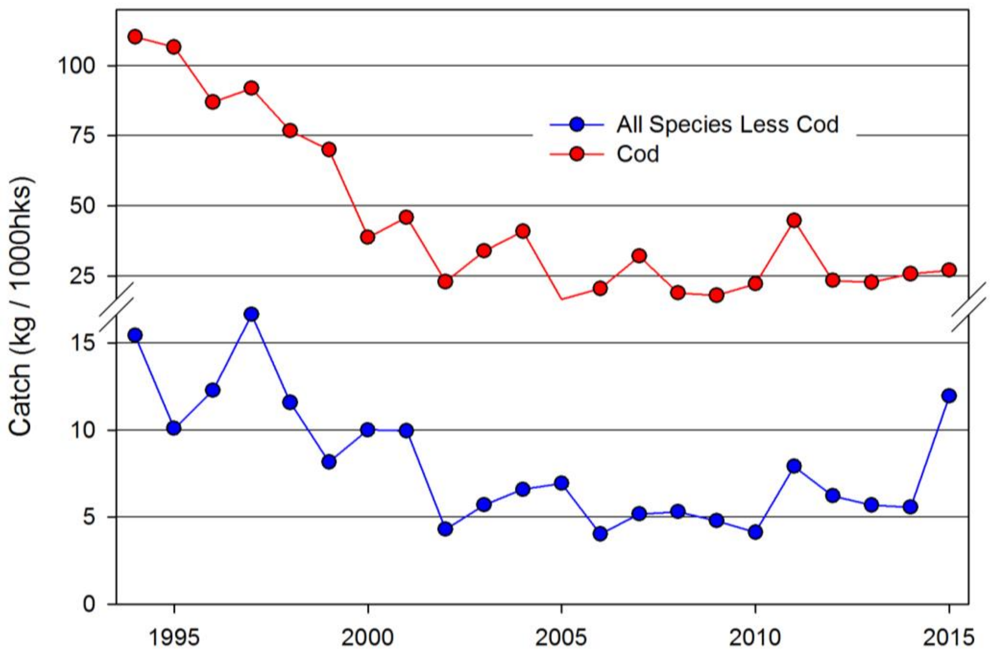


Figure 10. Groundfish catch rates in 4Vn from 1994 to 2015.

Catch rates of groundfish species of interest other than cod are shown in Figs. 11 to 13. All species of skate are included in the one data set. The majority were logged as unspecified but when identified, were nearly all listed as thorny skate and it is probable that most of the unspecified were thorny. Likewise, most wolffish were listed as unspecified but almost as many as striped Atlantic. Since boat captains were instructed to pay particular attention to and identify in the catch record any occurrences of endangered spotted and northern wolffish, it is almost certain that those unidentified were actually the striped Atlantic species. Sculpins were rarely identified as to species and nearly all listed as unspecified on data sheets.

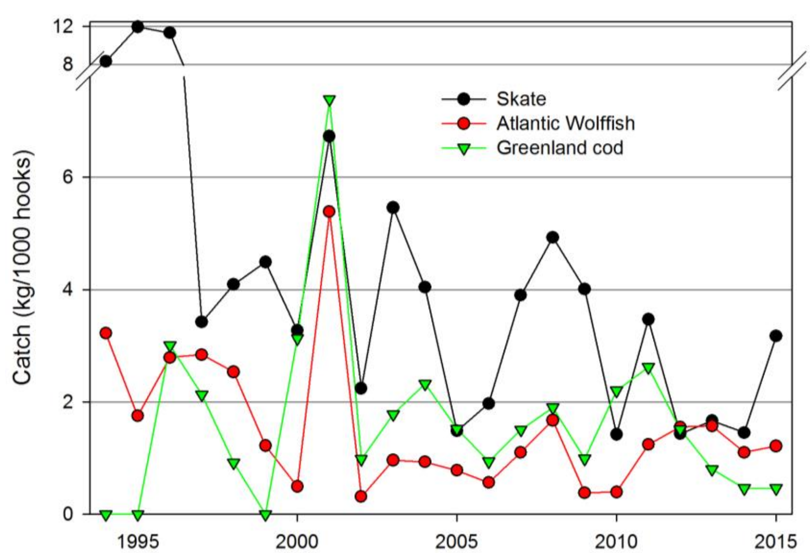


Figure 11. Annual catch rates of halibut, white hake and American plaice 1994 – 2015.

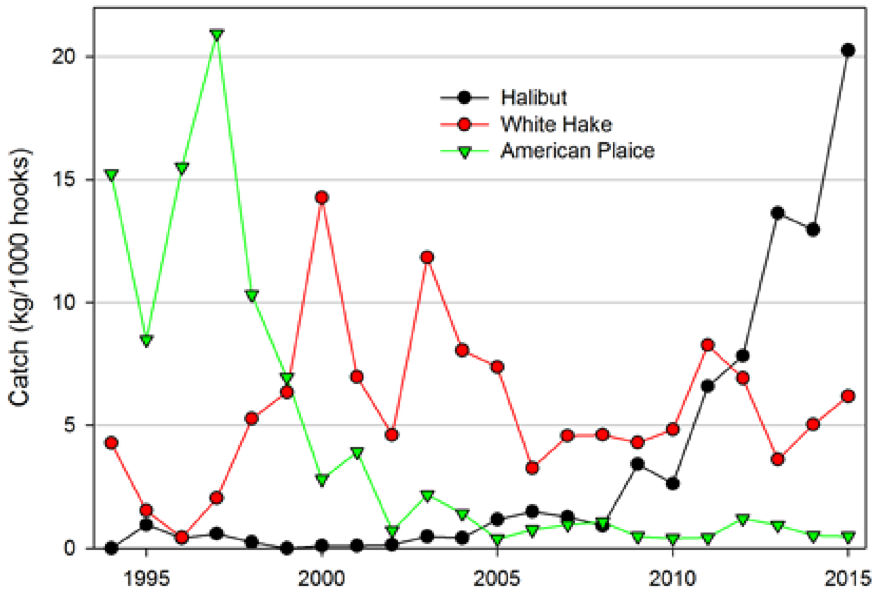


Figure 12. Annual catch rates of Atlantic wolffish, Greenland cod and skates 1994 – 2015.

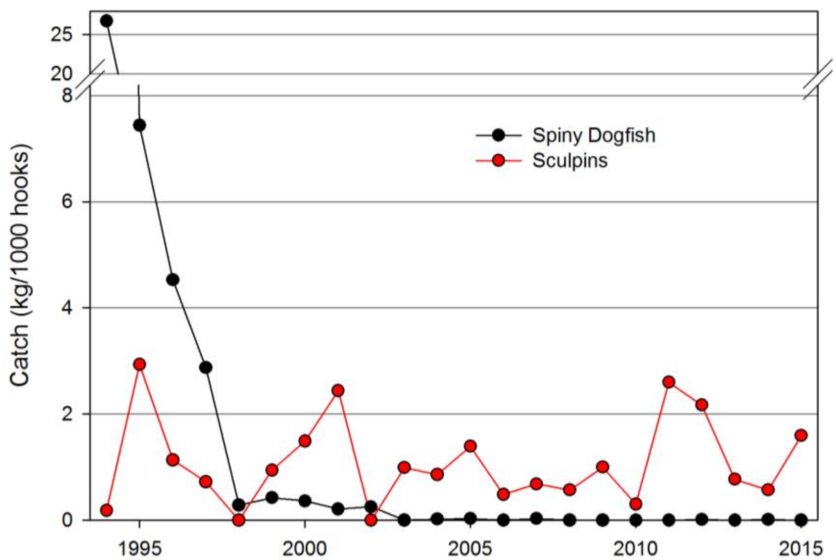


Figure 13. Annual catch rates of spiny dogfish and sculpins 1994 – 2015.

There were three patterns in the species abundance trends with all but one exhibiting a decrease. The first, albeit rapid to 1997 from an initially high level, was a gradual decrease over the span of the survey period, as illustrated in the catch of skate. In the second, not dissimilar to the first in that these three species displayed a rapid decrease in catch over the first 5 to 10 years, there were in contrast fairly stable catch rates thereafter. Cod, American plaice and dogfish fit this category, although dogfish practically disappeared in the catch after 2002. The third category included species whose catch remained relatively stable throughout all years; these were sculpins, wolffish and Greenland cod. The only departure from this pattern occurred in 2001 when there was a large upward spike in the catch of wolffish and Greenland cod. The only species to achieve an increase was halibut, which for the first 15 years of the survey was quite scarce. Thereafter, from 2008 to 2015, catch rates climbed rapidly, about ten-fold.

Depth Distribution

The distributions of species of interest are illustrated in Fig. 14. Although the species shown can be found in all three depth strata, clearly based on catch rates there are depth preferences. The majority (7) were caught more often in deeper water, three preferred shallower bottom and halibut was found in roughly equal numbers in the deep and shallow strata but low numbers at intermediate depths. The preference for deep water was most marked in hake and haddock; whereas, Greenland cod and sculpins were rare at depth with the latter being practically absent there.

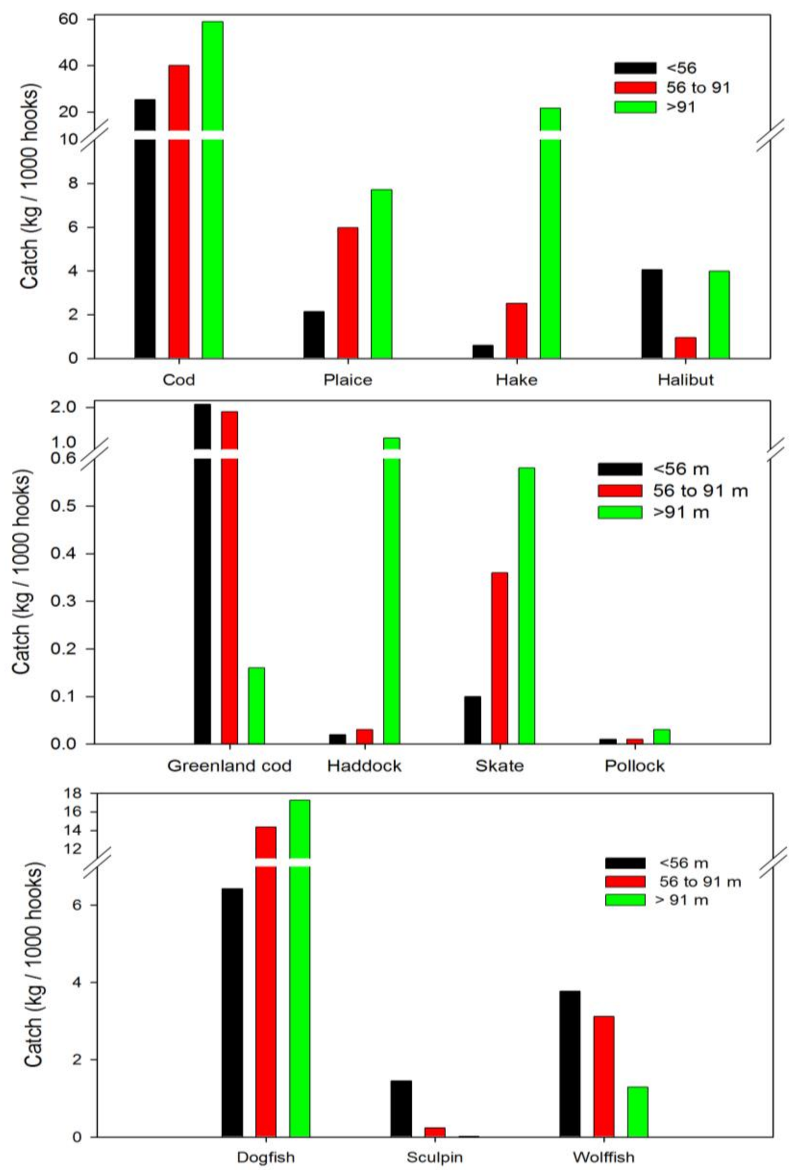


Figure 14. Depth distribution of selected species.

The distribution of halibut bears further investigation considering it was unlike any other in that there appeared to be no preference between deep or shallow water. The length frequencies of fish were examined for each of the three depth strata. Whereas the largest individuals of most species are found in deeper water than smaller, the opposite was true for halibut (Fig. 15).

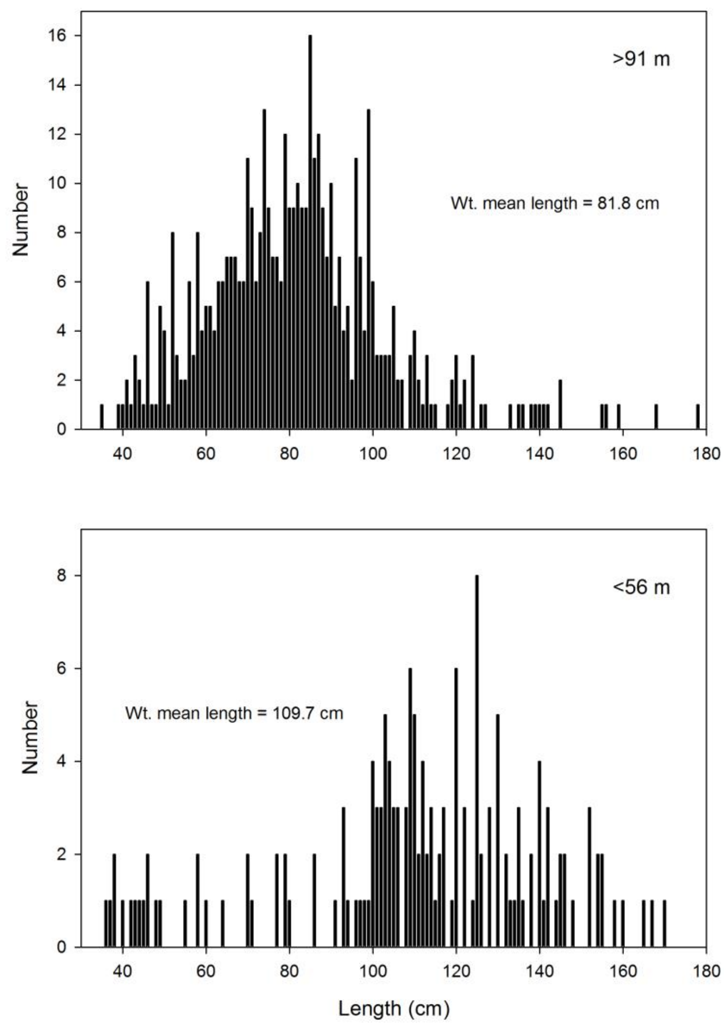


Figure 15. Length frequency of halibut at deep and shallow strata.

The weighted mean size of halibut in the shallow stratum was 109.7 cm and the deepest, 81.8 cm. Few individuals (58) were caught at intermediate depths and their size ranged from 42 cm to 155 cm with a mean of 97.3 cm.

COD

Catch

Despite the imposition of the moratorium on commercial cod fishing, the abundance of cod in 4Vn continued to decline over the first decade of the survey, from a high of 110 kg/1000 hooks in 1994 to a low of 16.7 kg./1000 hooks in 2006 (Fig. 10). Thereafter, the catch rate has remained low but fairly stable at about 25kg/1000 hooks, although it could be argued there has been a slight increasing trend over about the last seven years. Catch declined over all depths (Fig. 16); however, the decline was relatively greater in the two shallowest strata. From 1994 to 2005 there was not much to choose between the deep and intermediate strata, whereas for subsequent years the catch in the 56 to 91m stratum declined to values similar to the shallow <56m stratum. This could possibly indicate a movement of fish between depth strata. The annual distribution of cod catch over the course of the survey can be seen in Appendix II. With today's modern electronic aids

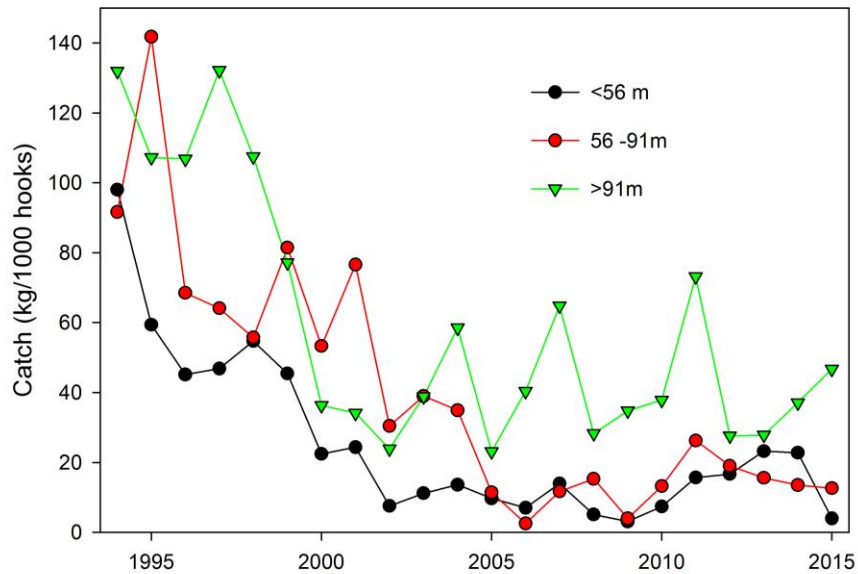


Figure 16. Catch of cod by depth.

the fishing industry is fast to locate where fish aggregate, so movement of fish will often be reflected in the location of fishing boats. From 1998 to 2004 the 4VnSFA conducted a commercial index fishery which mimicked a commercial fishery but with a very limited quota. The mean depths of sets made over the seven years showed a distinct movement toward deeper water (Fig. 17).

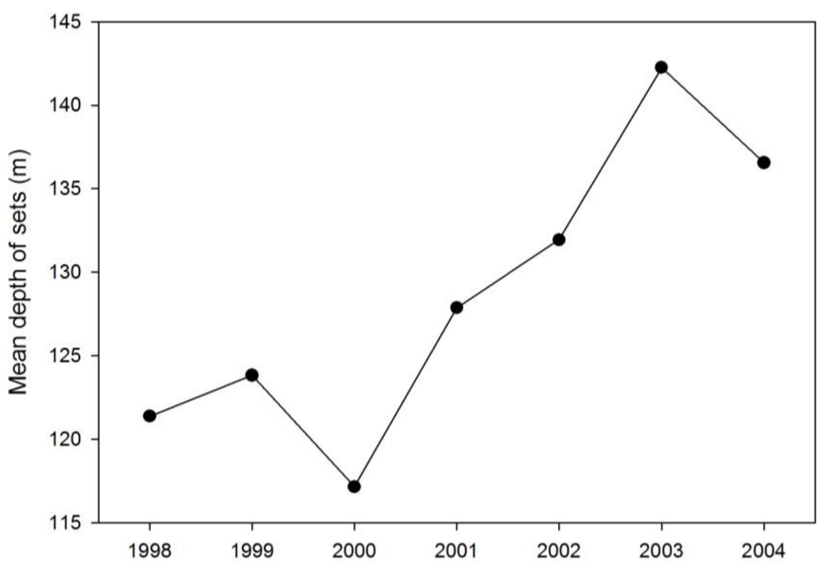


Figure 17. Mean depth of sets made during commercial index fishery.

A trend of random survey catches to deeper water over the entire 22 year period coincided with an increase in temperature in the deep water stratum from around 2°C to over 3°C (Fig. 18).

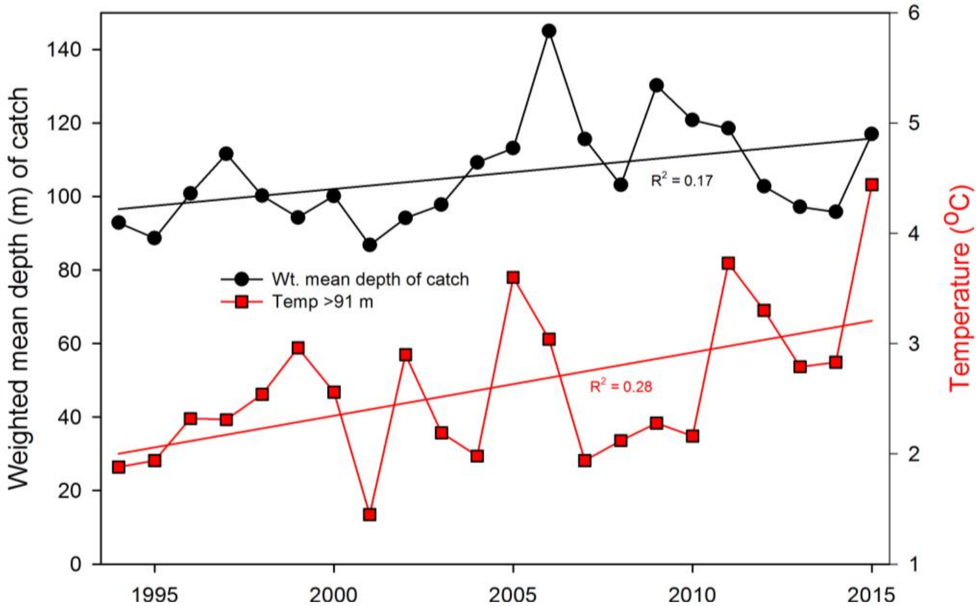


Figure 18. Weighted mean depth of cod catch and mean water temperature at depths >91m.

To examine further the apparent link between fish movement and temperature, data from the shallow and deep strata were considered separately. Temperature was plotted against the weighted mean depth of the cod catch over all strata. In the shallow stratum temperatures ranged from about 2°C to 10°C. The trend line indicates that when temperatures were low in shallow water, cod were found in deeper water than when temperatures were higher (Fig. 19).

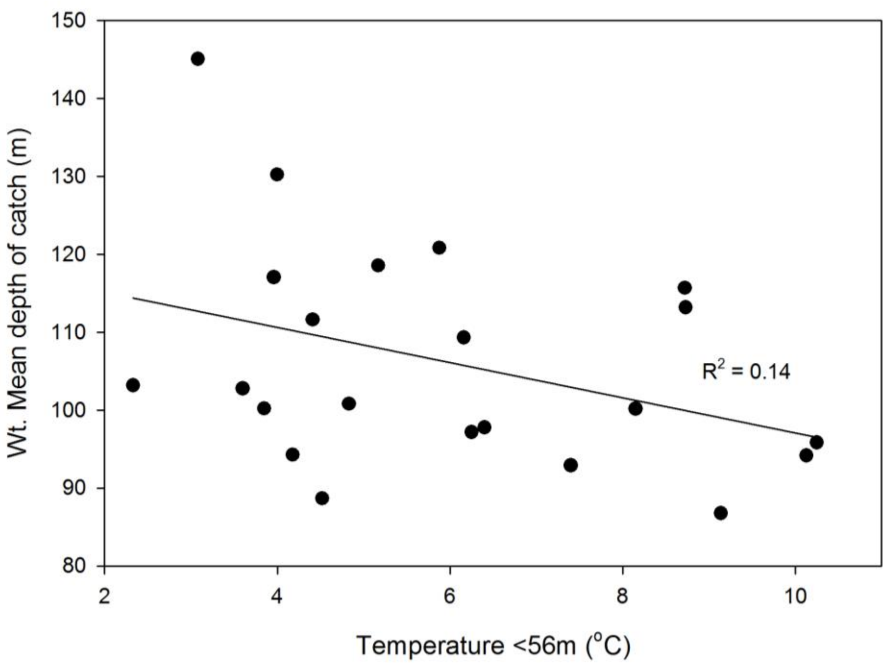


Figure 19. Mean depth of cod catch in relation to water temperature at depths less than 56 m.

Or in other words, as inshore temperatures warmed, cod tended to move towards shallower water. The range of temperature in the deeper stratum was much less, about 4 °C. In this case the trend line has an opposite slope (Fig. 20) and here the temperatures are mostly representative of conditions where the cod are actually caught. When water is very cold in the deep stratum the cod were found in shallower depths at the inshore boundary of the deep stratum. However, as the deep water warmed the cod moved deeper within this stratum. In both cases cod appear to move away from very cold water exhibiting a sensitivity to temperature as indicated also by Figure 18.

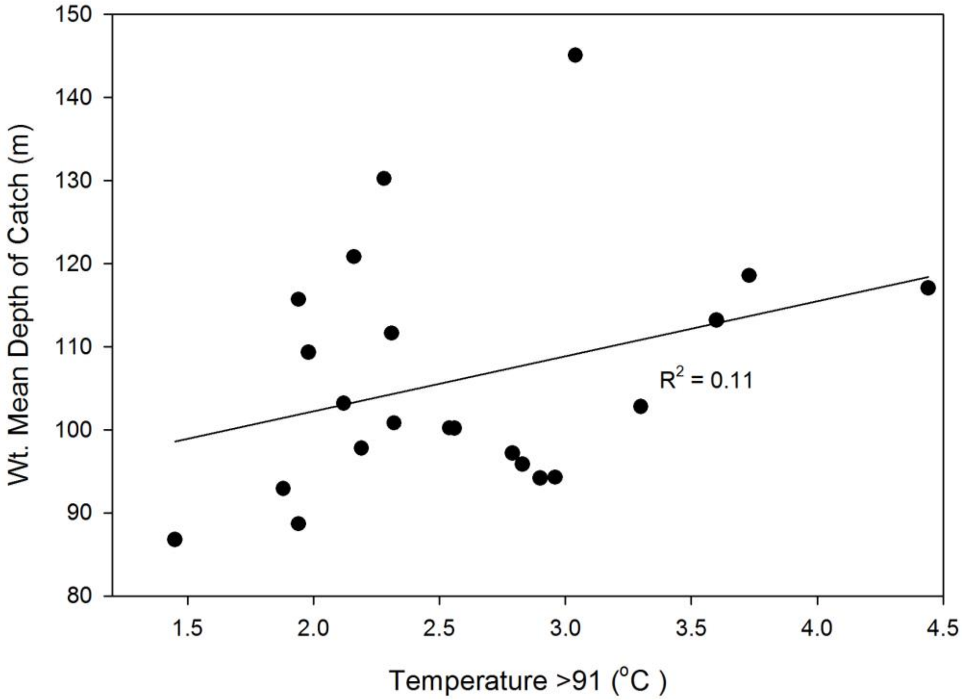


Figure 20. Mean depth of cod catch in relation to water temperature at depths greater than 91 m

Length and Weight

The moratorium on cod fishing was imposed in the autumn of 1993. From 1994, at the start of the survey, mean size of cod increased until 1996 (length by about 2 cm and weight by about 260 g). Thereafter, there has been a more or less continuous decrease in size (Figs. 21 & 22). A substantial increase in 2015 was not sustained, as preliminary calculations for mean length and weight in 2016 show a decrease to 46.7cm and 978g respectively. This decrease in length and weight was apparent at all depths (Figs. 23 and 24).

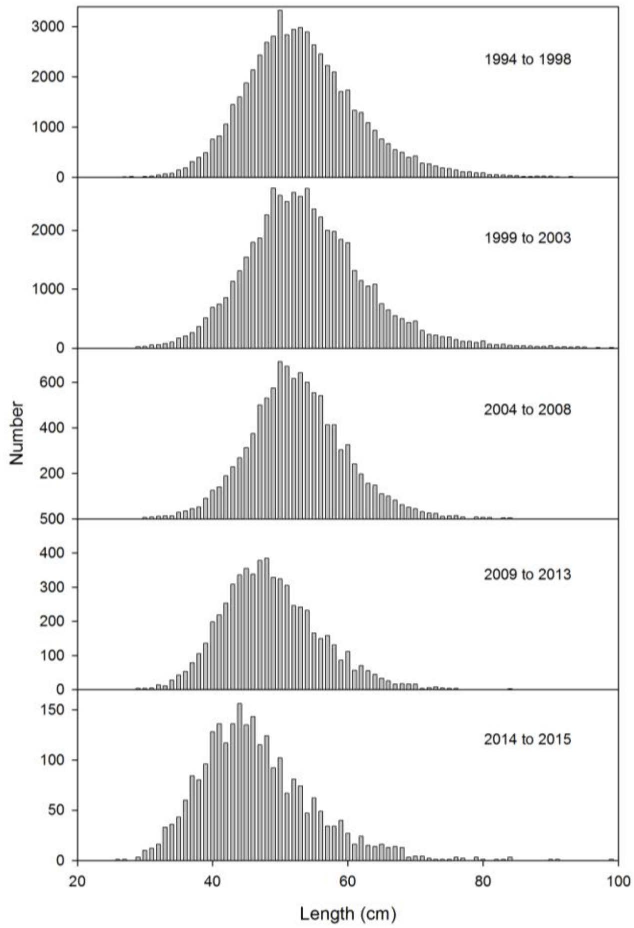


Figure 21. Length frequency of 4Vn cod from 1994 to 2015.

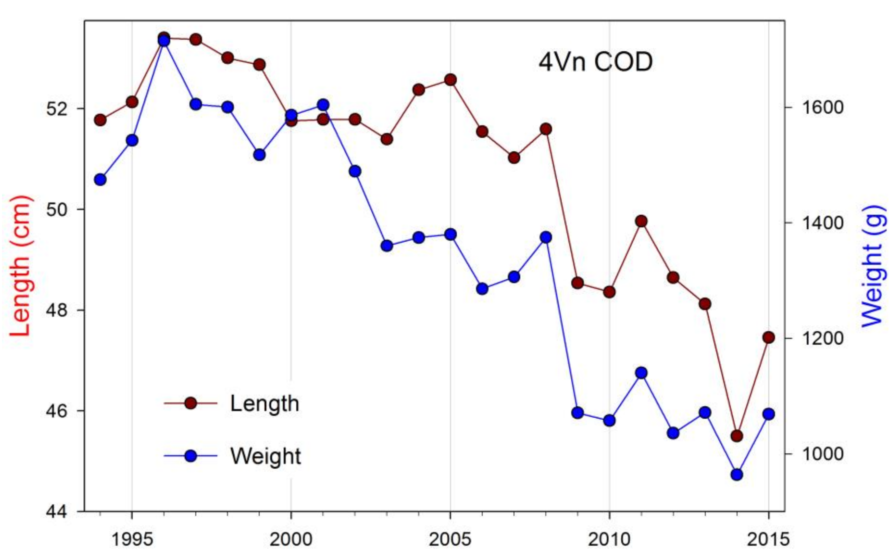


Figure 22. Mean length and weight of 4Vn cod from 1994 to 2015.

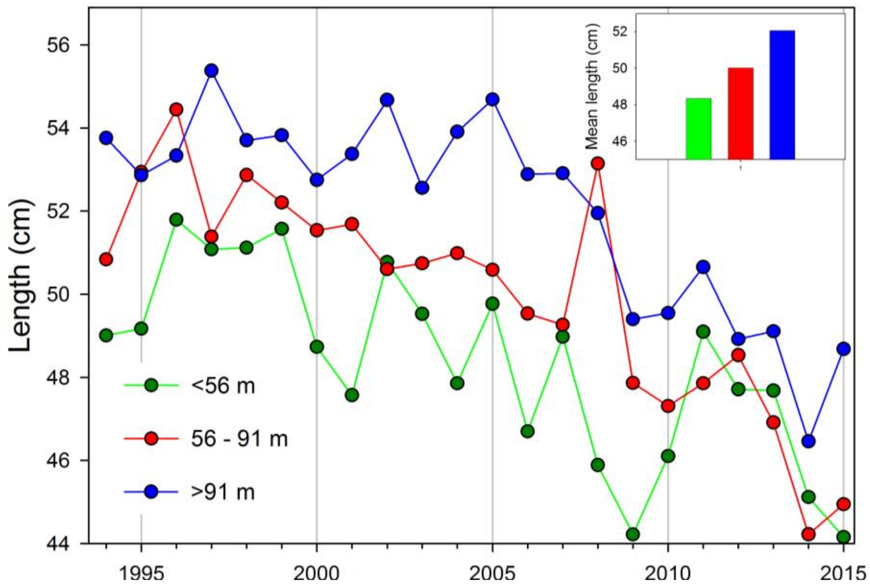


Figure 23. Change in mean length of cod by depth between 1994 and 2015.

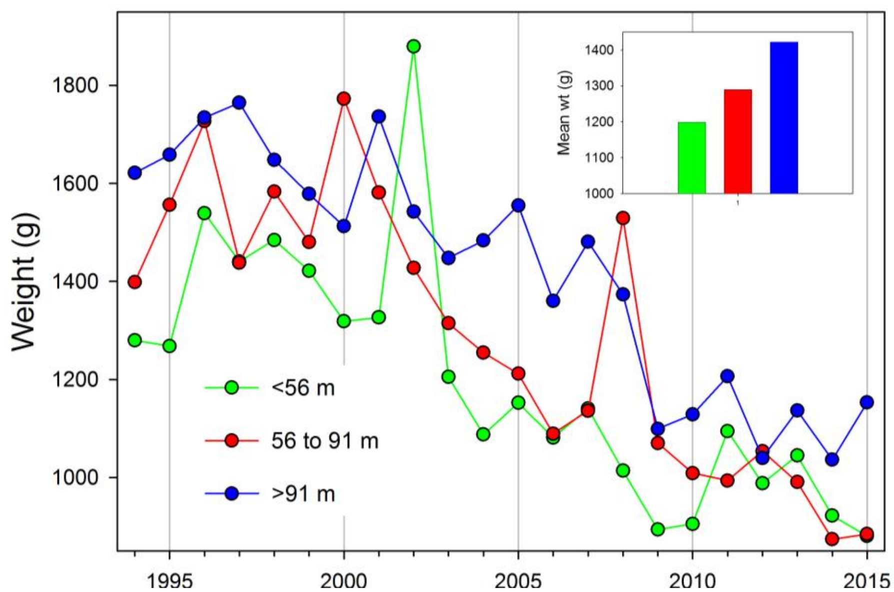


Figure 24. Change in mean weight of cod by depth between 1994 and 2015.

The bar graph insets within Figures 24 and 25 show the average sizes over the span of the survey and indicating quite clearly the relative differences between strata with a gradient of small to larger fish with the increase in depth.

Age

After 2007 aging of cod was discontinued . Between 1994 and 2007 there was a decrease in the mean age (Fig. 25). The average age of cod over this period was about six.

Obviously no good year-classes developed during the span of the survey as the stock has shown no signs of recovery to the levels seen decades ago. Be that as it may, the age frequency plots provided in Figure 26 give evidence of relatively dominant year-classes.

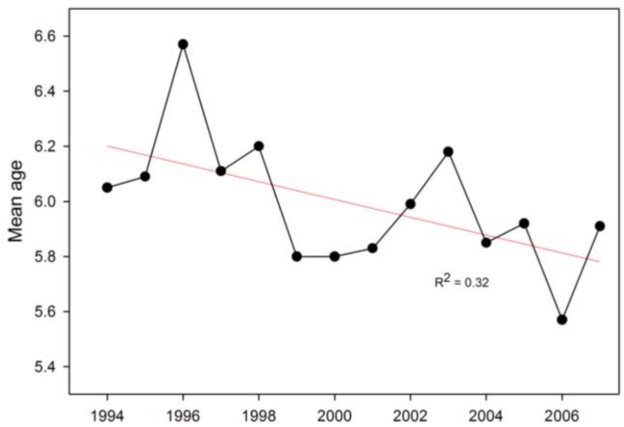


Figure 25. Mean age of 4Vn cod 1994 to 2007.

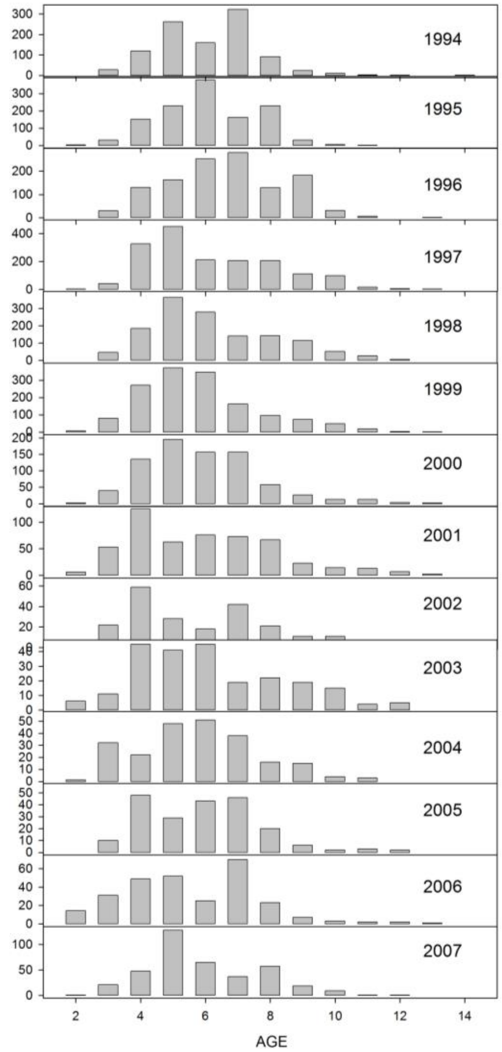


Figure 26. Age frequency of 4Vn cod 1994 to 2007.

Perhaps the best in the series would be the 1987 year-class which shows up in 1994 as 7 year old fish. Better than average year classes were 1989, 1993, 1999 and 2002.

Despite the relative brevity of this data set, interesting trends were evident in the ages for the early part of the survey (Fig. 27). Whereas there was little change in size-at-age of the youngest cod, an increase was evident in older fish. This increase can be seen more clearly when the ages of older fish are plotted independently (Fig. 28).

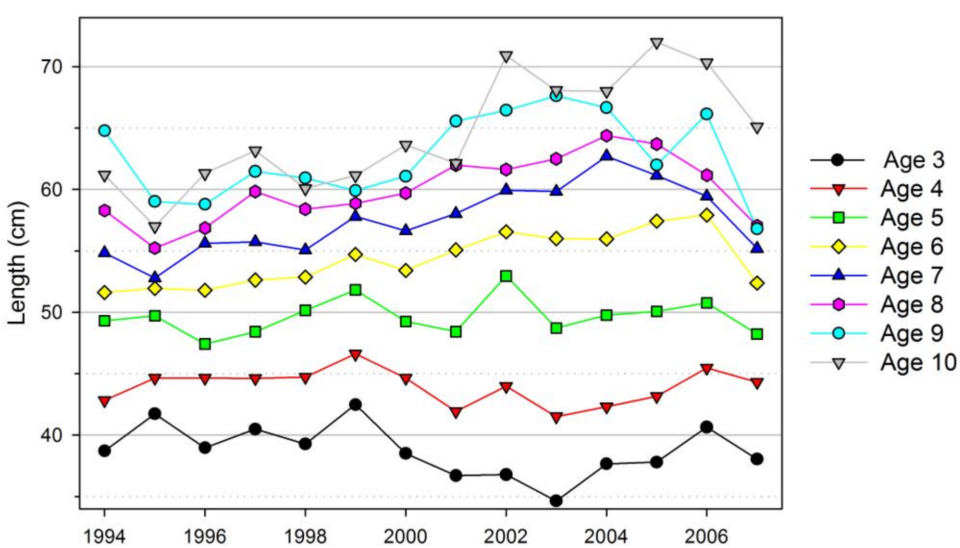


Figure 27. Mean length of 4Vn cod for ages 3 to 10 from 1994 to 2007.

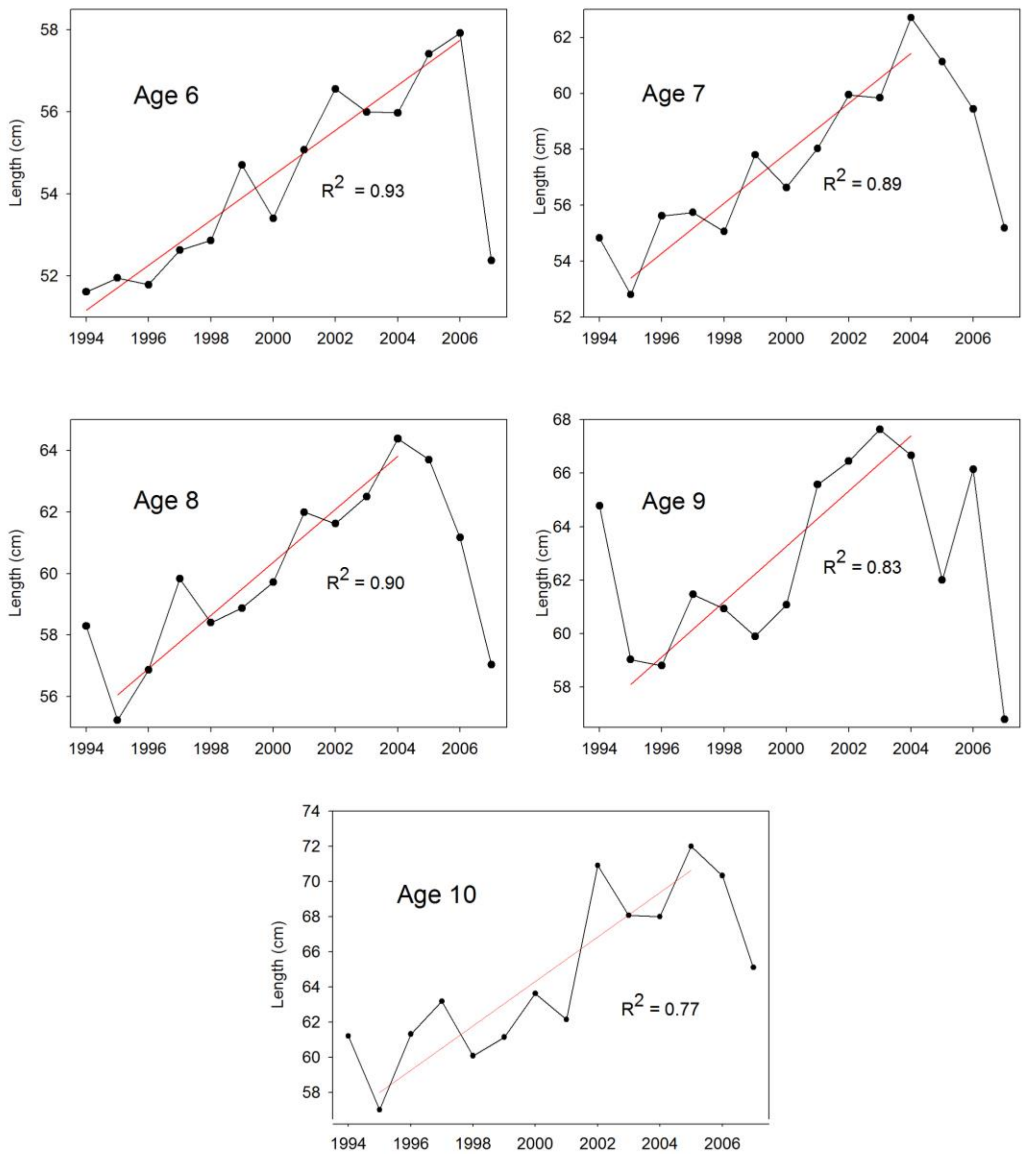


Figure 28. Size of 4Vn cod for ages 6 to 10 from 1994 to 2007.

From 1995 to about 2004 value there was a large increase in the size of cod in older fish. The difference in size between 1995 and 2004 for each age class were obtained from the regressions in Figure 28 and are given in Table 6. Clearly, the trend becomes greater as the cod age; the size increase for a 10 year old cod is more than double that of a six year old over the eight year period. It should be noted that all cod from 1994 to 2001 and 2005 and 2007 were aged by the same technician. Only ages for four years from 2002 to 2005 were obtained by a different reader; these ages fitted well with the trends of the other determinations.

As expected the change in mean length at age is curvilinear; whereas, the change weight with age over the same time span (ages 2 to 12) is virtually linear (Fig. 29). The values at age 13 are no doubt unreliable since only 8 cod at this age were recorded over whole time period.

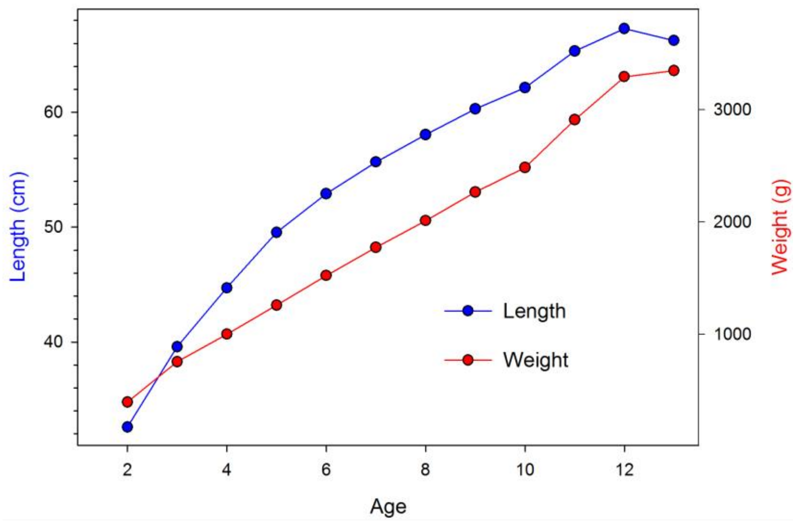


Figure 29. Relationship of length and weight to age in 4Vn cod.

Table 6. Average increase in size between 1995 and 2004 for 4Vn cod ages 6 to 10.

Age	*Increase (cm)*
6	4.9
7	7.6
8	7.5
9	9.1
10	12.0

Sex and Maturity

For most of the survey maturation stage was assessed as well as gonad weights taken to determine a gonadosomatic index [GSI (gonad W/total W)*100]. A comparison of these shows that the two agreed well (Fig. 30).

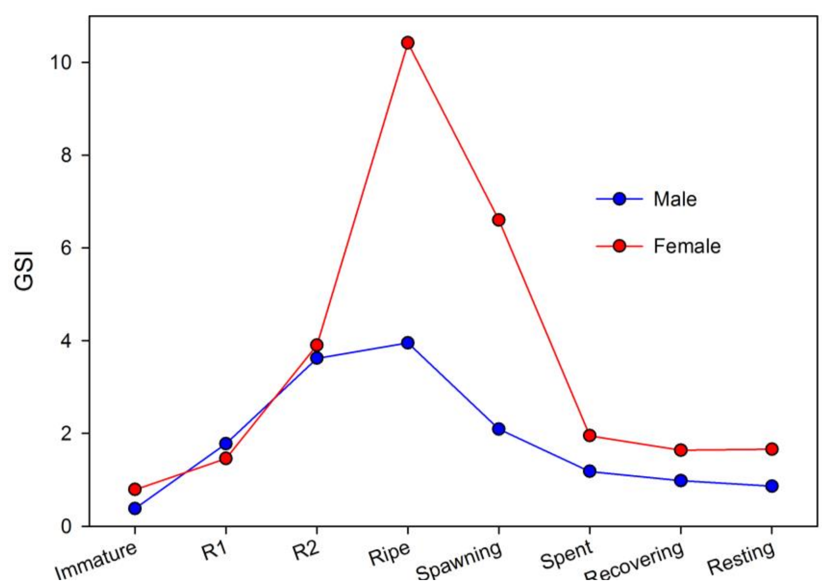


Figure 30. Comparison of GSI and maturation stage.

The number of fish at age totaled for the entire 22 year period is given in Figure 31 along with the percentage of females in the sample of cod that were aged. Between the ages of 3 and 11, the proportion of females averaged 58.5%. Males predominated at ages 2 and 13 but the sample numbers were very low, being only 38 and 8 respectively making these estimates unreliable. Sample number at age 12 was 25, so the female proportion at that age was not

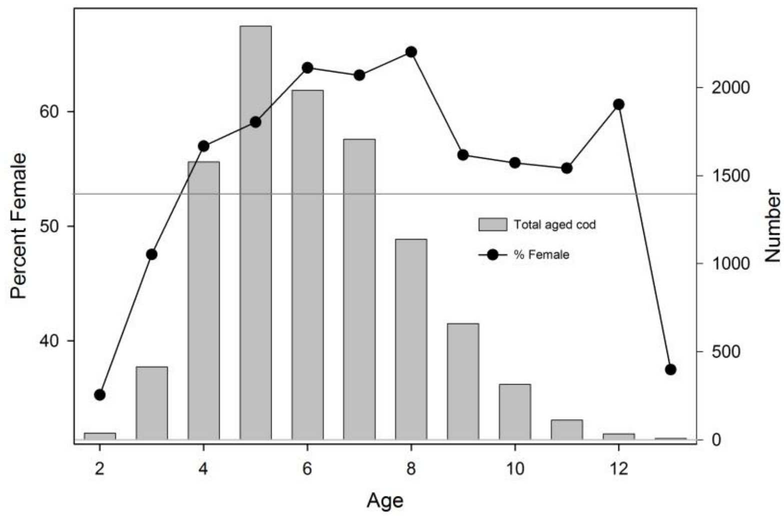


Figure 31. Proportion of female cod at age vs number of fish aged.

used in calculating the mean value for the series. Lambert (2013) reported that, between 1983 and 2009, 51% of the population of 4T Gulf cod was represented by females with min. and max. of 46% and 58%.

There was considerable variation in the GSI of both sexes over the period of the survey (Fig. 32). Up to 2002 there was a fairly close correspondence between sexes but much less so afterwards. There was a strong reduction in male GSI from 2005 onwards with a more gradual but more variable decrease in the female index.

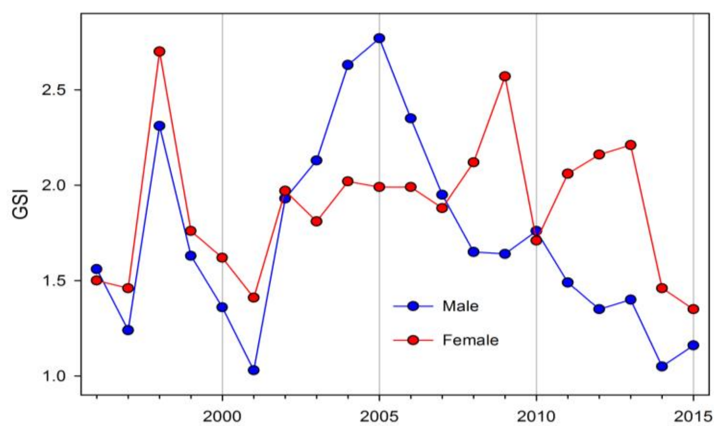


Figure 32. GSI for male and female cod, 1996 to 2015.

A breakdown of maturation stage of male and female cod is given in Figure 33.

Plots indicate, as would be expected for a spring spawning stock, that maturation stages resting, and ripening (R1 & R2) are the predominant classifications. Males appear to be more advanced in the maturation cycle there being more in the ripening stages than resting; the reverse being true for the females (Table 7). Cod in ripe and spawning condition were found in all years, sometimes in surprisingly high numbers. Fourteen percent of male cod were in spawning condition in 2002 and 3.4% of females in 2014. The number of males in ripe condition ranged between 1 and 5% in most years and in 2013 over 20% of male cod were ripe. Over most of the time series the level of females in ripe condition ranged between 1 and

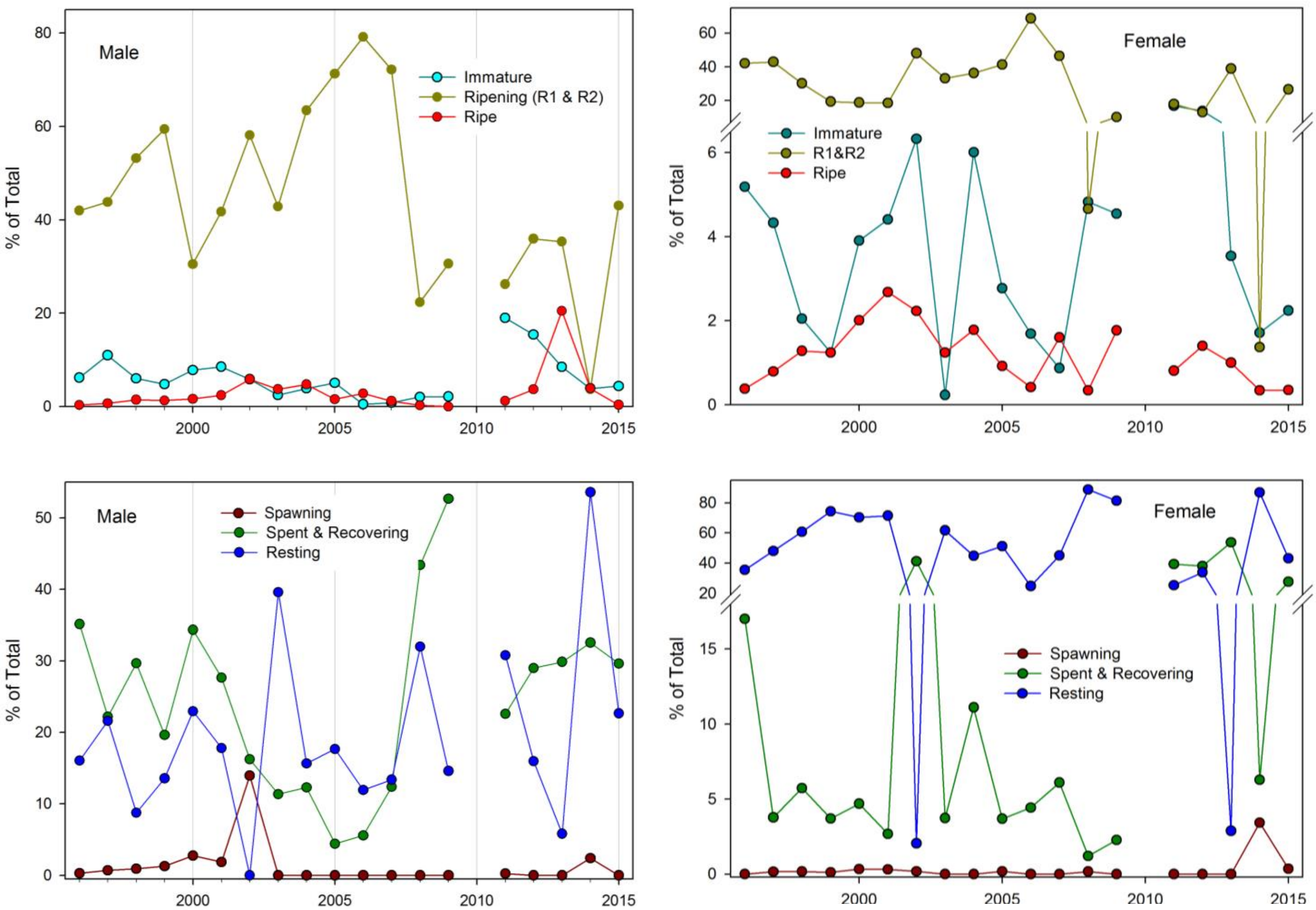


Figure 33. Maturation stage of male cod (left) and female cod (right) 1996 to 2015.

2% reaching a high of 2.7% in 2001. These cod in ripe and spawning condition were usually widely distributed throughout the survey area and mostly located in shallow and intermediate depths. Distributional maps of these cod can be found in Appendices III and IV.

Table 7. Time series mean percentages for four maturation stages of cod in 4Vn.

Sex	*R1-R2*	*Ripe*	*Spawning*	*Resting*
Male	44.99	3.02	1.28	19.70
Female	29.36	1.18	0.28	50.08

There was evidence that the timing of the spawning changed over the span of the survey. Looking at the ripening (R1&R2) maturation stage alone in both male and female cod, there is an increasing proportion of that stage up to 2006 and a decrease afterwards (Fig. 34). An opposite trend is true of the late maturation stages Spent/ Recovering and Resting (Table 8). Thus at the beginning of the survey nearly half the cod are recovering or resting after spawning; whereas, after 10 years have elapsed, the majority of cod are preparing for the next spawning season being in the Ripening stage. Concurrently, late maturation stages decreased. This is particularly true of the Spent/Recovering stage. In the ten years after 2006 the pattern of the previous decade is reversed.

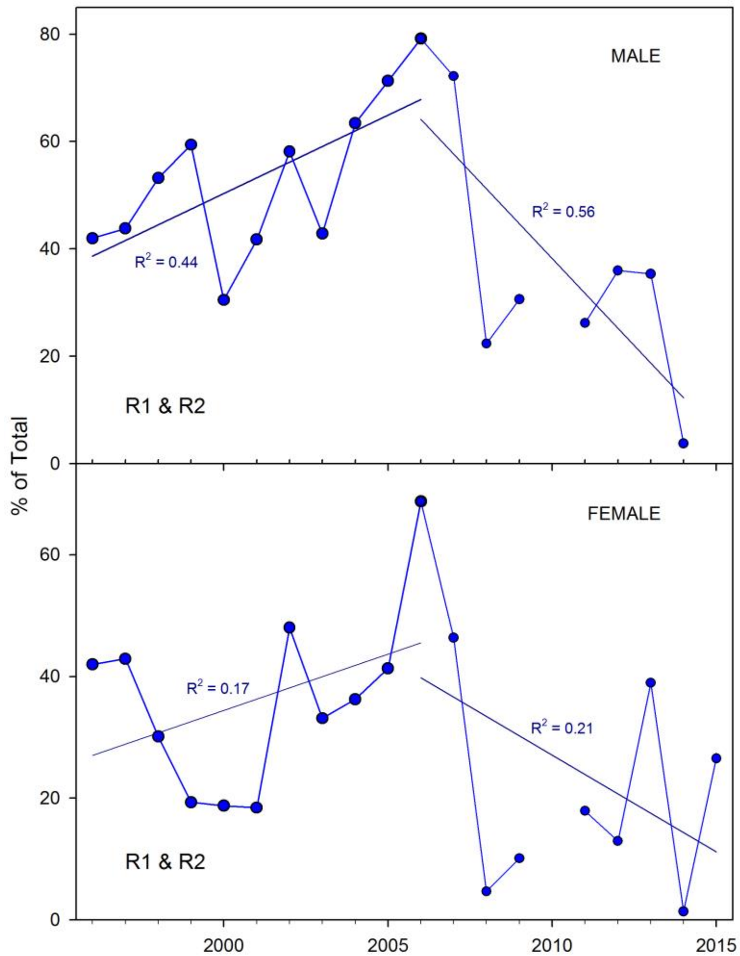


Figure 34. Percentage of R1/R2 stage 4Vn male and female cod from 1996 to 2015

Table 8. Two year means of maturation stages at the beginning and end of two decades (1996- 2006 and 2006-2015) for male and female cod in 4Vn.

	Male		**Female**		**Male**		**Female**	
Stage	96/97	05/06	96/97	05/06	06/07	14/15	06/07	14/15
Immature	8.59	2.78	4.76	2.23	0.68	4.12	1.28	1.98
R1/R2	42.89	75.24	42.45	55.00	75.70	23.38	57.58	13.95
Ripe	0.50	2.19	0.59	0.67	1.99	2.12	1.01	0.35
Spawning	0.50	0.00	0.08	0.09	0.00	1.20	0.00	1.89
Spent/Recovering	28.68	5.00	10.40	4.06	8.98	31.08	5.27	16.88
Resting	18.83	14.80	41.73	37.90	25.32	38.12	34.87	64.96

The conclusion is that from 1996 to 2006 the timing of spawning season advanced or came earlier in the year and that after 2006 the season moved to later dates. One would suppose that water temperature would have an effect on the maturation cycle and indeed the similarity of Fig. 34 to Fig. 7. is noticeable. At intermediate depths, bottom temperature rose during the first half of the survey and fell thereafter.

During the survey there appeared to be a decrease in the age of first maturity. Unfortunately the age record is incomplete, age determinations only being made during the first decade of the survey. In 1996 about half of fish aged 2 and 3 were mature; however by 2006, more than 98% of cod were mature (Fig. 35).

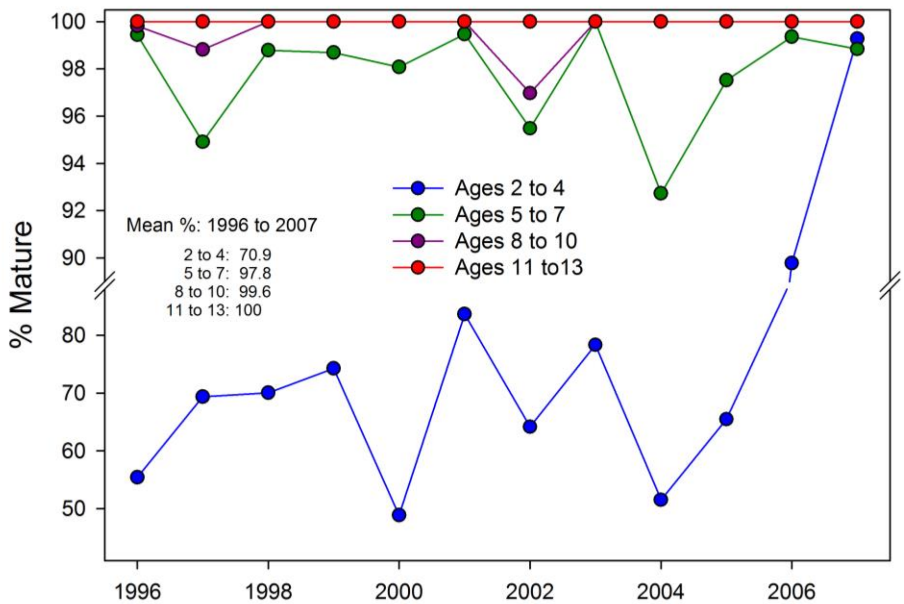


Figure 35. Percentage of mature cod by age groups from1996 to 2007.

Condition

Fish condition was measured in three ways; Fultons's K using whole body weight, Fulton's K using carcass weight (whole weight minus stomach, gonad and liver weights) and hepatosomatic index (HSI). Fulton's K using whole body weight is the easiest to determine but is the least accurate being influenced among other things by sex, stage of maturity, and stomach fullness. Determining K using carcass weight removed much of this variability to give a better index. Since the liver plays an important role in the storage of energy its weight relative to the total body weight is perhaps the most sensitive index of nutritional welfare. Organ weights were not taken in the first two years of the survey so HSI and Fulton's K using carcass weight were not available. The three indices are compared in Figure 36.

Fulton's K: $(W/L^3)*100$ HSI: (liver W/total W)*100

As would be expected, the Fulton's index using carcass weight is lower than that using whole weight. The separation between the two appears to be greater when the HSI is greater; no doubt a reflection of higher liver weights which of course are subtracted in deriving carcass weight. The three indices agree in the first few years and the last few but part company for the bulk of the time series. Between 2001 and 2008 the HSI increases then, except for 2006, remains high; whereas, the K's show a steady decrease in condition during this time. Figures 37 and 38 show condition indices broken down by depth.

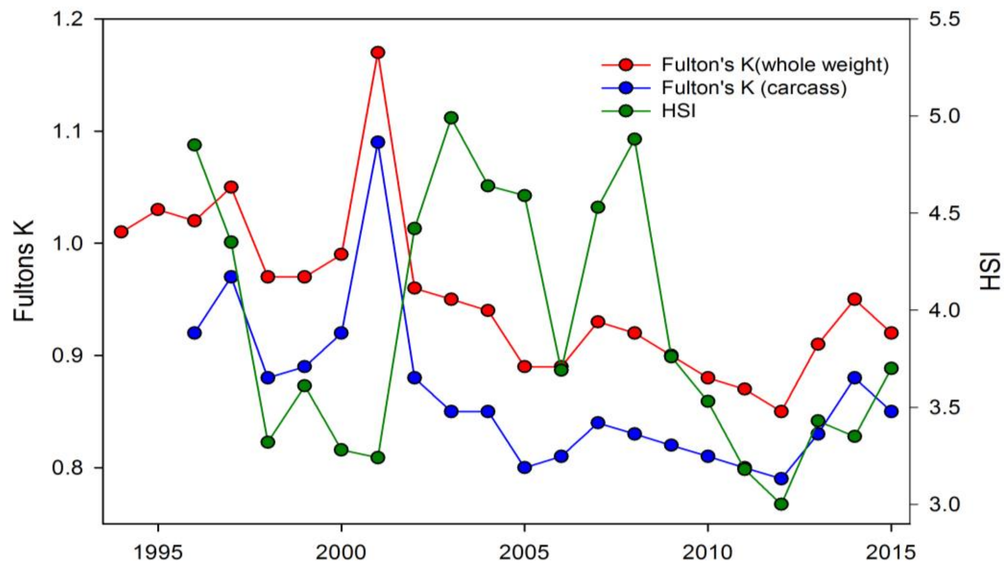


Figure 36. Comparison of condition indices from 1994 to 2015.

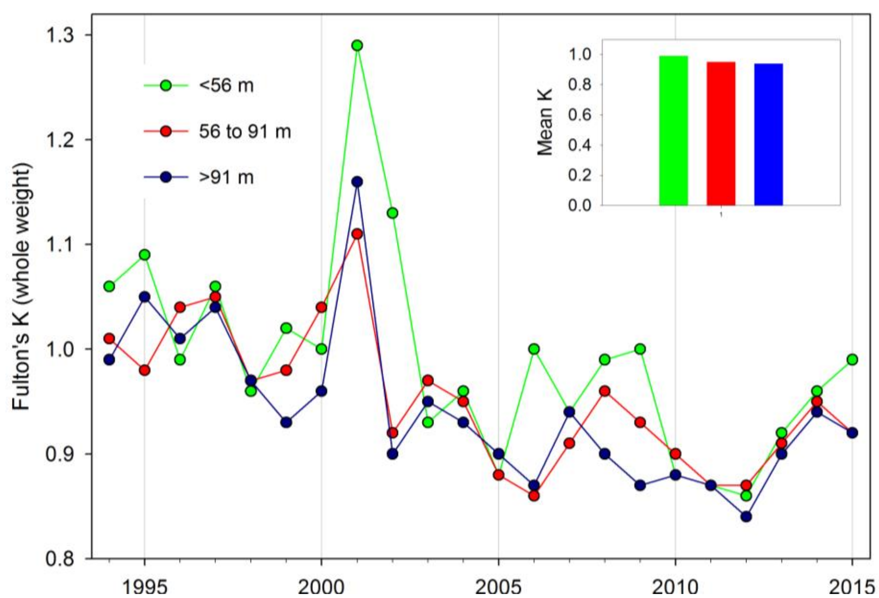


Figure 37. Fulton's K by three depth strata from 1994 to 2015

Although the differences in mean indices among depths are not great (inset graphs), particularly in the case of Fulton's K, it is curious that the two indices show different trends. HSI indicates a gradient of higher condition in deeper water to lower in shallow, opposite to that of Fulton's K.

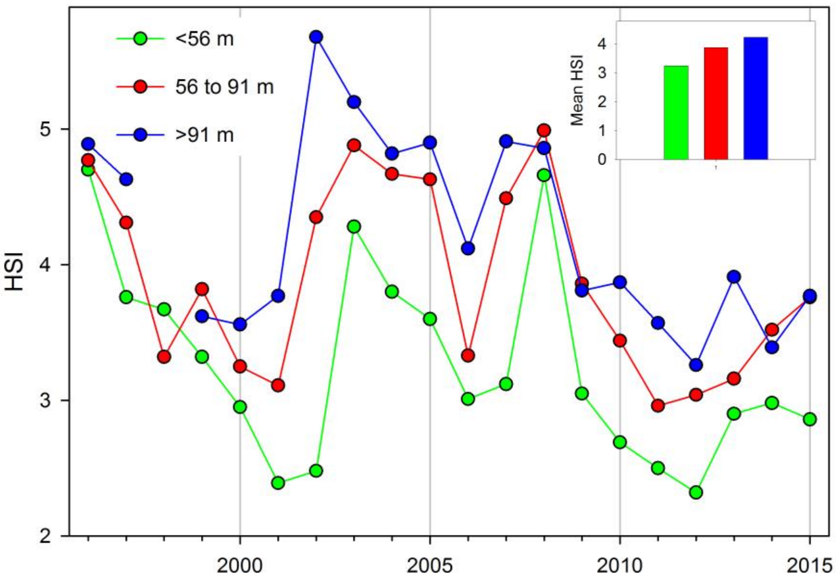


Figure 38. Hepatosomatic index at three depth strata from 1994 to 2015.

Feeding and Diet.

Stomachs were sampled routinely from 1996 onwards. However, at time of writing all of the data had not been keypunched; hence a detailed examination will be left for a future publication. Results presented herein are a partial analysis of incomplete data collected up to 2002 and are largely qualitative. They are for all cod irrespective of size, sex, depth, location or time of year.

Cod in Sydney Bight appeared to be fairly well fed on the whole; the mean percent of empty stomachs over the span of the survey was 5.8%. There were two periods of about two to three years each where incidences of empty stomachs increased, although it never exceeded 20% (Fig. 39).

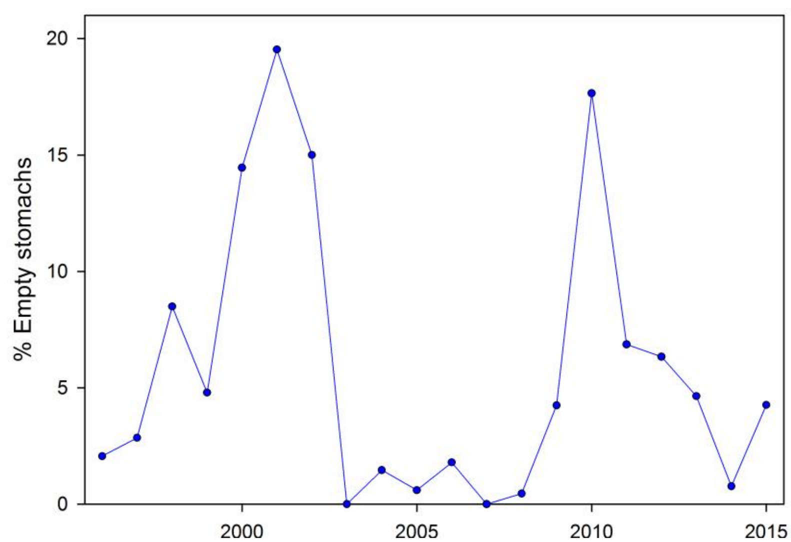


Figure 39. Incidence of empty stomachs 1996 to 2015.

These two higher incidence periods corresponded with decreases in stomach fullness around the years 2000 and 2010 (Fig. 40). Here fullness is expressed as weight of food as a percent of the gross stomach weight. Curiously, the pattern of stomach fullness is cyclic with peaks every five years. This pattern is seen at all depths but strongest in deep and shallow water (Fig. 41). Overall though the average stomach fullness did not vary much between different depth strata.

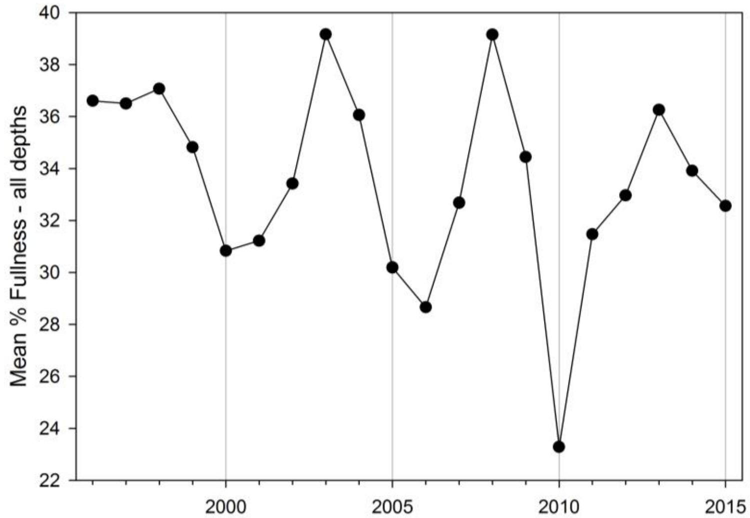


Figure 40. Stomach fullness, 1996 to 2015.

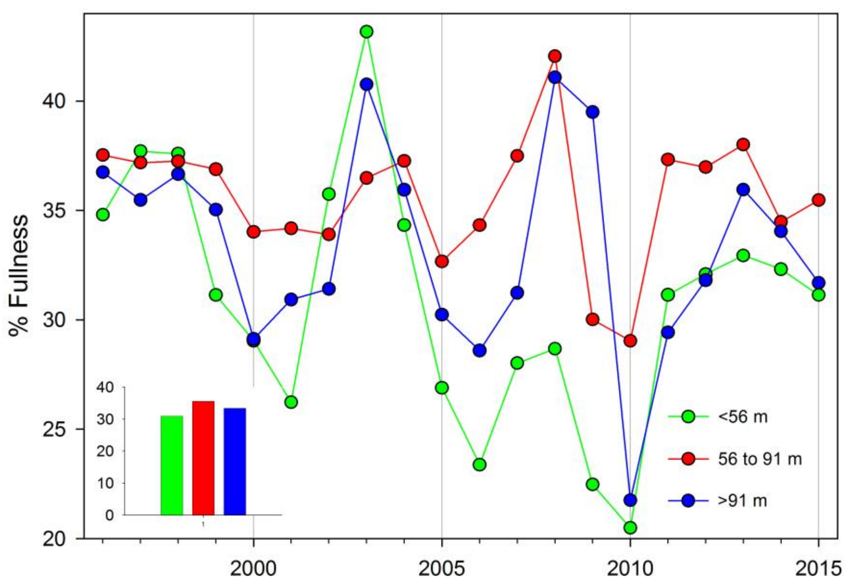
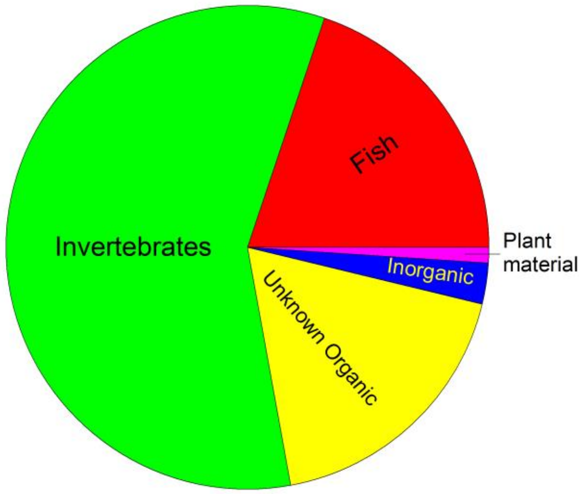


Figure 41. Stomach fullness by depth; inset graph shows annual means .

Based on occurrences in stomachs, the major food types were invertebrate, these being about three times more prevalent than fish (Fig. 42). Of invertebrate fauna in the diet, crustaceans made up the largest proportion with echinoderms second and polychaetes third (Fig. 42). Most of the crustaceans were shrimp with various crab species being next most common (Fig. 43). Many of the fish occurring in the stomachs were too far digested for identification but those that could be are shown in Figure 43.



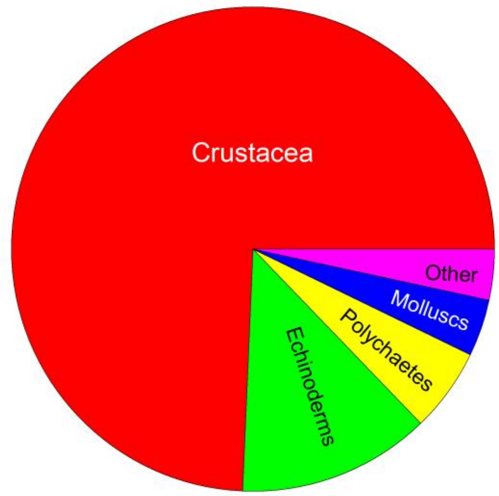
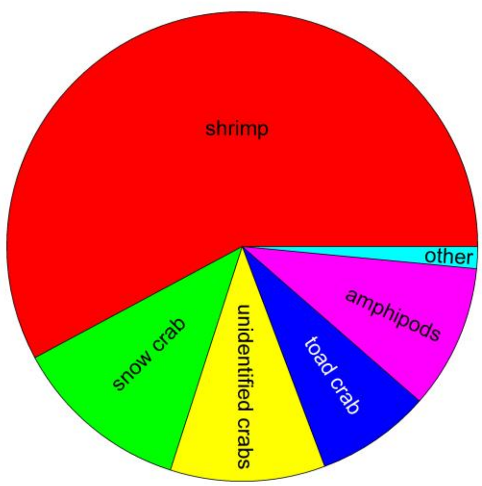


Figure 42. Overall diet types for 4Vn cod (left) and composition of invertebrates in cod diets (right).



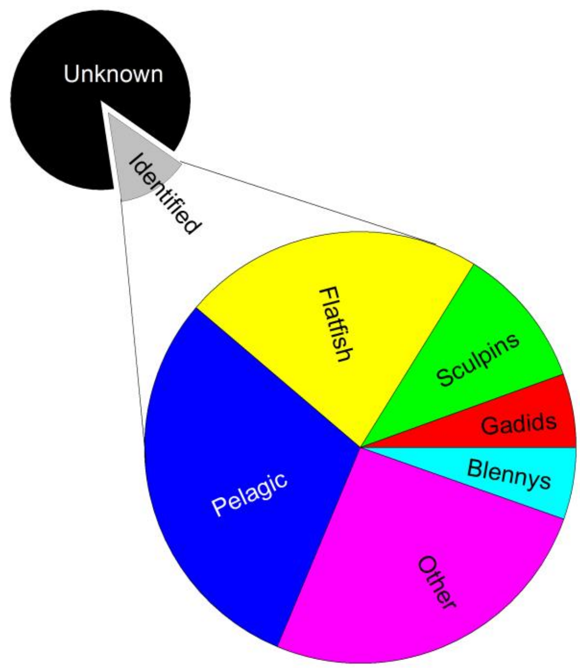


Figure 43. Crustacean types in cod stomachs (left) and identified fish species in cod stomachs (right)

Monthly Monitoring

Limited sampling at fixed stations at three depth strata was conducted from 1998 to 2001. Due to weather and other constraints not all strata or months were sampled in all years. The mean catch rate for all four years combined is shown in Fig. 44. The pattern in the cod catch was similar in all four years (Fig. 44). The most obvious common feature was low catch rate in September rising rapidly to a high in October.

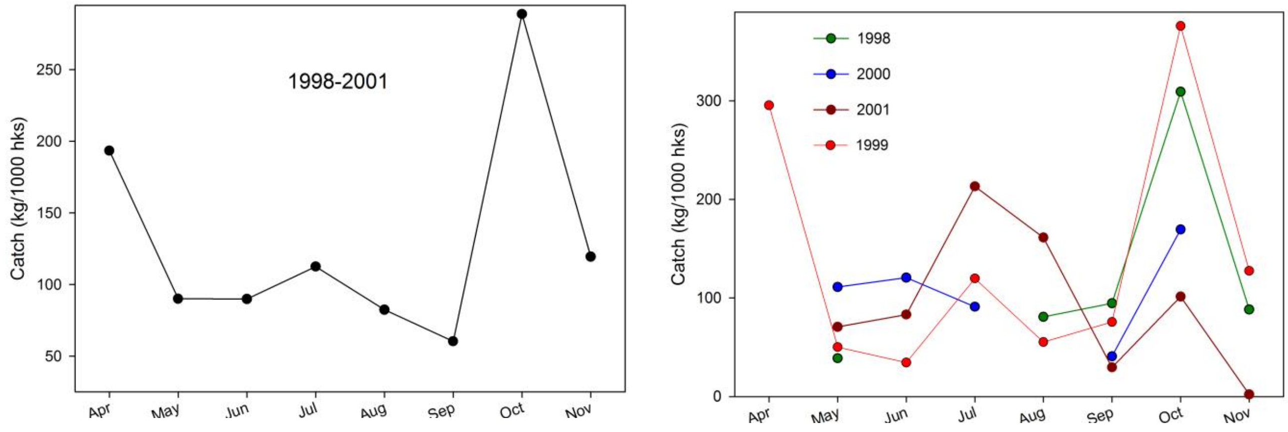


Figure 44. Mean cod catch rate 1998 to 2001combined (left) and by year (right).

As will be confirmed in a later section, this increase in catch from September to October marks the entry of NAFO sub division 4T cod into Sydney Bight as they undergo their annual winter migration out of Gulf of St. Lawrence (Lambert 1993). All cod move to deeper waters over the winter period to avoid cold inshore water and the decrease in catch rate in November no doubt marks the beginning of this relocation. Further evidence of 4T cod exodus from the Gulf is seen in mean length and weight plots (Fig. 45). There is an increase in mean size of cod from September to October. This marks the start of the migration with the entry of the oldest and largest cod first, later to be followed by the smaller members of the population as indicated by the steep decrease in size in November.

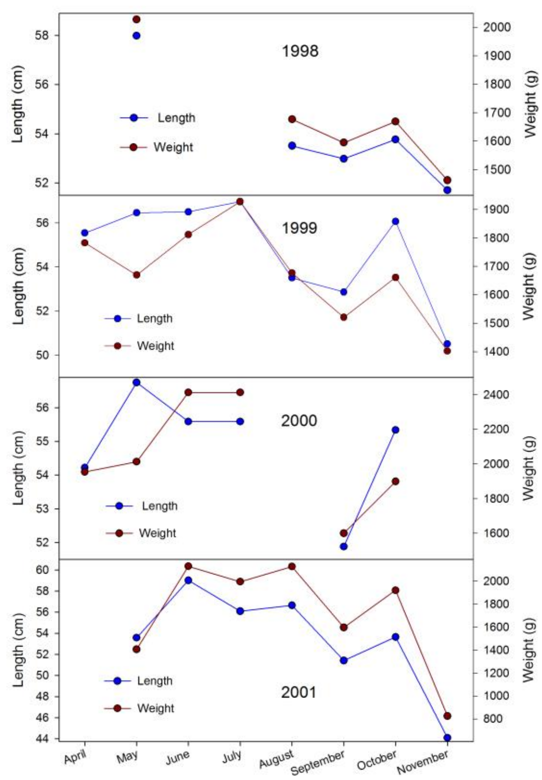


Figure 45. Monthly change in mean length and weight of cod in Sydney Bight.

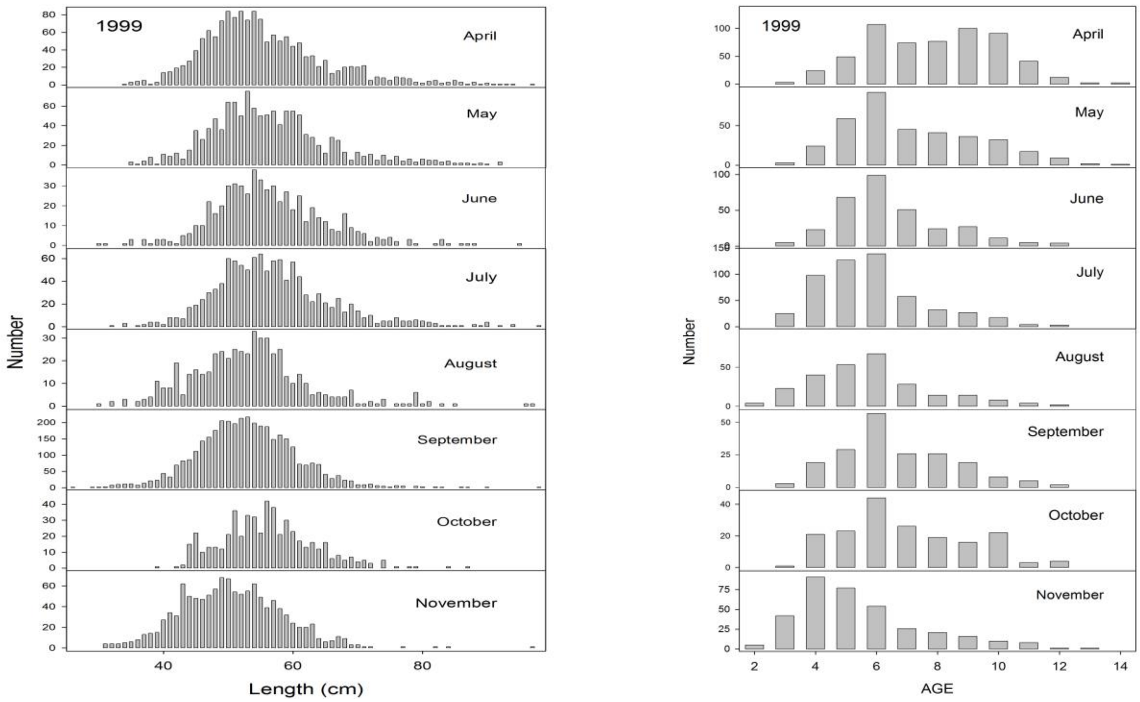


Figure 46. Length frequency of cod by month (left) and age (right) in 1999.

The most complete record in the monthly monitoring series was 1999 when sampling began in April, the earliest of all years. Sets were then made in all months up to November. Length and age frequency plots for this year are provided in Figs 46. A plot of age and size over this eight month period adds further verification of the timing of the Gulf cod winter migration. There is a sudden increase in mean age from September to October and a rapid decrease in age thereafter, confirmation of older fish leading the migration with youngest arriving last (Fig. 47).

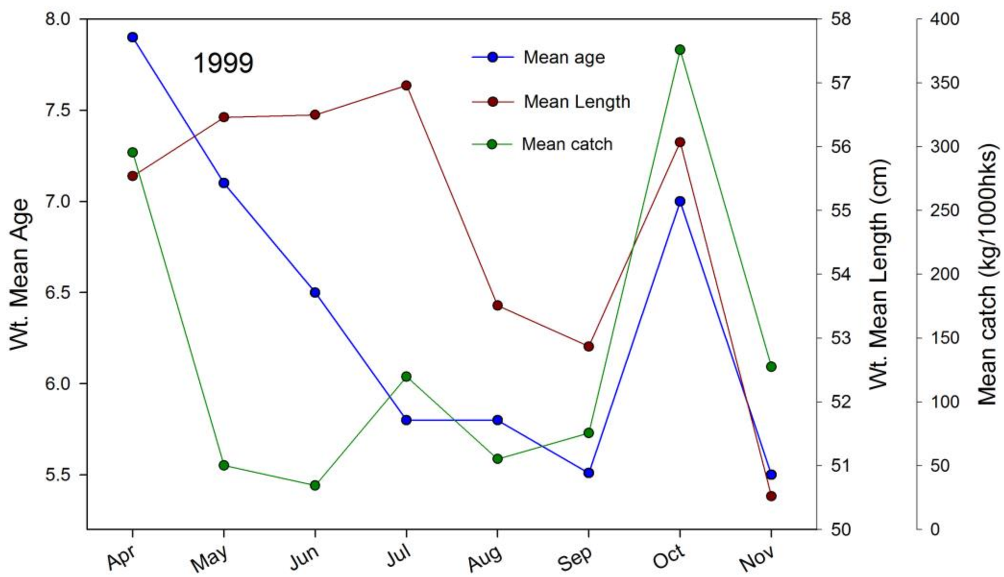


Figure 47. Mean age, length and catch from April to November, 1999.

Change in condition is illustrated in Fig. 48 The gonadosomatic index (GSI) declined over the span of the sampling, which is to be expected since cod in this area are spring spawners. Fulton's K and the hepatosomatic index (HSI) follow more or less the same trends except for November when the former rose steeply as the HSI continued a steep decline. The reason for this is unclear. If these November fish were mostly Greenland cod (*Gadus ogac*), one might expect a higher K because this species at the same weight as an Atlantic cod (*G. mohua*) is relatively shorter. However, this can be ruled out since *G. ogac* are separated from *G. morhua* during the shore base analyses and treated separately.

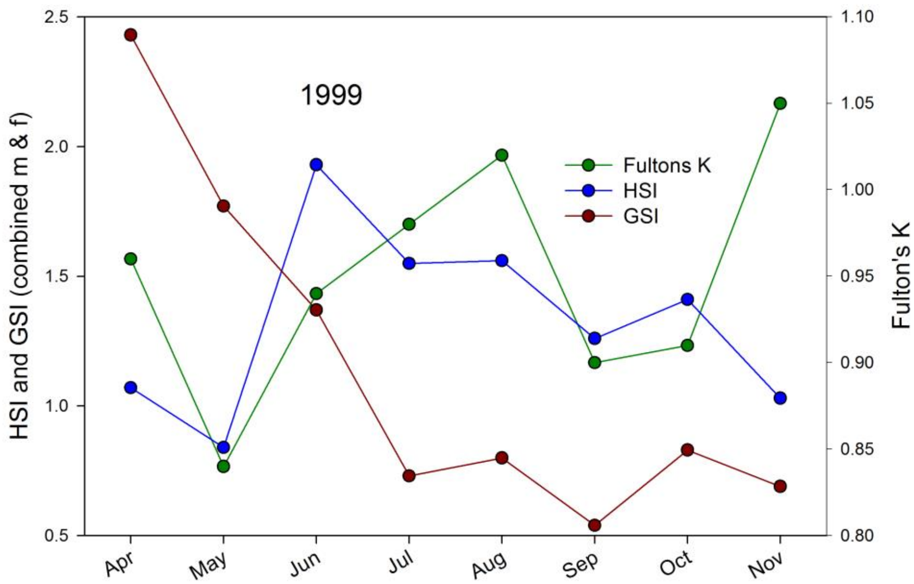


Figure 48. Changes in GSI, HIS and Fulton's K from April to November, 1999.

Migration Monitoring

It has been known for many years that cod (4T) leave the Gulf of St. Lawrence to overwinter in deeper relatively warm water of the Cabot Strait in 4Vn. Historically, for management purposes cod catch in 4Vn from May to December was treated as resident stock and January to April a mix of Gulf and Sydney Bight cod (4TVn). In the early 1990s, motivated by concerns and anecdotal evidence of local longline fishermen, Lambert (1992) determined that most of the cod catch taken in Sydney Bight in November and December were Gulf (4T) cod. Longline catches had declined greatly by that time and boats were unable to attain their allocated quota; whereas, at that time the 10000 tonne quota for 4Vn was easily reached being taken mostly by the mobile gear fleet in November and December. Thus resident cod were being seriously depleted, masked by the fact that the proportion of Gulf cod in the 4Vn total catch was increasing to make up the shortfall of resident fish and quotas were easily attained.

Local fishermen thought that Gulf cod had been entering progressively earlier and that many were leaving the Gulf in October. In an attempt to substantiate this, the Sentinel Association mounted a monitoring programme with sets made in the north-west area of Sydney Bight from October to December. For each trip two sets were made, most just off Neil's Harbour at around 100 m depth. A few were made further south and east to check for distribution of Gulf cod within Sydney Bight.

It is well known that cod vary greatly in size at age depending on location. Generally those further north in colder water grow more slowly than their more southerly counterparts and hence are smaller at any given age. Southern Gulf of St. Lawrence cod (4T) are smaller at age than Sydney Bight (4Vn) cod. This is seen clearly in Figure 49 where data from Swain et al (2015) are compared to corresponding data from the 4Vn Sentinel survey (2006 and 2007 are the last years that age data are available for the Sentinel survey). On average, cod from 4Vn were 9cm longer at age than 4T in 2006 and 7 cm longer in 2007.

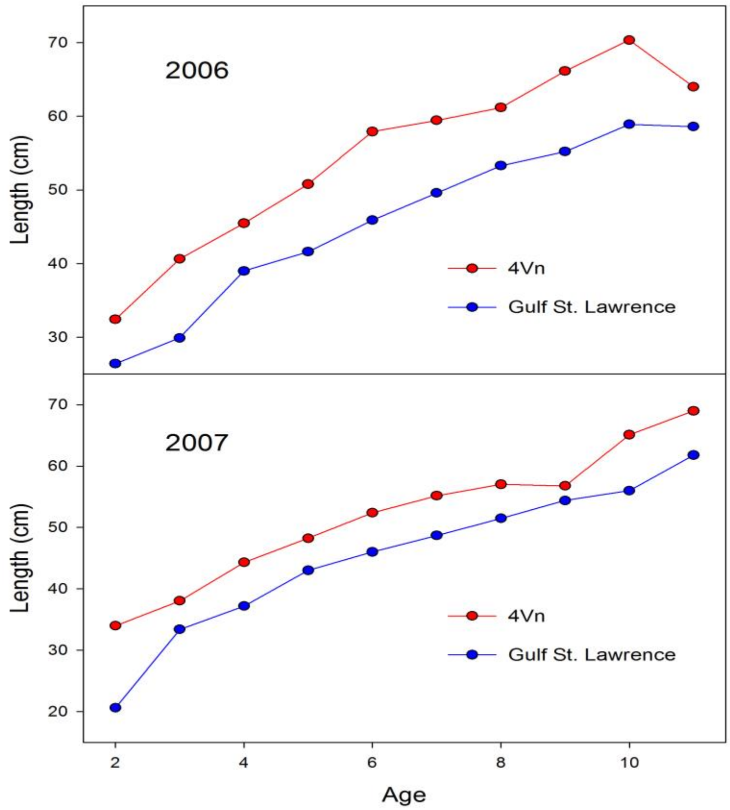


Figure 49. Comparison of length at age for 4Vn and 4T cod in 2006 and 2007.

This characteristic difference in the two stocks was used when monitoring the cod caught in the area mentioned above. Length-at-age of cod taken in September in the regular survey were compared to that of cod taken later in October and November later that same year. These data were fit to a von Bertalanffy equation using the non-linear regression curve fitting routines included in the plotting program, SigmaPlot. The migration monitoring program was conducted for eight years, 1994 to 2001. Some examples from 1998 will illustrate how this was done. The first trip was made on October 23, with sets just off Neil's Harbour. There was no difference in cod length-at-age for set 1, which started about 3 km (~1.5 nm) offshore at a depth of 83 m and ran to a depth of 119 m. Set 2 began further offshore about 7 km (~4 nm) east of set 1, running from 132 m to 172 m depth. Here there is a clear separation in length-at-age in cod from about age 6 and older, these set 2 cod being smaller at older ages than the September reference cod (Fig. 50). This is consistent with our understanding that older cod lead the migration out of the Gulf and are the first arrivals in Sydney Bight. The second trip occurred on October 27 and both sets were about 7 and 12 km respectively (~4 nm & ~6.5 nm) NNE of the October 23 sets. The depth of longline was similar for both sets and varied little, averaging about 135 m. Here there was a clear separation at all ages between the September sample and those taken on October 27 (Fig. 51). The difference in length between the two stocks at age 10 in set 1 was 5cm and 6.7 in set 2. Although perhaps slightly less, these values are consistent with differences evident in Fig. 52. The lower values are easily accounted for by 4Vn cod being mixed with the 4T cod.

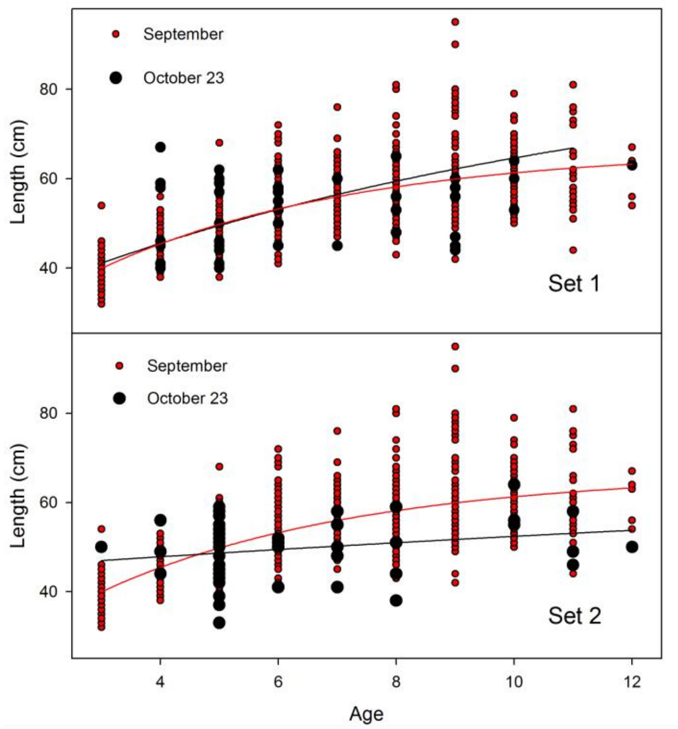


Figure 50. Comparison of length-at-age for cod caught in September and October 23, 1998.

It would appear, not surprisingly, that the Gulf cod enter Sydney Bight in waves or discrete groups. In 1996 the first monitoring trip on October 22 indicated that Gulf cod were already in the area (Fig. 52a); whereas, 6 days later the next trip in the same area showed no evidence of Gulf cod (Fig. 52b). However, the third trip once again showed evidence of Gulf cod in the area (Fig. 52c).

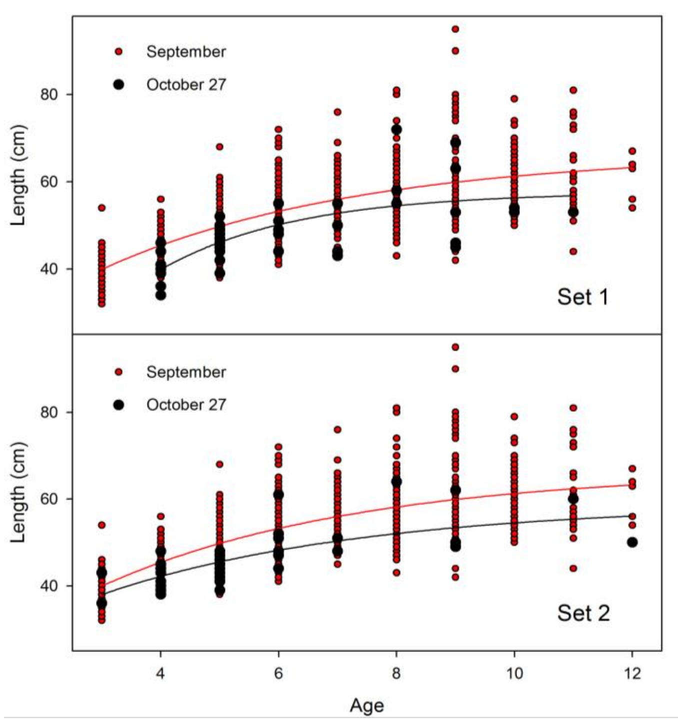


Figure 51. Comparison of length-at-age for cod caught in September and October 27, 1998.

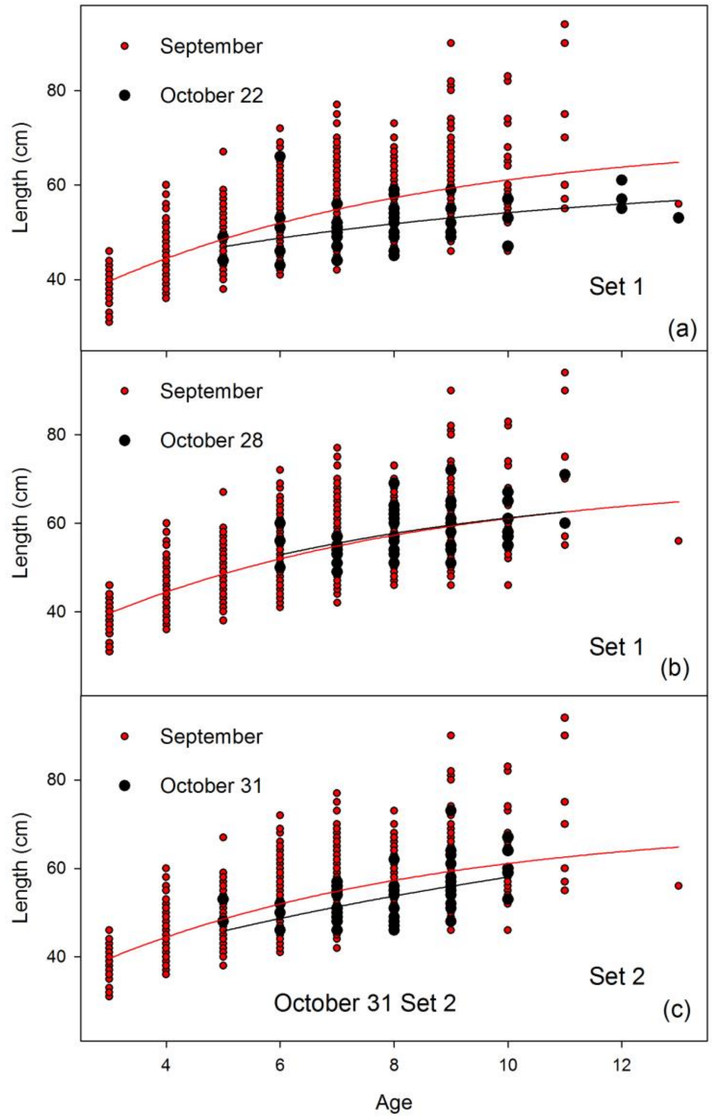


Figure 52. Comparison of length-at-age for cod caught in 1996 in September and October 22 (a) October 28 (b) and October 31(c). All sets in same area off Neil's Harbour.

Gulf cod could be identified as far away as St. Anns Bank at the eastern extremity of subdivision 4Vn. Unfortunately, weather conditions that late in the year often prevented fishing and probably in all years Gulf cod were already in Sydney Bight before the first trip was made. Also many sets had a low number of fish (15 of the 88 sets made had 10 or fewer fish) and some only 2 or 3 age classes present making curve fitting a pointless exercise.

There was evidence of Gulf of St. Lawrence (4T) cod being present in Sydney Bight from the first trip of every year except for 1997 (Table 9). The number of cod taken in the first trip of 1997 was too low for any conclusion to be made. For four of the years monitored, large 4T cod appeared in the early sets, as in the case of 1998 as detailed above. One could surmise that these sets were taken near the beginning of the migration and that in three years, when 4T cod of all ages were present, that the migration was well underway. In 1995, only young 4T cod were present in the first trip on October 13; this could mean that the migration into 4Vn was almost complete.

Table 9. Dates of occurrence of 4T cod in first sets made during migration monitoring trips.

Year	Date	4T Cod Present	Comment
1994	Oct 30	Yes	One set no; second set yes; large, older Gulf cod
1995	Oct 13	Yes	Both sets; smaller, age 2 to 7 Gulf cod
1996	Oct 22	Yes	Both sets; all ages Gulf cod
1997	Oct 22	?	Sample too small; only 8 and 10 cod
1997	Oct 30	Yes	Both sets; large, older Gulf cod
1998	Oct 23	Yes	One set yes, second set no; see text above, page 41
1999	Oct 22	Yes	Both sets; all ages Gulf cod
2000	Oct 26	Yes	Both sets; large, older Gulf cod
2001	Oct 11	Yes	Both sets; all ages Gulf cod

CONCLUSIONS

Despite the moratorium that was imposed on cod fishing in NAFO subdiv. 4Vn in 1993, the stock continued its decline from approximately 110 kg/1000 hooks in 1994 until about 2002, after which it stabilized at around 25 kg/1000 hooks. However, the abundance of the groundfish community as a whole showed the same pattern of decline to a low level which continues today. The only species to buck this trend was halibut, which from very low levels throughout the early part of the survey has suddenly increased rapidly from 2008 to the present. As of 2015, catch rates of halibut were about 10 times higher than in 2008.

Cod weight and length varied little until the early 2000s after which there was a substantial decline in both. It would appear that the reason for the overall decline in cod size is due to the disappearance of older fish as there was a clear downward trend in the mean age of cod. Concurrently there was an increase in the size at age, most noticeable in older fish, up to about 2004 after which there appeared to be a sudden decline . Whether this trend continued is not known since ages are not available for cod after 2007.

Not surprisingly, there was evidence to show that bottom water temperature influenced both distribution and maturation. Data from the commercial index fishery and the Sentinel survey both indicate a movement of cod away from cold water.

The maturation data strongly suggest that spawning occurred progressively earlier during the first half of the survey and then gradually returned to later dates during the last half of the survey.

A strong 5 year cycle in stomach fullness is intriguing. It does not appear to be related to changes in temperature and there is little relationship between stomach fullness and the incidence of empty stomachs except for 2010 when the lowest value for fullness coincided with the second highest number of empty stomachs. Perhaps the best explanation for this strange cyclicity lies in the composition of cod food supply. Unfortunately analysis of stomach contents has not been completed, so this avenue of investigation cannot yet be pursued.

The monthly monitoring exercise revealed a high degree of variability in nearly all indices examined during the year. The most consistent features occurred in the latter part of the year when there were similar trends in catch rate, age and size of cod; that is, low in September, rapid increase in

October and rapid decline during November. This indicates two things. Firstly, September appears to be the best month to assess the resident 4Vn stock. There are strong indications of fish originating from other regions being present in Sydney Bight in most months, less so in September when various measured parameters displayed less variability; secondly, there is clear evidence of the entry of Gulf of St. Lawrence (4T) cod into 4Vn in October. This appearance of Gulf cod is further substantiated by the sets taken during the migration monitoring exercise. It is probable that the technique employed during this analysis could be used to determine the degree of mixing of cod stocks during the overwintering period in the Sydney Bight's Cabot Strait. Using age/length relationships of both stocks as templates, catch from this overwinter period (the 4TVn management period) could be compared. A statistical procedure could be developed to quantify the degree of separation between these winter (mixed stocks) age/length plots and the age/length relationships of the discrete stocks.

This lengthy data set on a cod stock (23 years at time of writing) is one of the best ever collected in Atlantic Canada. A lot of its value lies in the fact that there is a wealth of biological data to accompany the standard stock assessment parameters. The treatment of these data in this report can be considered an overview and due to the sheer amount of information available, analyses have been somewhat cursory; trends are indicated rather than detailed statistical analyses performed. The 4Vn Sentinel database is available on DFO Industry Surveys Database (ISDB) and can be made available from the author in a more easily manipulated, simplified form.

ACKNOWLEDGEMENTS

The 4Vn Sentinel Survey is an example of an extremely productive cooperative venture between DFO and the fishing industry. Over the 23 years it has been operating, literally hundreds of people have had a hand in ensuring its success. There are too many to name, but above all, one needs to be recognised. More than anyone Kevin Nash is most responsible for the success of this survey. He was hired by the 4Vn Sentinel Fishery Association in 1994 to be the manager of the project and until his untimely death in 2015 he more than ably carried out this duty. A quiet, unassuming man, he anticipated problems before they occurred and solved them when they did, ensuring the survey was efficiently run during his tenure. He commanded respect from both fishing and scientific communities and his loss is felt deeply. Thanks to Heath Stone and Tania Davignon-Burton for reviewing the manuscript.

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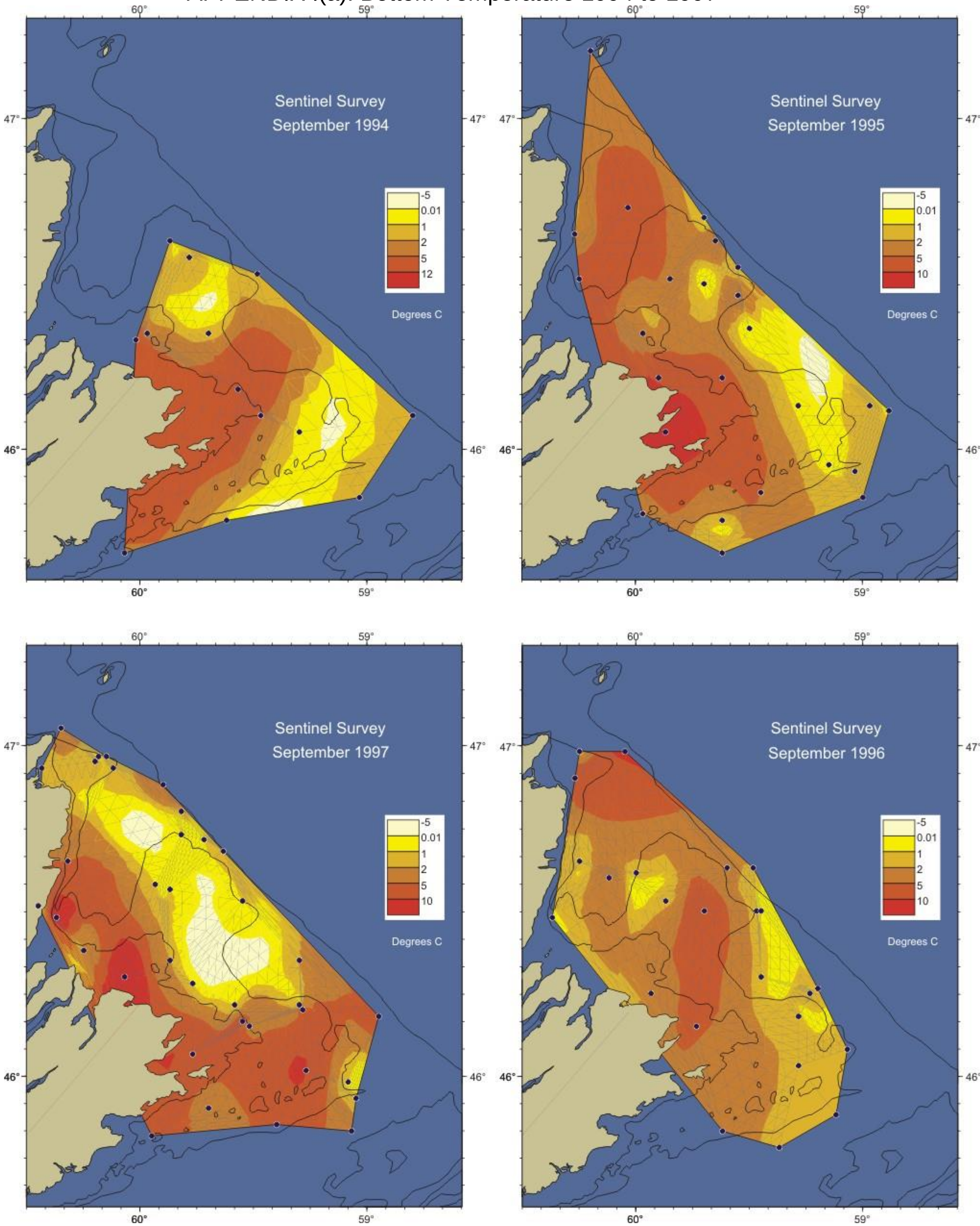
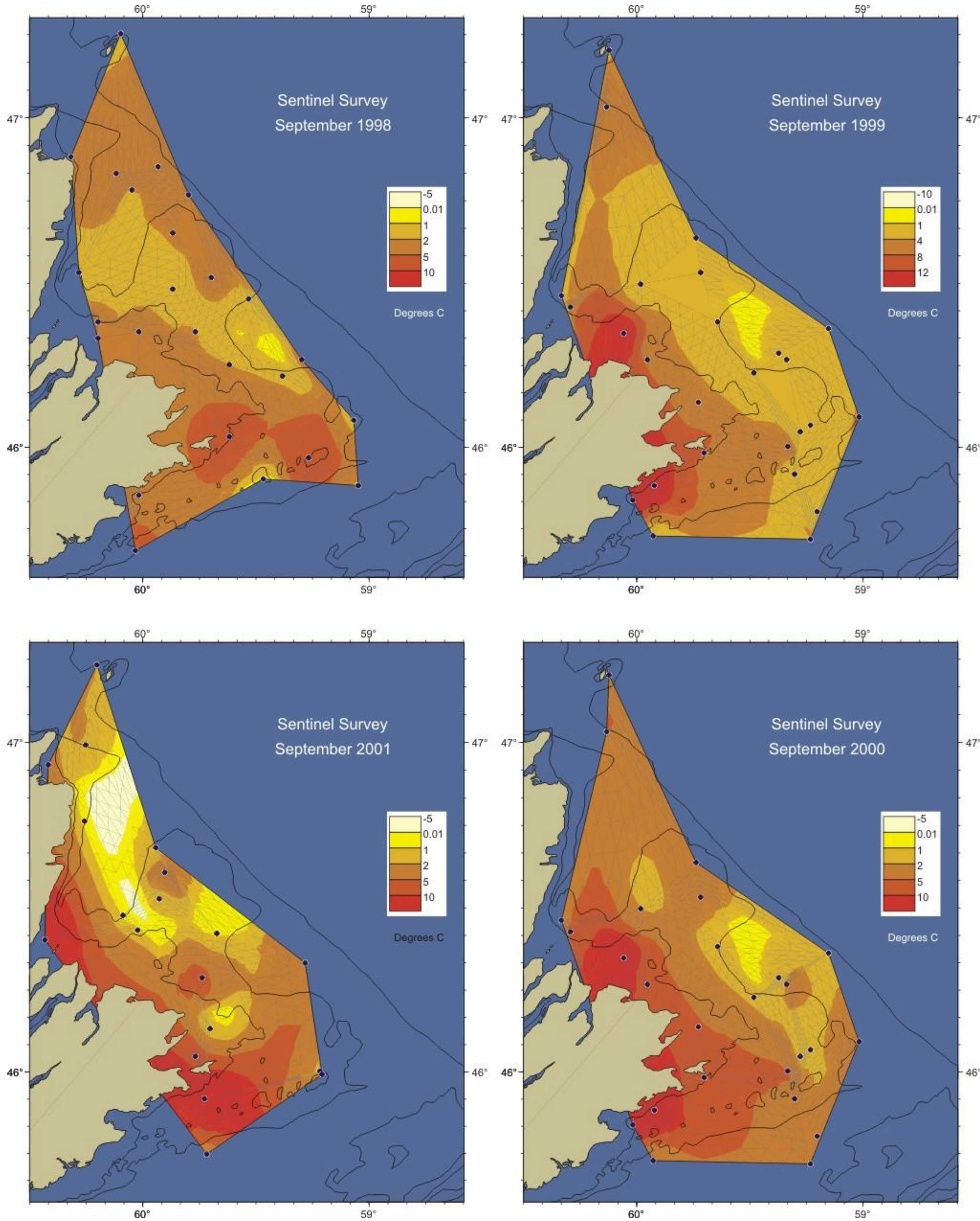
Swain, D.P., L. Savoie, S.P. Cox and É. Aubry. 2015. Assessment of the southern Gulf of St. Lawrence Atlantic cod (*Gadus morhua*) stock of NAFO Div. 4T and 4Vn (November to April), March 2015. Can. Sci. Advis. Sec. Res. Doc. 2015/080.

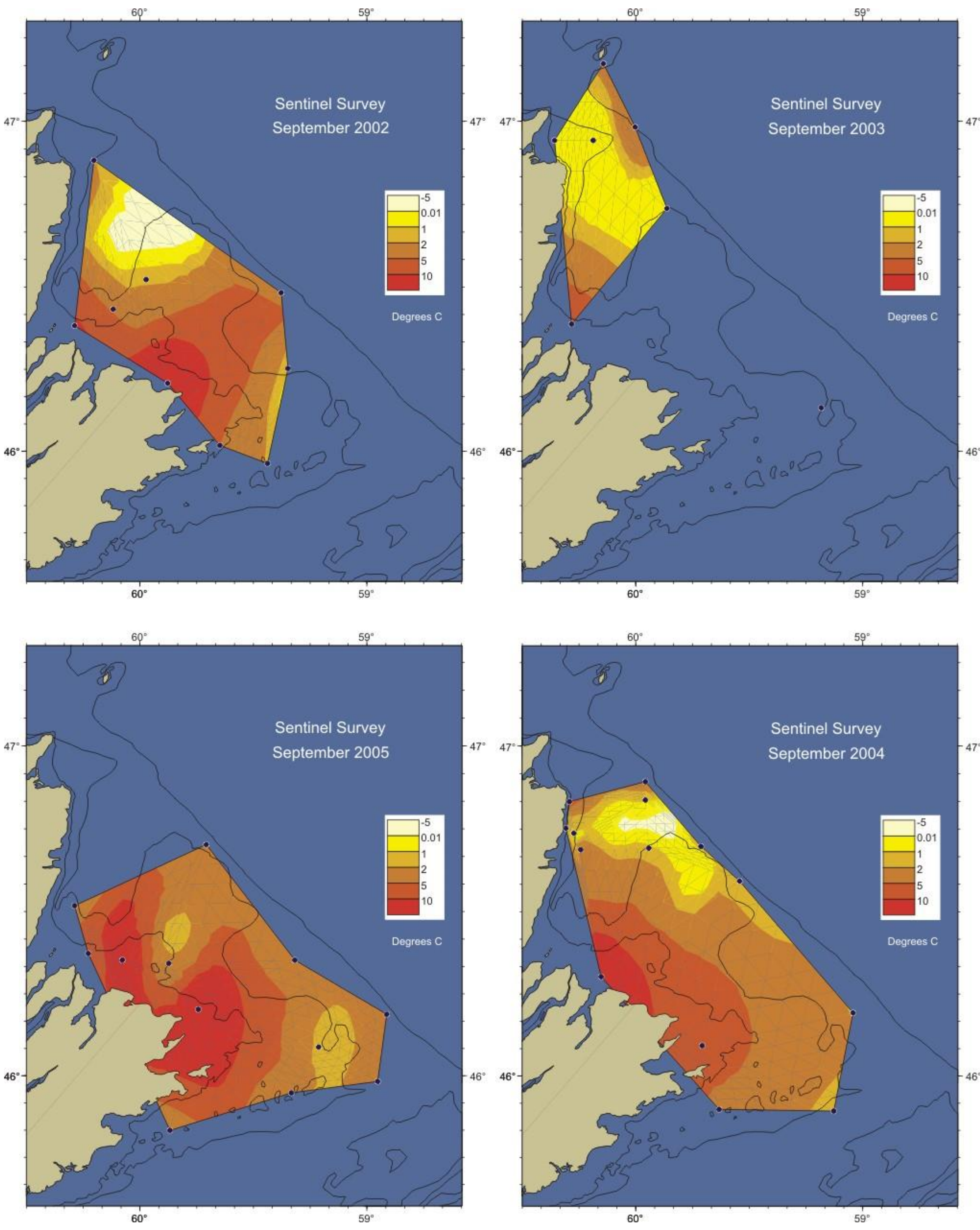
APPENDIX I(a): Bottom Temperature 1994 to 1997



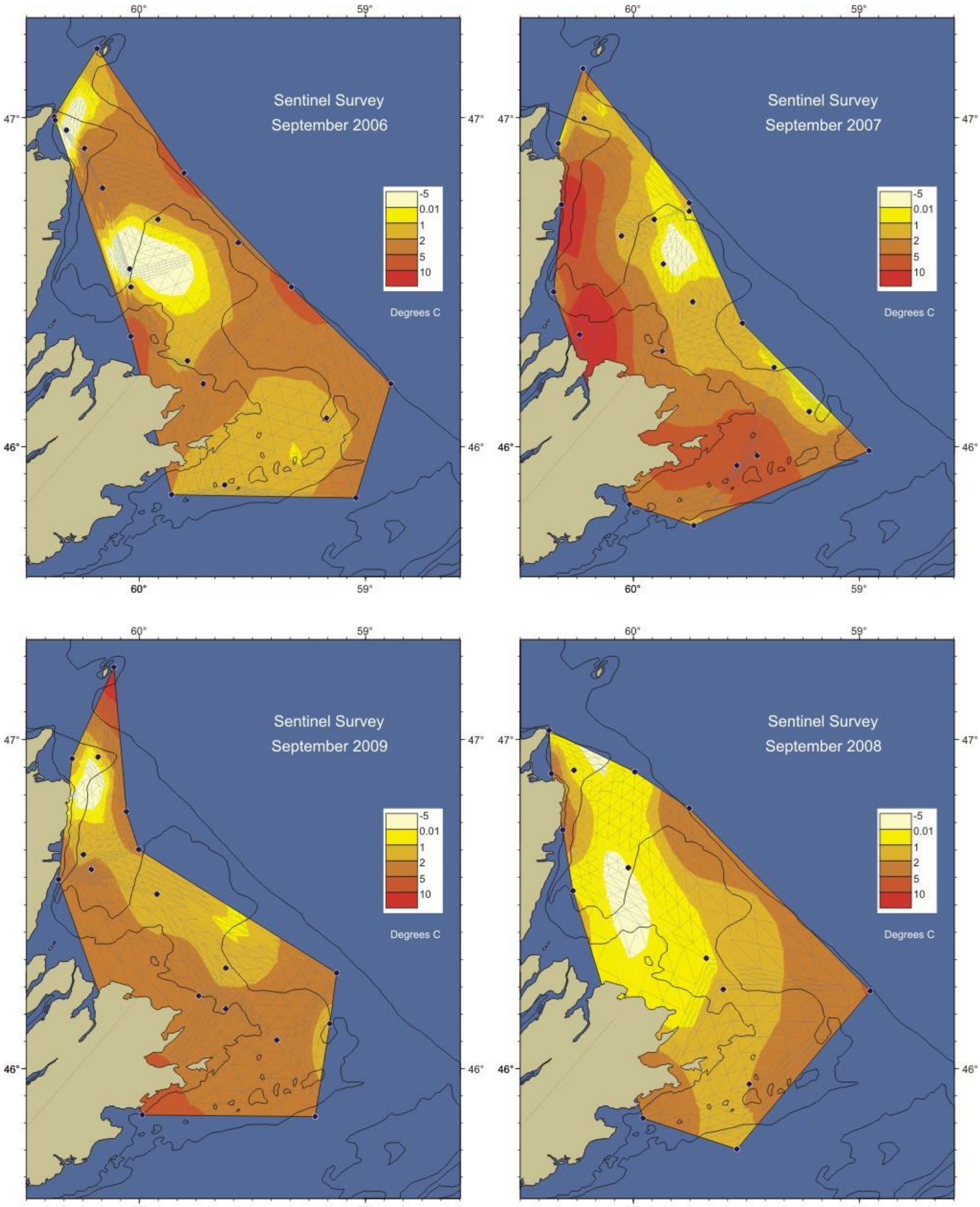
Appendix I(b): Bottom Temperature 1998 to 2001



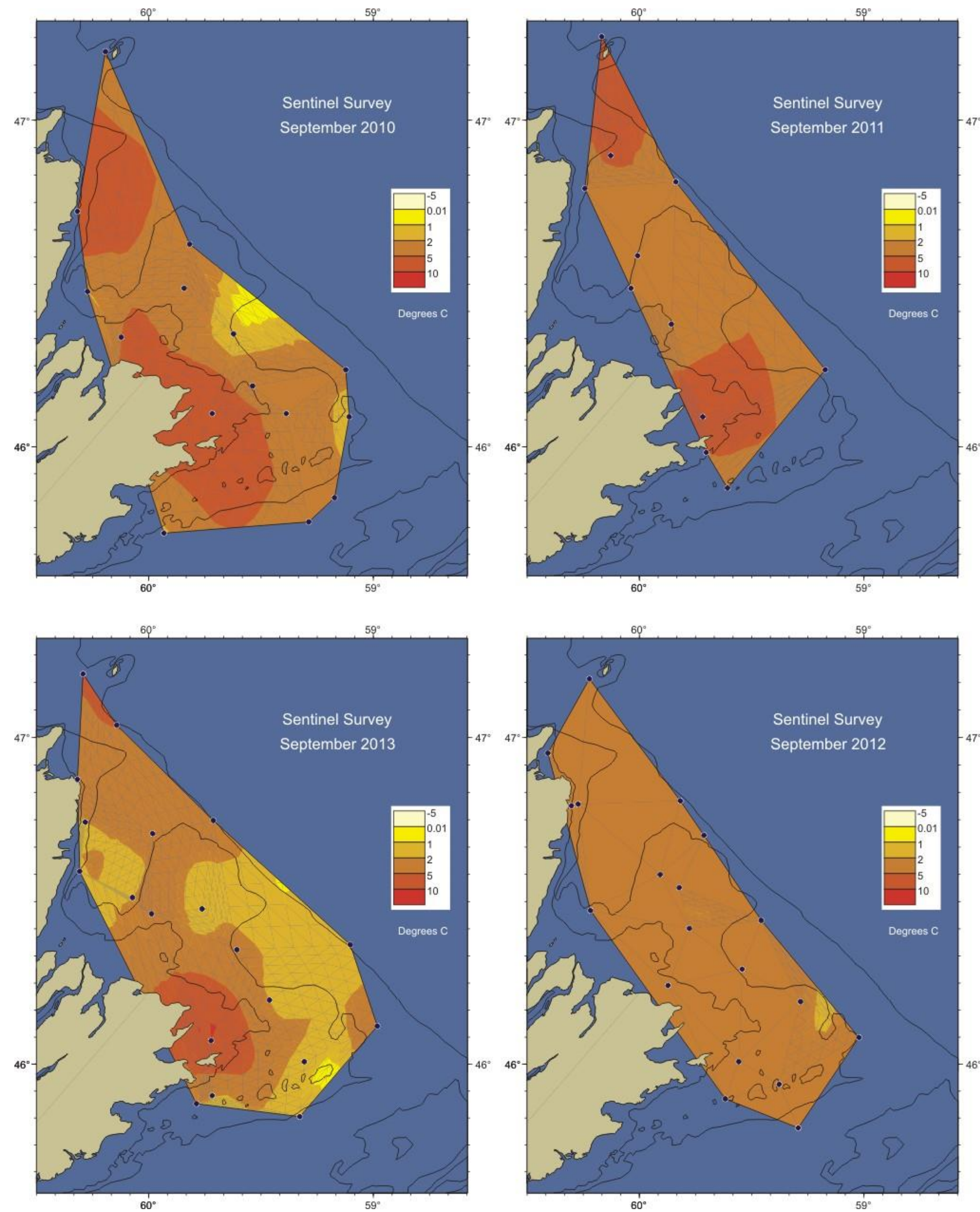
Appendix I(c): Bottom Temperature 2002 to 2005



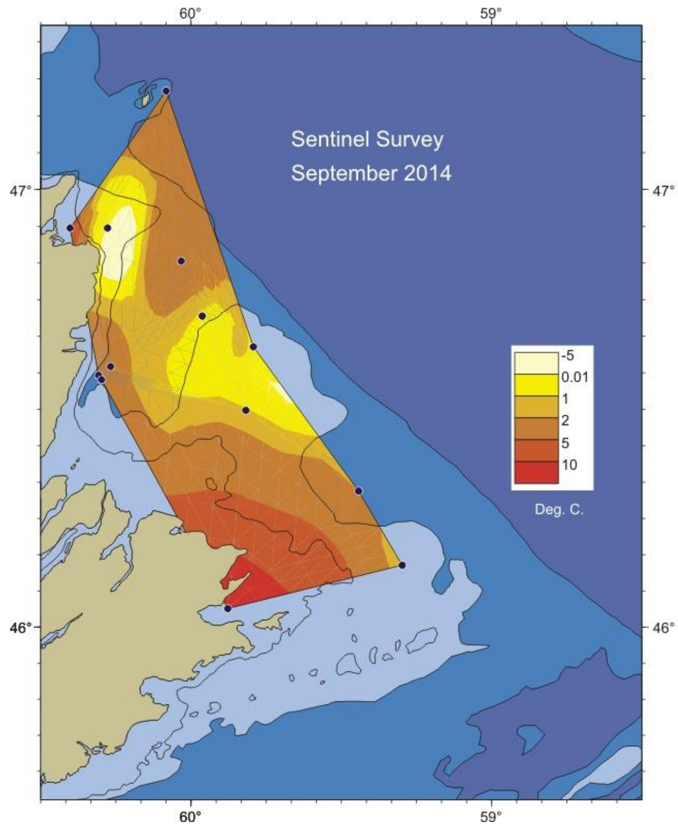
Appendix I(d): Bottom Temperature 2006 to 2009

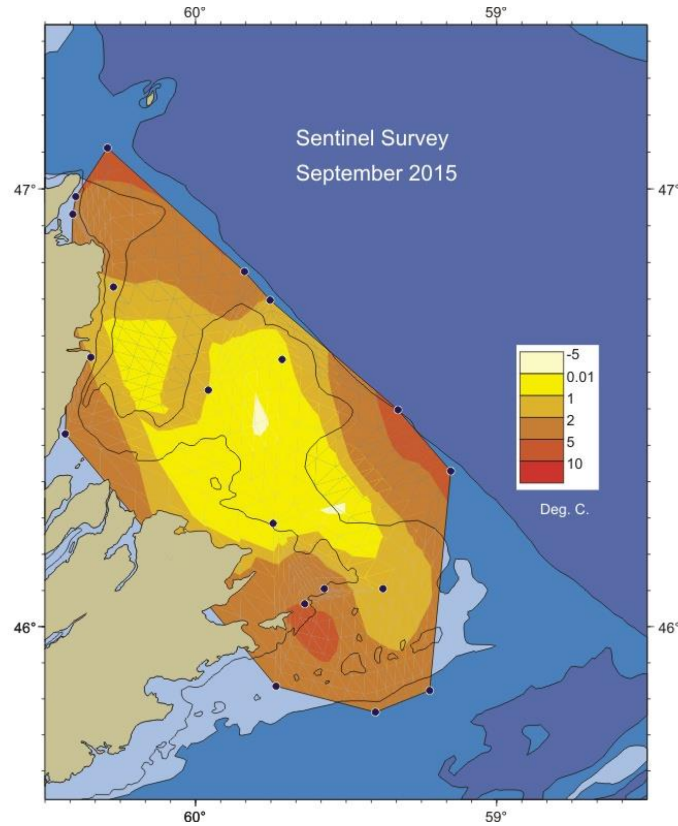


Appendix I(e): Bottom Temperature 2010 to 2013

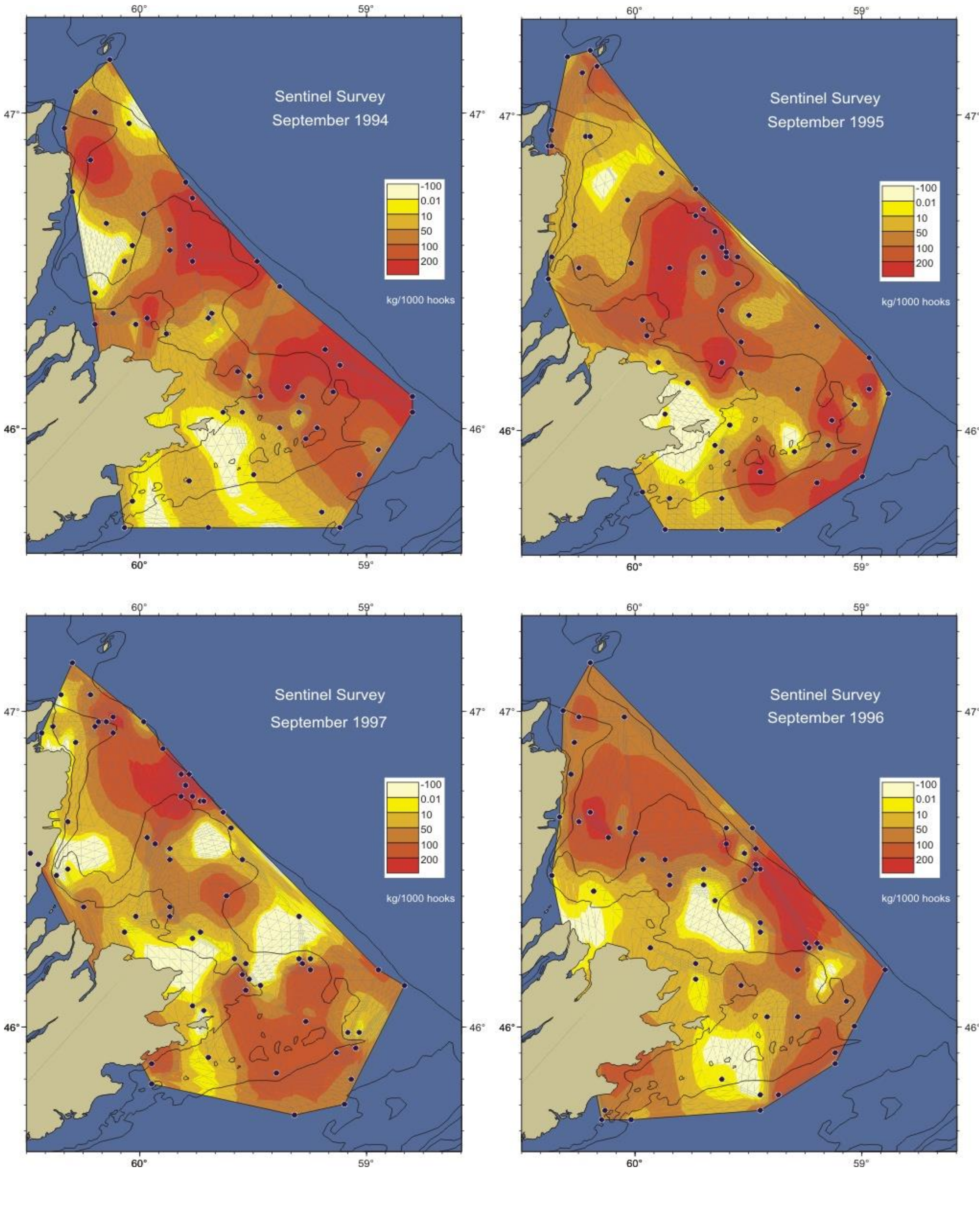


Appendix I(f): Bottom Temperature 2014 and 2015

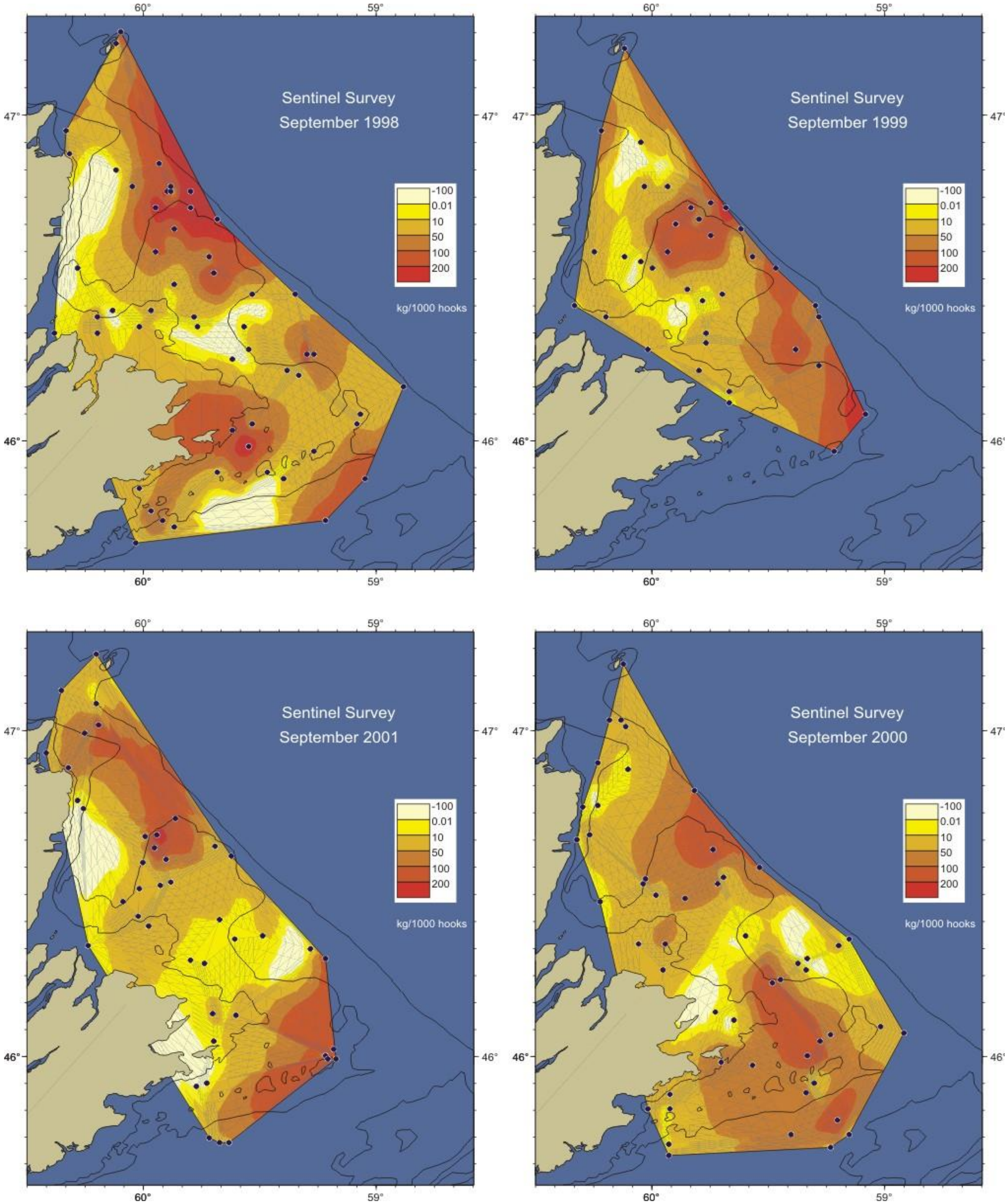




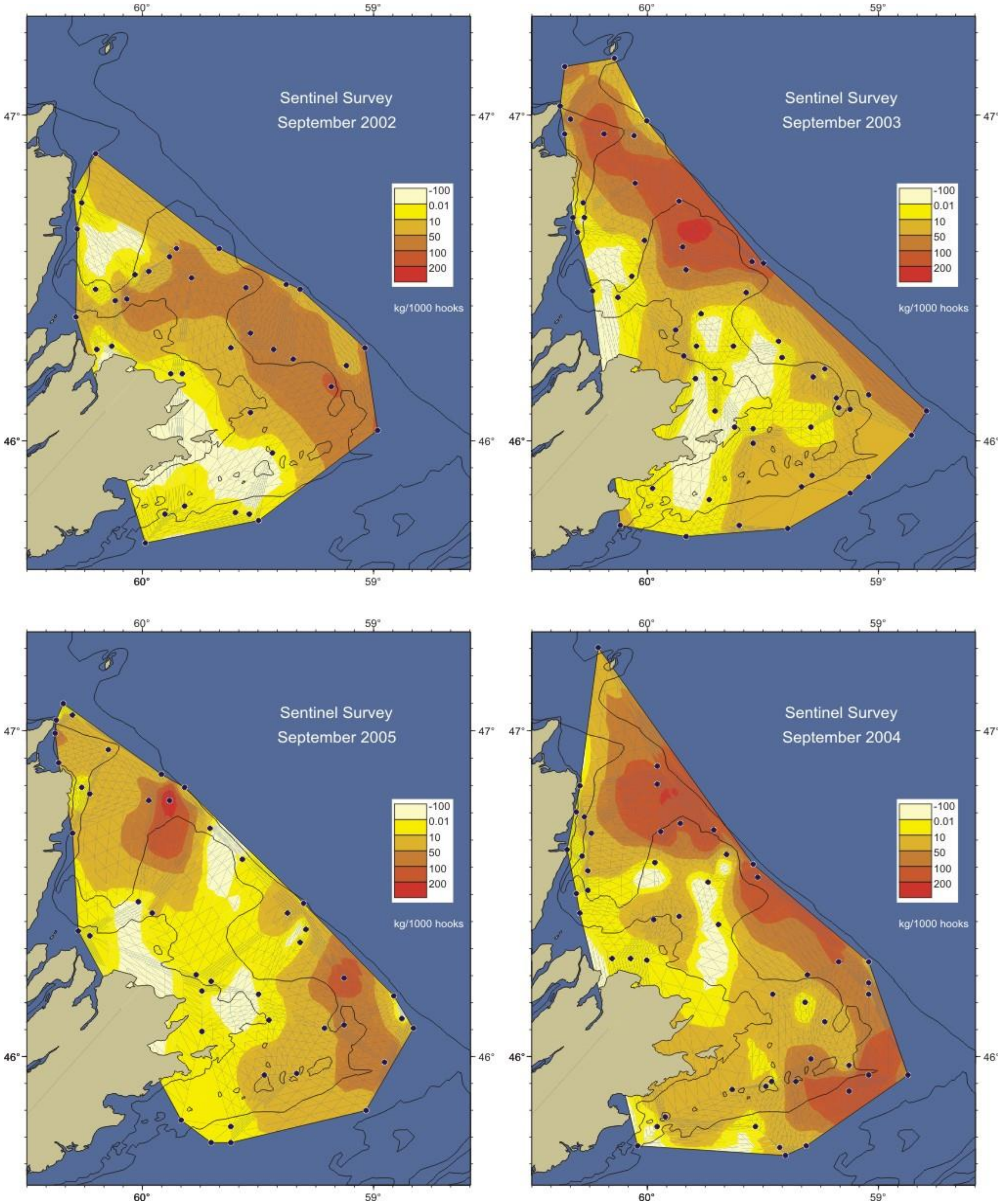
Appendix II(a): Cod catch distribution 1994 to 1997



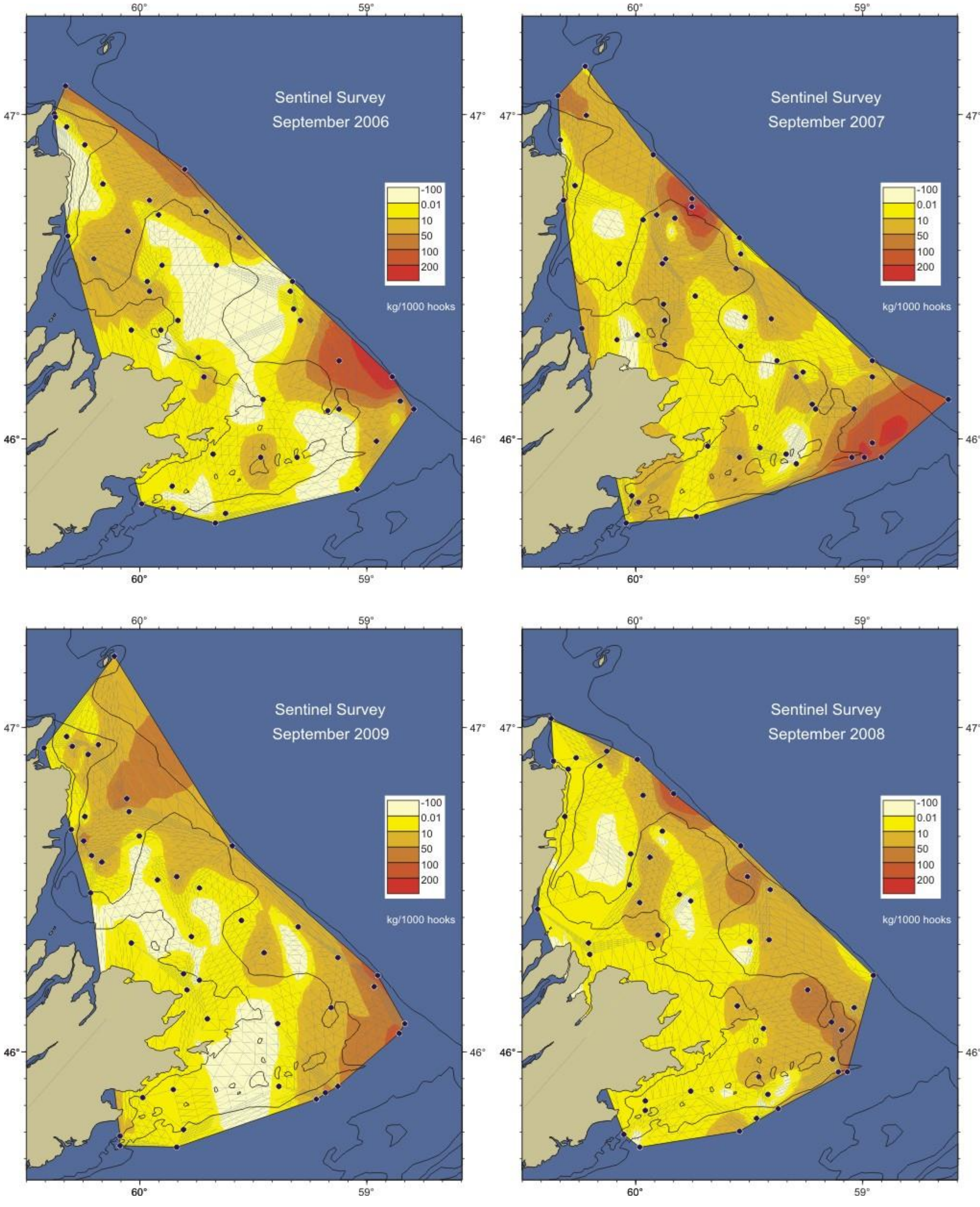
Appendix II(b): Cod catch distribution 1998 to 2001



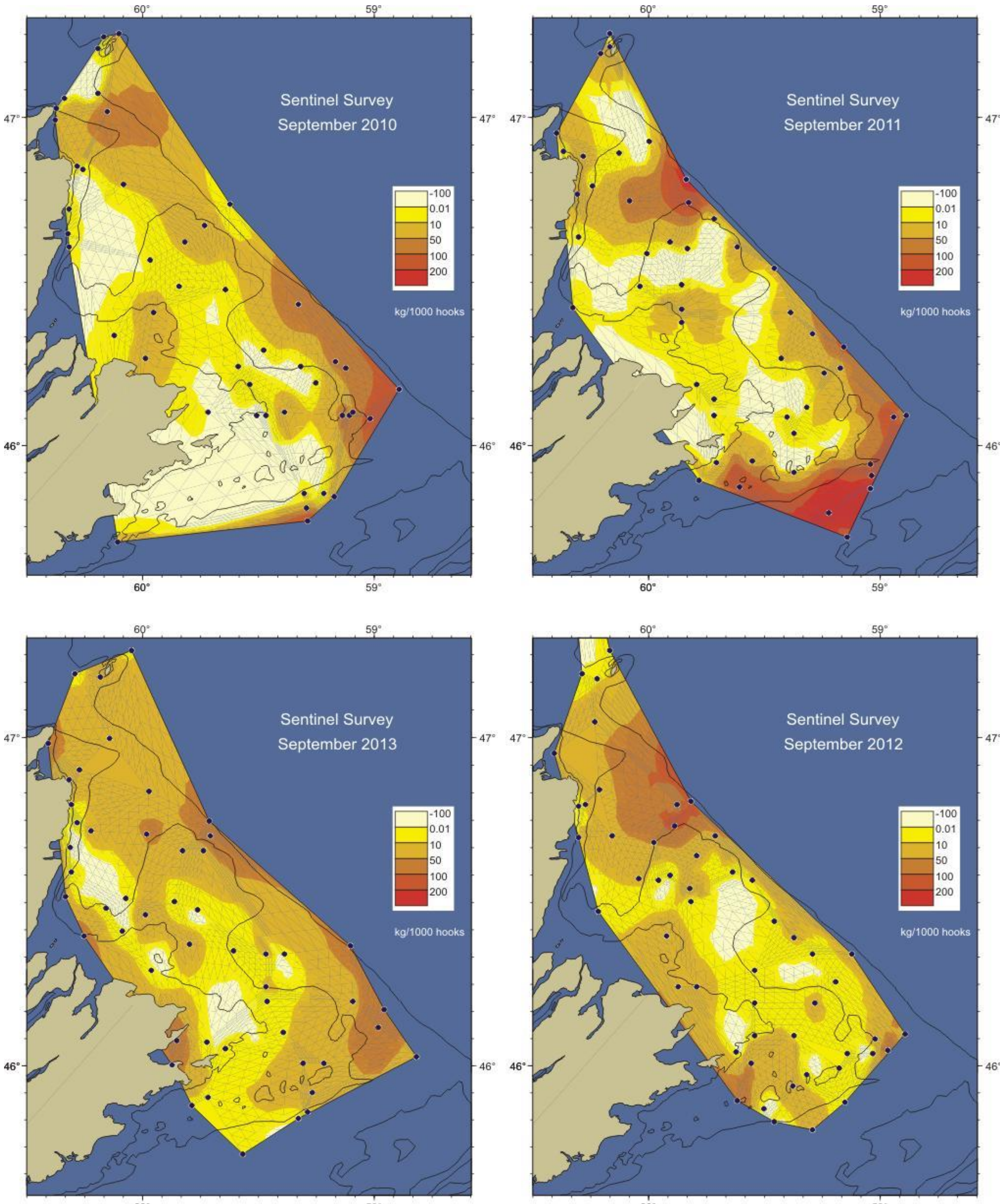
Appendix II(c): Cod catch distribution 2002 to 2005



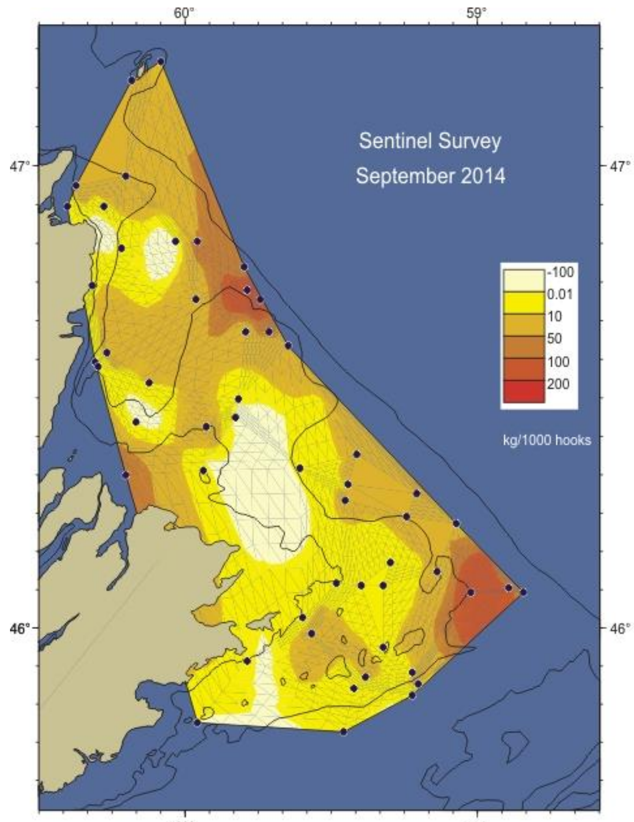
Appendix II(d): Cod catch distribution 2006 to 2009

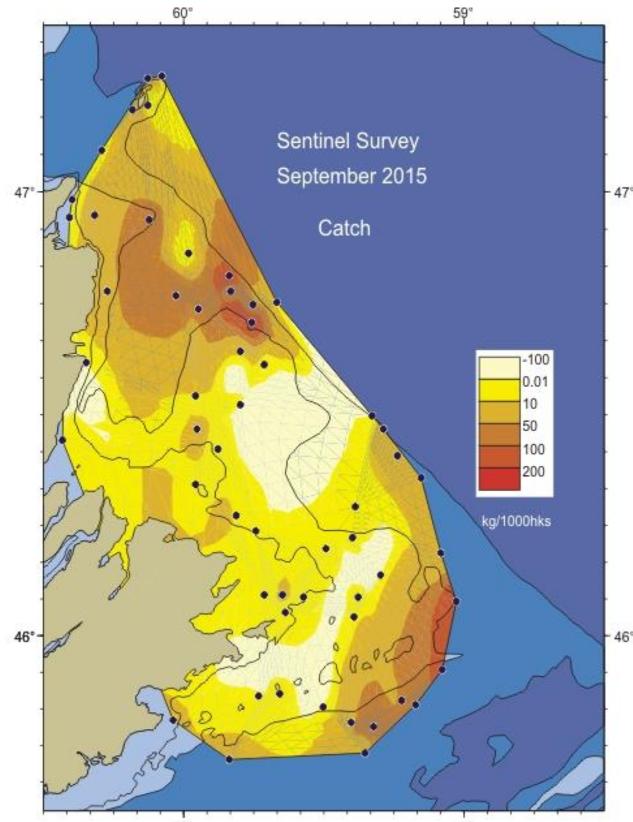


Appendix II(e): Cod catch distribution 2010 to 2013

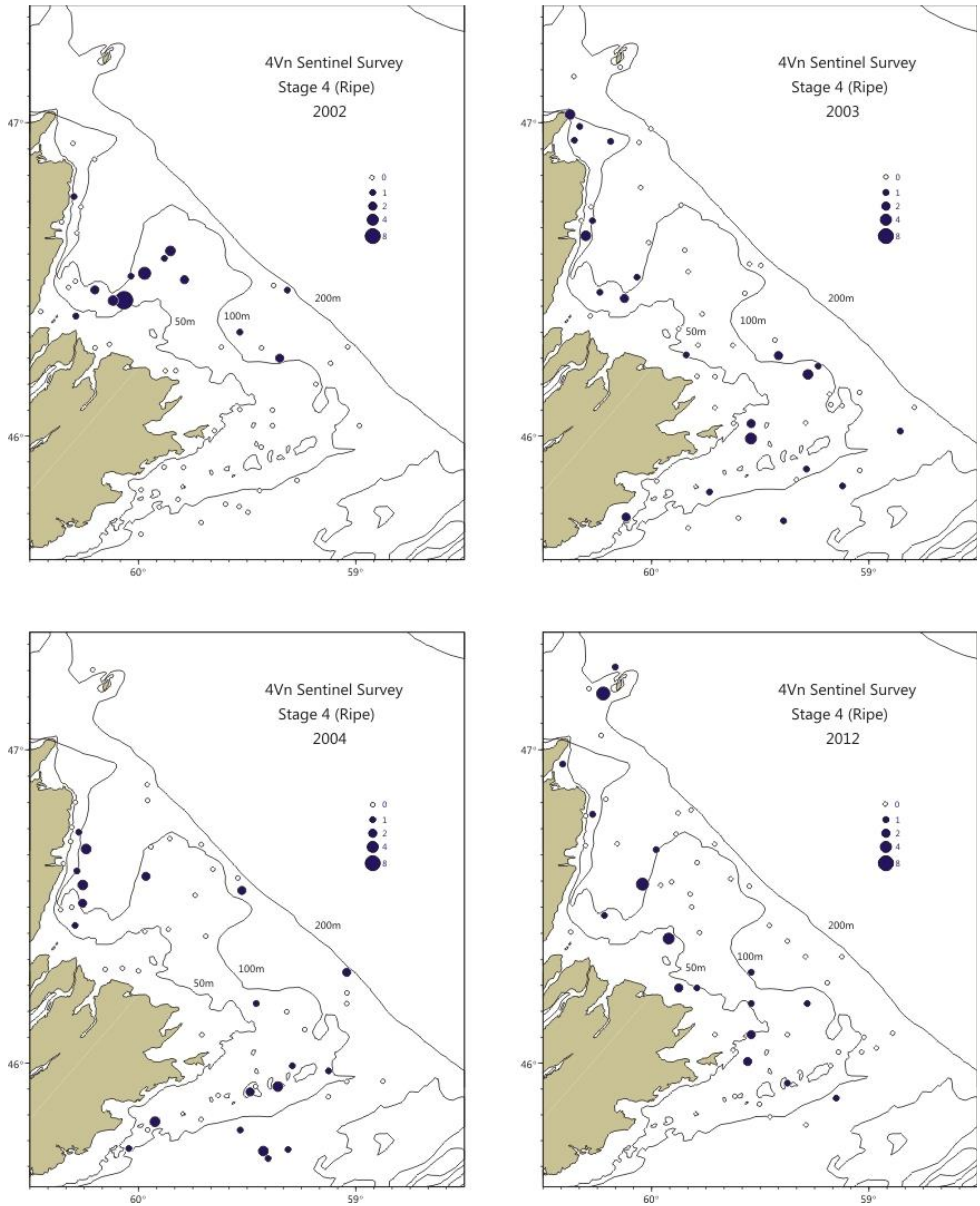


Appendix II(f): Cod catch distribution 2014 and 2015

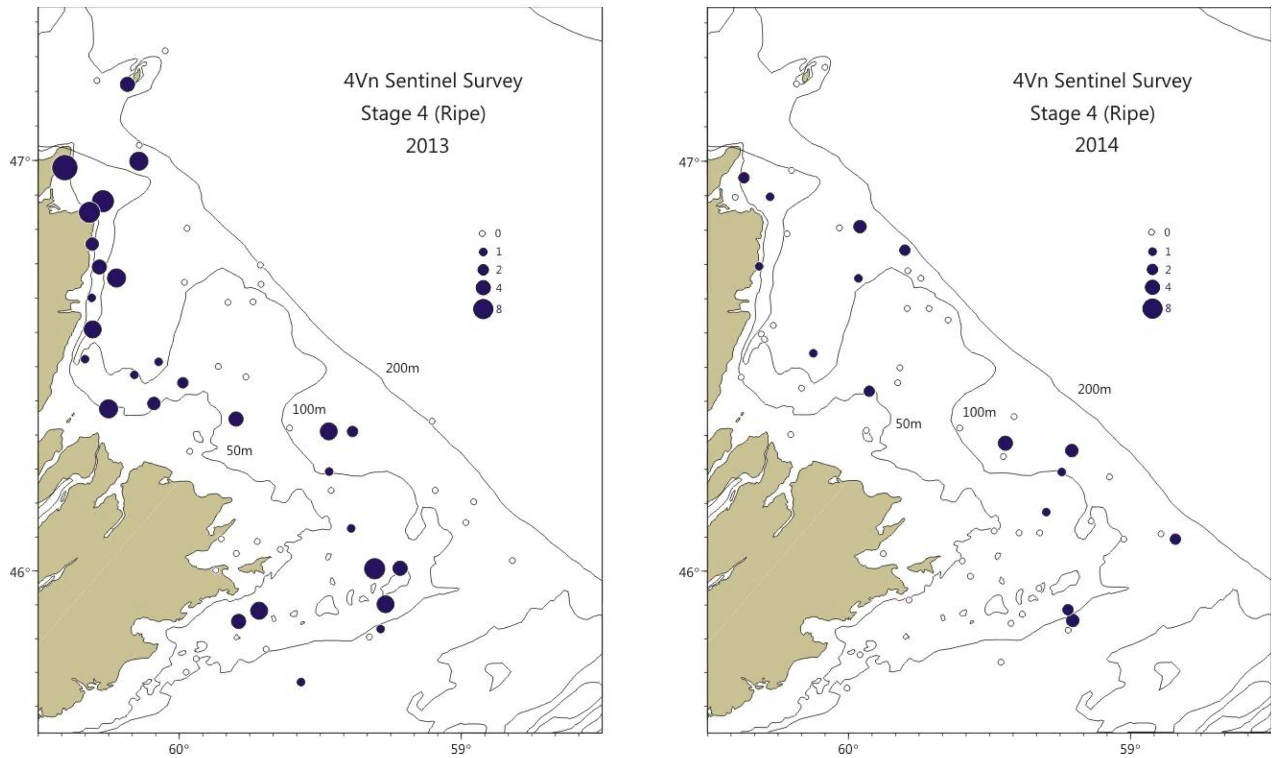




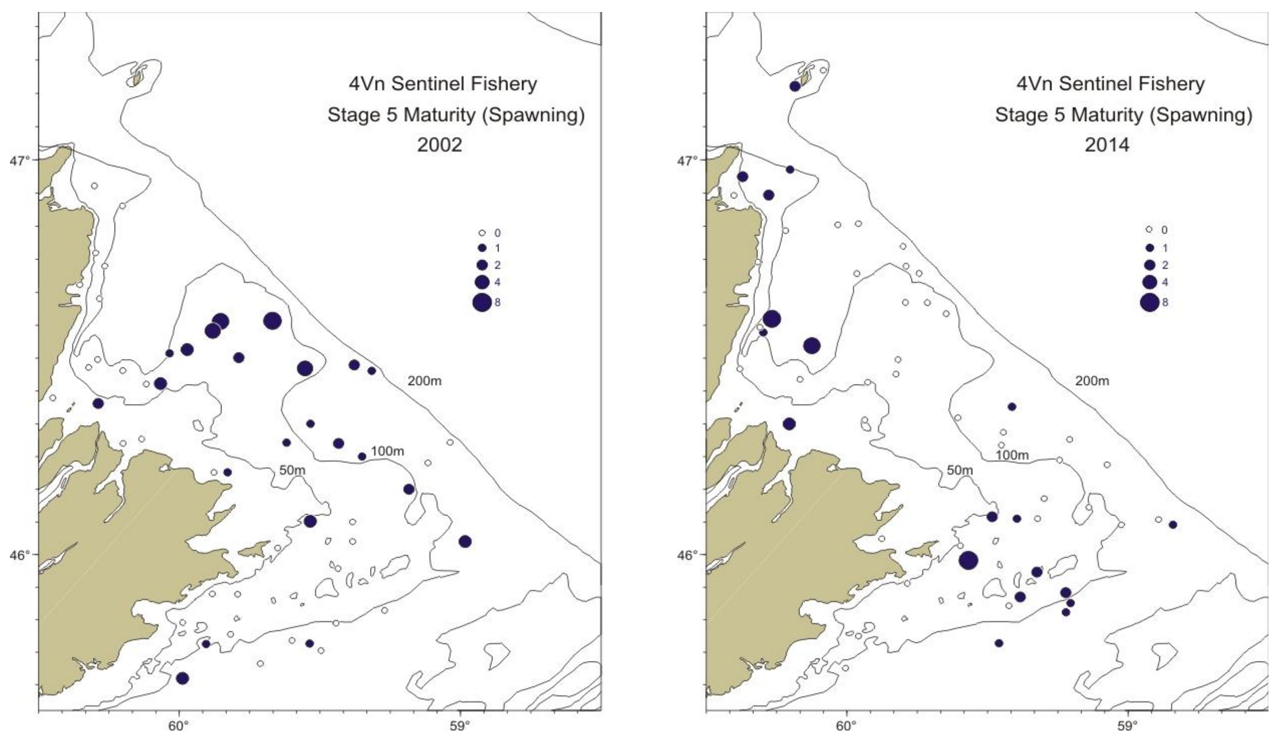
Appendix III(a): Cod in ripe condition (maturity stage 4) in years 2002, 2003, 2004 and 2012



Appendix III(b): Cod in ripe condition (maturity stage 4) in years 2013 and 2014



Appendix IV: Cod in spawning condition (maturity stage 5) in years 2002 and 2014



Appendix V: Interpretation of Trip Name

In the ISDB database the trip name is nine characters long consisting of eight characters separated into two block of four by a hyphen. The first two letters represent the boat name and the following two numbers are the year. After the hyphen the first two letters are the type of survey followed by two digits for the trip number.

Therefore: KG01-FM02 stands for

KG	-	King Gregory
01	-	2001
FM	-	Fall migration
02	-	Trip 2

Type	#Trips	# Sets	Comments about Type and Set Location Decisions
BL	33	66	Bras D'Or Lakes (captains choice)
CI	660	1856	Commercial index (captains choice)
COM	14	40	Commercial (captains choice)
FM	48	96	Fall migration (captains choice)
FS	16	174	Fixed station (chosen by captain and then fixed)
GC	6	35	Gear comparison (standard survey gear vs newer 'floating' longline)
HE	16	32	Hook experiment (#12 circle and #12 semi-circle hooks compared)
JS	88	172	July survey (random design)
MM	83	200	Monthly monitoring (chosen by captain and then fixed)
SM	43	86	Spring migration (captains choice)
SS	488	1272	September survey (stratified random design)