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Abundance and Distribution of Demersal Sharks on the Grand Banks with Particular Reference to the NAFO Regulatory Area

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Abstract

Six species of small sharks have been recorded in Canadian waters, but only two are abundant: spiny dogfish, *Squalus acanthias* and black dogfish *Centroscyllium fabricii*. Others less commonly encountered are a warm temperate vagrant, the smooth dogfish, *Mustelus canis*, a bathydermal species, Portuguese Shark, *Centroscymnus coelolepis*, the deepsea cat shark, *Apristurus profundorum* and great lantern shark, *Etmopterus princes*. On the south west Grand Banks, spiny dogfish are at the northern fringe of their distribution in the northwest Atlantic, concentrated on the western extent of St. Pierre Bank mainly in 100-250 m in the warmest available temperatures (>5°C) and comprise mature adults. The Grand Banks constitutes only 6% of the area occupied by spiny dogfish in Canadian waters and on average, 10% of the extent of the total distribution of spiny dogfish on the Grand Banks (Div. 3LNOP) occurred within the NRA. Over the past ten years, the area occupied by spiny dogfish on the Grand Banks has diminished. Spiny dogfish were observed the trawl surveys and in commercial catches in all months of the year, indicating that some proportion of the spiny dogfish that occur on the western Grand Banks do not migrate south in winter. The index of abundance for spiny dogfish is highly variable, without trend. Given their highly aggregated distribution and migratory behaviour, it is unlikely that theses patterns reflect trends in population size. On average, only 14 t are taken annually as bycatch in Grand banks fisheries. Black dogfish distribute along the entire length of Canadian slope waters and in the Laurentian Channel where they are about 10 times more densely concentrated On average, 41% of the extent of the area occupied by black dogfish on the Grand Banks (Div. 3LNOP) occurred within the NRA (15% of the Canadian distribution). Only 1.5% of the abundance occurred within in the NRA because dogfish were highly concentrated in the Laurentian Channel. Black dogfish occupy a wide range of depths: 98% from 400 to 1 400 m, highest concentrations in 350-500 m (Laurentian Channel). Black dogfish were associated primarily with temperatures > 3.8°C. In the Laurentian Channel, the spring index of abundance fluctuated at a relatively low level during the 1970's-early 1980's then increased rapidly. The index leveled off and stabilized until the mid-1990s. Since that time, it has declined, perhaps reaching stability in recent years. All evidence indicates that black dogfish in Canadian waters have a highly structured distribution with some separation by stage. Large (pregnant) females migrate to the shallow (<400 m) portion of the Laurentian Channel where pupping occurs. The young then move into deeper waters of the channel. As they mature they move out of the channel and onto the slope waters. As they grow they move into deeper waters of the slope. Bycatch in Canadian waters averaged 68 t annually between 1996 and 2005. No data were available from the NRA.

Introduction

In Canadian waters, six species of small sharks (Order Squaliformes) have been recorded, but only two are abundant in that area: spiny dogfish, *Squalus acanthias* (Family: Squalidae, Linneaus 1758) also referred to as piked dogfish (spurdog in the northeast Atlantic) and black dogfish *Centroscyllium fabricii* (Family Etmopteridae Reinhardt 1825). Others less commonly encountered in Canadian waters is one warm temperate vagrant: the smooth dogfish, *Mustelus canis* (Family Triakidae Mitchill 1815) with center of distribution in USA waters (Scott and Scott, 1988;

Bigelow and Schroeder, 2003). Three other species are bathydermal species: Portuguese Shark, *Centroscymnus coelolepis* (family Squalidae, Bocage and Capello 1864), the deepsea cat shark, *Apristurus profundorum* (Family Scyliorhinidae Goode and Bean 1896) and great lantern shark or rough sagre, *Etmopterus princeps* (Family Dalatiidae), widely distributed in other parts of the world but uncommon in Canadian waters (Scott and Scott, 1988, FishBase http://www.fishbase.org/). Although uncommon and of no commercial value in Canadian waters, Portugueses shark, deepsea cat shark and the lantern shark comprise part of a deepwater fishery in the northeast Atlantic.

Spiny Dogfish

Spiny dogfish is a widely distributed boreal to warm-temperate species, occurring over continental and insular shelf waters, and onto upper slopes of the Pacific and Atlantic Oceans. They can be found from nearshore in enclosed bays and estuaries, to shelf edge waters out to at least 900 m, throughout the water column but typically near bottom (Compagno, 1984). In the Atlantic, they tend to concentrate where bottom depths are between 10 and 200 m (McEachran and Branstetter, 1989; McMillan and Morse, 1999) and are generally associated with water temperate ranging between 7 and 15°C.

Spiny dogfish have been the subject of considerable research in other parts of the world because of its considerable commercial value. It a relatively small (<120 cm total length) squaliform, aplacentally viviparous (bearing live young) shark with embryos reliant on the yolk sac during development. Size and age at maturity varies by region, between about 60 and 100 cm in females. The reproductive biology of this species is well documented (summarized in Hammond and Ellis, 2005). Although there is some uncertainty in regard to aging of this species (see Hammond and Ellis, 2005), Saunders and MacFarlane (1993) have reported the oldest animals as great as 70 years and age at 50% maturity of 35 years off British Columbia. Aging studies in the Atlantic indicate that age at maturity and maximum age are much lower there: age at 50% maturity in the northwest Atlantic ranges from 7 to 12 years and maximum age observed at around 40 years (Templeman 1944, Marques da Silva 1993). The diet of this species is highly varied as these are opportunistic predators, as summarized in MacMillan and Morse (1999), Wilga and Motta (1998) and Templeman (1944) for the north Atlantic. The papers of Templeman (1944, 1954 and 1984) comprise most of the knowledge of spiny dogfish on the Grand Banks. These papers indicate that spiny dogfish are seasonal visitors. Fist sightings along the south coast of Newfoundland are reported in June and along the northeast coast in July/ August but those papers also suggest the possibility of an overwintering component that are likely killed by the cold, as winter temperatures there are much lower than the preferred range of the species.

In the Pacific, spiny dogfish range widely along North and South America from the Bering Sea to Chile and as far west as New Zealand, Japan and southern Australia (Compagno, 1984; Hanchet, 1988). The Pacific population is considered to be a single population although Wallace et al. (in press) suggest the presence of two inshore stocks off Canada. The Pacific commercial fishery has a long history, back to 1870 pre-dating the European fishery (Bonfil, 1999). Catches peaked in 1944 at 31 000 t but have been much lower since, averaging ~5 000-7 000 t annually in recent years. The present day Pacific quota of 14 940 t is based on the last stock assessment undertaken in 1987 (Saunders 1988). Indicators suggest that the population off the Pacific coast of Canada is stable but there may have been a decrease in larger individuals in recent years (Wallace *et al.*, in press)

In the northeast Atlantic, spiny dogfish are generally considered to form a single stock within the ICES area ranging from the Barents Sea westward to Iceland and southwards to the Bay of Biscay with greatest concentration in the seas surrounding Great Britain (ICES, 2005). A separate population occurs in the south Atlantic along the coast of Africa. Referred to as spurdog in the northeast Atlantic, it is the most commercially important shark species in northwest Europe. There have been landings since the early 1900s and a directed fishery for at least 70 years. Landings in the North Sea increased rapidly to 58 000 t in the mid-1960s. Since, landings have declined greatly: catches in 2004 amounted to ~5 000 t (ICES, 2005). As with many elasmobranchs, spurdog have biological characteristics such as low reproductive potential and longevity that make them particularly vulnerable to fishing pressure, After many years of intense directed effort, the northeast Atlantic population is depleted. Hammond and Ellis (2005) employing a Bayesian assessment estimated that the population is likely to be at less than 10% of carrying capacity, and possibly as low as 5% of virgin biomass.

In the western Atlantic, spiny dogfish range from Labrador to Florida but are most abundant between the southern Scotian Shelf off Nova Scotia and Cape Hatteras, and are considered to be a unit stock in NAFO Subareas 2-6 (McMillan and Morse, 1999) although tagging studies suggest that the population structure and movements are complex. Seasonal migrations occur northward into shallower waters in spring/summer and southward in autumn/winter although stock structure and movements are not well understood (Jenson, 1965, 1969; Templeman, 1954, 1984). Recent studies suggest that movements throughout its range differs between sexes and stages of maturity. This has resulted in an apparent increase in abundance on the Scotian Shelf in Canadian waters while indicators to the south (Georges Banks and south) show a decline (Wallace *et al*., in press). This has resulted in a good deal of uncertainty with regard to the status of the northwest Atlantic population.

Northwest Atlantic landings peaked in 1974 at about 25 000 t then again in 1996 at about 28 000 t, the USA fishery dominating from 1979 to 2000. Total landings have declined steadily since 1998. Since 2000, the Canadian catches (Scotian Shelf) are the largest proportion of estimated landings and recreational catches are, for the first time, a significant proportion of total landings (about 2 500-3 500 t catches in 2000-2002). Although discarding has declined in recent years, total catch mortality in previous years may have been much higher than reported landings (Anon., 2003). The most recent assessment of northwest Atlantic dogfish by the USA noted that female spawning portion of the biomass has declined by about 75% since 1988 and recruitment estimates from 1997 to 2003 have been very low (Anon., 2003). Current USA quota and possession management measures are designed to rebuild the stock through lower *F*. Canada is undertaking a five year research program through a Joint Project agreement with industry to address some of the uncertainties outline above.

IUCN (International Union for Conservation of Nature and Natural Resources) noted that spiny dogfish is an important and wide-ranging commercial species, particularly vulnerable to overfishing because of its late maturity, low reproductive capacity and longevity (Baillie *et al*., 2004). The population in the northeast Atlantic has a well-documented history of over-exploitation followed by near-collapse, suggesting that 'Vulnerable' might be an appropriate assessment for some regions. However, the species is still landed commercially in significant numbers from target fisheries (some of which are managed) in many parts of the world and is of high value in international trade. The spiny dogfish is presently classified as Lower Risk – near threatened (LR/nt) over the whole of its range on the IUCN Red List 2004. The northeast Atlantic population is classified as Endangered (EN A2bd + 3bd + 4bd) and the northwest Atlantic population is classified as Vulnerable (VU A2bd + 3bd + 4bd) on the IUCN Red List (refer to http://www.iucn.org/themes/ssc/redlists/RLcats2001booklet.html for an explanation of IUCN categories of risk of extinction).

Black dogfish

Centroscyllium fabricii is widespread along the slopes of the Atlantic Ocean basin. In the northeast Atlantic, although not commonly encountered it is found in slope waters from central Africa to Iceland. In the northwestern Atlantic Ocean, it is observed to be abundant on the upper and middle continental slopes and along the Mid Atlantic Ridge (Compagno, 1984; Whitehead *et al*., 1984, Gordon and Duncan, 1985; Snelgrove and Haedrich, 1985; Haedrich and Merrett, 1988). In Icelandic waters, the black dogfish is most abundant off the west, southwest and southeast coasts between 800 and 1200 m (Jakobsdottir, 2001). It is common off southwest Greenland at depths of 338-1 299 m (Yano, 1995) and Baffin Island, in slope waters off Labrador, Newfoundland, the Scotian Shelf, and Georges Bank. Murua and Cardenas (2004) observed them down to a depth of 1 750 m on the western slope of the Grand Bank. Its range continues down to Cape Hatteras (Sedberry and Musick, 1978) and possibly to Florida and into the Gulf of Mexico.

Black dogfish is a bathydemersal species taken at occasionally at depths as shallow as 300 m but generally deeper than 500 m. Very little is known about its biology although like other sharks, it is aplacentally viviparous with embryos reliant on the yolk sac during development Two papers Jakobsdottir (2001) off Iceland Yano (1995) off Greenland have provided the first descriptions of biological aspects of this poorly studied species. The latter paper provides some insight into the biology of the species in contiguous Canadian waters. Size at maturity was measured at 55 and 65 cm in males and females respectively. Litter size was 4 to 40 and the smallest size observed was 16.5 cm. The species distributed by size and sex with respect to depth, mature fish distributed in waters > 800 m and were almost exclusively mature at >1 000 m. On the slope of the Grand Banks, Murua and Cardenas (2004) also noted that mean length increased with depth.

Purpose

The Fisheries Commission of NAFO, in accord with the recommendation from the 2002 NAFO Symposium on Elasmobranch Fisheries that "the NAFO Scientific Council investigate the status and management needs of elasmobranchs in NAFO waters", the Scientific Council is requested to review all available information from both research vessel surveys and commercial catches on the stock structure, relative biomass, geographic distribution, life history, and size/age/sex composition of spiny dogfish (*Squalus acanthias*) occurring within the NAFO Regulatory Area. The Council is also requested to provide similar information on black dogfish (*Centroscyllium fabricii*) in the NRA and update the information on this species previously provided by the Scientific Council in 2001. For both species, the Council is requested to provide historical and recent information on catches and by-catches, and to identify those fisheries in which either of the two species are taken as bycatch.

As well, the IUCN (Baillie *et al.*, 2004) and the most recent assessment by the USA (Anon., 2003) noted the vulnerable and possibly depleted state of spiny dogfish in the northwest Atlantic Ocean. Black dogfish are the most abundant shark on the Grand Banks. Thus, the primary purpose of this paper is to compile available information these two species on the Grand Banks with particular reference to the NRA. Additional information is provided for other small sharks that occur in the NRA or adjacent waters.

Methods

Two sources of data were used to examine the distribution, abundance, sizes and incidental catch of the two species of shark on the Grand Banks.

Survey Data

Demersal trawl surveys (random-stratified, Engel and Campelen trawl gear, spring and autumn, post-1970 using Yankee 41.5 to 1983, Engel 145 Hi-lift to 1996 and Campelen 1800 shrimp trawl to date) have routinely been prosecuted around Newfoundland and Labrador for the purpose of estimating biomass and abundance (STRAP). A summary of the stratified-random survey design (standard sets) adopted by the Newfoundland region after 1970 can be found in Doubleday (1981). While survey design has remained constant, additional strata have been included in recent years along with modifications to some of the original strata. An accounting of these modifications up to 1994 can be found in Bishop (1994). One of the recent significant changes in the surveys is the addition of and deeper (and shallower) strata after 1993. Refer to Kulka *et al*. (2001 and 2005) and for a discussion of changes particularly with respect to depth issues.

The most significant alteration in NL survey design was a change in gear in the autumn of 1995, from Engel 145 High Lift Otter (demersal) Trawl to Campelen 1800 Shrimp Trawl. McCallum and Walsh, 1996; and Walsh and McCallum, 1996, describe the geometry and specifications of the two gears. In addition to gear dimensions, the mesh size was different – 160 mm in the bellies and codend for Engel and 40 mm for Campelen. Visual analyses verify that the two gears capture different size ranges of fish. While size based conversion factors for amounts of fish caught were derived from comparative surveys for the major commercial species, this exercise was not done for "minor" species, including dogfish species. Thus, the catch rate data and resulting biomass and abundance indices must be considered as separate indices. The change in gear occurred in the autumn of 1995. The change in scale is delineated on the various tables by spatial separations and on the figures. All of these issues and changes were taken into account when selecting the appropriate data for analysis of abundance trends, as elaborated in the results.

In addition, extra sets using the same gear and effort (tow time) were done on occasion, apart from the proportional allocation of the random-stratified sets used for STRAP. These were done primarily to survey redfish, mainly in the vicinity of the Laurentian Channel and for diurnal studies at location on the Grand Bank. Those extra sets are particularly useful for delineating autumn distribution along the southern St. Pierre Banks and Laurentian Channel (NAFO Div. 3Ps), not covered by the standard survey in the autumn.

Analyses

For the analysis of abundance and biomass, the standard sets from the seasonal surveys, spring and autumn are used while a combination of the standard and special sets are used to map the distribution.

A GIS - SPANS was used to investigate the spatial distribution of the shark species with survey data. Potential mapping in SPANS (Anon., 2000) transforms points (kg per tow) to density surfaces (areas of similar kg per tow) by placing a circle around each point and averaging the values of all points that fall within the circle. The 12 km circle diameter selected for annual maps provided complete coverage of the survey area while minimizing gaps in the density surface and thus maximizing spatial resolution. The resulting map was then post-stratified into 15 classes defining density of the fish, each density class covering approximately the same amount of area. The method is further described in Kulka (1998).

Fishery data

Information on small sharks removals was obtained from three sources: Canadian Fisheries Observer database as the primary source; Zonal Interchange Format (ZIF) data files for Canadian landings; and NAFO STATLANT-21A for reported non-Canadian landings. Observers collected set-by-set information on catches, employing methods described in Kulka and Firth (1987; periodically updated in unpublished versions as the Fisheries Observer Program Training Manual (Science) – Newfoundland Region).

Catches of black and spiny dogfish from Canadian fisheries were derived for the period 1996-2005 from fishery observer records, which sampled a portion of each fishery and recorded amounts of dogfish taken as bycatch. Canadian landings by directed fishery were compiled using Canadian fishing log records and landings purchase slips; both contained in the ZIF database. Total catches of spiny and black dogfish were calculated by applying the following raising factor: reported directed catch (landings data, Canadian ZIF files) **/** directed catch in the Canadian Fisheries Observer database **x** observed catch of dogfish (by species).

Results and Discussion

Spiny dogfish

The southern Grand Banks is at the northern extent of the distribution of spiny dogfish in the northwest Atlantic (red box, Fig. 2). Note that this figure constitutes an accumulation of various Canadian and USA demersal trawl survey catch per hour from prior to 1994, not adjusted for differences in catchability among gears. While the catchability of the various gears used would differ somewhat, all were demersal groundfish trawls with similar mesh sizes and thus differences in catchability, particularly with respect to size should not be great. It can be deduced from this figure that the centre of distribution of spiny dogfish lies well south of the Grand Banks on southern Georges Bank. Catch rates are on the scale of 100 to 1 000 times greater on Georges Bank compared to the Grand Banks. Total area occupied by spiny dogfish in Canadian waters is 425 000 sq km (Wallace *et al.*, in press) whereas on average they occupy an area of 25 000 sq km on the Grand Banks (1996-2005) thus amounting to about 6% of the Canadian distribution.

On the Grand Banks, spiny dogfish are largely confined to the outer southwestern shelf over the entire time that the area was surveyed (survey data examined back to 1947). The highest concentrations consistently occurred along the western portion of the St. Pierre Bank adjacent to the Laurentian Channel and into the Heritage Channel in NAFO Div. 3P (Fig. 3). Over the past ten years, the area occupied by spiny dogfish on the Grand Banks has diminished, by about five times (Table 3, Fig. 4). During this same period, spiny dogfish indices on the Scotian Shelf have increased (Wallace et al. in press) but have decreased in USA waters (Anon., 2003). Mix of stages are different on the Scotian Shelf compared to USA waters (see discussion on sizes caught on the Grand Banks, below)

Over the past ten years (1996-2005), between 0 and 25.8% (average 10%) of the extent of the total distribution of spiny dogfish on the Grand Banks (NAFO Div. 3LNOP) occurred within the NRA among years (about 0.6% of the Canadian distribution). However, only 0.22% (0-1%) of the Grand Banks abundance occurred within in the NRA (Fig. 4) because dogfish were consistently highly concentrated on St. Pierre Bank (NAFO Div. 3P), well away from the NRA. Over the past two years, no spiny dogfish were taken in the Canadian survey in the NRA.

The Templeman papers (1944, 1954 1984) indicate that spiny dogfish were also common nearshore in the bays around Newfoundland, first seasonal sightings occurring in June on the south coast and July-August on the northeast coast based on commercial fishery observations. This part of the distribution of the species is not captured by the trawl surveys except along the western extent of the south coast of Newfoundland. What proportion of the population on the Grand Banks the inshore component constitutes is unknown. However, spiny dogfish were observed in the trawl surveys (and in commercial catches) in all months of the year, the highest catches occurring in the winter and spring months. These winter catches were consistently concentrated along the western extent of St. Pierre Bank where bottom temperatures were highest on the Grand Banks remaining at about 6°C year round (see discussion on temperature associations below). This indicates that some proportion of the spiny dogfish that occur on the western Grand Banks do not migrate south in winter and thus appears to be a wintering ground for spiny dogfish. Winter concentrations offshore coupled with evidence of nearshore fish in the summer/autumn suggest local inshore/offshore seasonal migrations. Degree of mixing to the south is unknown but tagging by Templeman (1984) shows that Grand Banks dogfish do mix with those to the south. Campana (2003) has suggested that there is little interchange between northern spiny dogfish around Newfoundland with those in southern populations along the Scotian shelf, thereby implying the possibility of two loosely structured stocks in Canadian waters.

Spiny dogfish is a shelf species and on the Grand Banks, found at depths ranging from nearshore in summer and autumn (as reported by Templeman, 1944, 1954, 1984) to 500 m with the exception of a small number (0.1% of total) of deeper records and 96% at <400 m. Highest concentrations occurred at 101-250 m (Fig. 5). A summary of depths and temperature ranges, and areas captured for spiny dogfish is given in Table 1.

Spiny dogfish were associated exclusively with the warmest available bottom temperatures on the grand banks: 91% of all individuals captured in the trawl surveys were taken where temperatures >5°C (Table 2, Fig. 6). The largest catch rates and the greatest proportion of sets with spiny dogfish were associated with 6-10°C (Fig. 6b), which effectively restricts their distribution primarily to the western extent of the St. Pierre Bank (Fig. 3) where sufficiently warm thermal conditions exist. Compagno (1984) noted that an important correlate of spiny dogfish movements seems to be water temperature noting that these sharks favour a temperature range with a minimum of 7-8°C and maximum of 12-15°C, and apparently make latitudinal and depth migrations to stay within their optimum range. This temperature preference helps to explain the consistently limited distribution of dogfish on the Grand Banks. Only a small portion of the NRA, the Tail of the Bank warms above 5°C in the summer/autumn and this explains their limited and sporadic distribution within the NRA.

Relative abundance of spiny dogfish on the Grand Banks, calculated by STRAP is illustrated in Fig. 7. Given that nearly all dogfish records occur at depths <500 m, the index pattern was the same regardless of whether deeper strata added in recent years were retained or removed (to retain spatial consistency in depths surveyed over time). The index for spiny dogfish is highly variable, without trend and with several fold increases or decrease observed between contiguous years. The most obvious pattern is the very low abundance in 1989-1996 with no spikes as observed in earlier years.

Spiny dogfish are patchy and form dense aggregations (closely spaced sets ranging from zero to thousands of animals per set) which causes high variance and spikes in the survey indices. As previously indicated, spiny dogfish are highly migratory and at the northern fringe of their population on the Grand Banks. Thus, it is unlikely that the patterns illustrated in Fig. 7 reflect trends in population. Rather, they may in part reflect degree of migration from the south onto the Grand Banks in a particular year.

Average weight of spiny dogfish on the Grand Banks fluctuated without trend with respect to bottom temperature and depth. This indicates that the larger juveniles and adults were mixed. Average weight declined slightly over the from the early 1970s to the mid-1990s but was stable/fluctuating in post 1995 (Fig. 7). The size of (unsexed) spiny dogfish recorded in the trawl surveys on the Grand Banks ranged from 56 to 108 cm with an average size of 79 cm (n = 1 268, Fig. 10). Thus, spiny dogfish on the Grand Banks are primarily adults. Smallest and largest sizes observed in 1974-2002 matches closely with the minimum and maximum size of 58-101 cm reported by Templeman (1944) around Newfoundland more than half a century ago.

Birth size for spiny dogfish are typically 18-33 cm and size at 50% maturity is about 59 cm (Nammack *et al.*, 1985). A significant portion of our specimens were captured with Campelen shrimp trawl (post 1995) and thus any small fish present would likely be captured by that gear. This and Templeman's finding that almost exclusively mature adults migrate into Newfoundland waters and that pupping does not occur there. On the Scotian Shelf during the same period using a dermal groundfish trawl with much larger mesh, a significant portion of fish smaller than 59 cm were regularly observed in the survey catches (Wallace *et al.*, in press). The apparent absence of younger juveniles and the large fluctuations in survey abundance estimates from years to year both suggest that spiny dogfish on the Grand Banks do not comprise an independent stock: early life history (pupping and young juveniles) occurs elsewhere.

Mortality due to fishing in the Canadian portion of the Grand Banks has been estimated at an average of 14 t annually between 1996 and 2005. There is no directed fishery in the area but spiny dogfish are taken incidentally in a number of fisheries, particularly with redfish, monkfish and crab in NAFO Div. 3Ps (Table 4a-c, Fig. 9). No data on removals are available form the NRA but it is expected that bycatch there would be minimal as it is away from the centre of concentration of spiny dogfish (see discussion above on distribution). As well, mortality due to bycatch is small compared to the Grand Banks biomass index (relative *F* averages 0.0004).

Two categories of demersal sharks were reported in NAFO statistics (Table 4d). An average of 7 tonnes of spiny dogfish was reported annually in 3LMNO. All other demersal shark were reported as Dogfish NS, averaging 423 t annually: most of this undifferentiated catch likely comprised black dogfish, the most common shark bycatch in the Greenland halibut fishery.

Black dogfish

Black dogfish is a bathydemersal species that distributes continuously along the entire length of Canadian slope waters (Fig. 11a) and beyond; around southern Greenland (Yano, 1995), Iceland (Jakobsdottir, 2001) and Europe (ICES, 2005) to the northeast and off the USA to the south (Sedberry and Musick, 1978).Within the area surveyed, black dogfish occupy an area of 225,000 sq km, in the Laurentian Channel and on the slope of the Grand Banks and north. However, the survey did not reach the entire extent of the distribution of the species in all years (Engel period) with respect to depth. As well, a portion of the Laurentian Channel to the north in NAFO Div. 4RS and to the west in NAFO Div. 4Vn where black dogfish occur, is not part of the NL survey area. Thus, area and abundance provided in this paper are underestimated in certain areas and periods.

Black dogfish are highly concentrated in the Laurentian Channel and into the Heritage Channel in NAFO Div. 3P (Fig. 10). Virtually all large catches in the NL surveys (defined as >15 individuals per tow) were located in the Laurentian Channel (Fig. 11). There, black dogfish were about 10 times more densely concentrated than in the Grand Banks and Labrador Shelf slope waters.

In 1996-2006, 5 to 56% (average 38%) of the extent of the area occupied by black dogfish on the Grand Banks (NAFO Div. 3LNOP) occurred within the NRA. This amounts to about 15% of the Canadian distribution, Grand Banks and north. However, only 1.5% (0.2-6%) of the abundance occurred within in the NRA because dogfish were highly concentrated in the Laurentian Channel (NAFO Div. 3P), outside of the NRA (Table 3b, Fig. 12). In 2003 (and to a lesser extent in 2005), areas of the Flemish Pass where black dogfish are present in other years was not sampled. Thus, the value of 5% of area occupied in that year is likely biased low. By removing that value from the series, it is estimated that 41% (2.1%) of the Grand Banks distribution (abundance) of black dogfish occurs is within the NRA.

Black dogfish occupy a wide range of depths: 98% of specimens recorded in the NL surveys came from sets in the 400 to 1 400 m range. Highest concentrations were observed at 350-500 m, nearly all within the Laurentian Channel (Fig. 5, Table 1). Along the shelf edge (Grand Banks and north) highest densities were observed considerably deeper, at 750 and 1 150 m. The Laurentian Channel appears to be unusual in terms of (shallow) depth of capture of black dogfish. Yano (1995) although indicating a minimum depth of capture of 338 m off west Greenland (adjacent to our area) most of their captures were at depths exceeding 500 m out to 1 225 m, similar to our slope observations.

Black dogfish and spiny dogfish concentrations can be found in close proximity on St. Pierre Bank. However, they are largely separated by depth: 92% of spiny dogfish captured were taken at <350 M while 97% of black dogfish were taken at >350 m.

In terms of bottom temperature, black dogfish were associated primarily with the warmest available bottom temperatures: 92% of all individuals captured in the trawl surveys were taken where temperatures >3.8°C (Table 2,

Fig. 6). With few exceptions, the largest catches (defined as >15 individuals per tow) came from the warmest available locations where bottom temperature was between 5 and 6.5°C, primarily in the Laurentian Channel.

Estimating relative abundance of black dogfish is problematic over the longer term because a significant proportion of the population occurs at depths that exceed the range surveyed, pre-1995. The autumn survey covers the slope portion of the distribution north to NAFO Div. 2J. However, during the Engel survey, pre-1995, only depths to about 700 m were sampled consistently over the entire series whereas the majority of the black dogfish population occurs at > 700 m (Fig. 5). Therefore, survey abundance indices for the slope area (NAFO Div. 2J to 3O) is estimated only for the Campelen period, post-1995 when the survey overlaps most of the black dogfish distribution. As well, the autumn survey does not cover NAFO Subdiv. 3Ps where the most dense concentrations of black dogfish occur. Therefore, the spring survey data were used to estimate trends in abundance in the Laurentian Channel (NAFO Subdiv. 3Ps). In 3Ps, both the Engel and Campelen series coved the full depth range of black dogfish in the area. However, the species also inhabits a significant territory within NAFO Subdiv. 4Vn and Div. 4RS (refer to Fig. 1) within the Laurentian Channel. Using this spring 3Ps series as an index of abundance assumes that densities observed in NAFO Subdiv. 3Ps are representative of the entire Laurentian Channel and that there is no significant movement into and out of adjacent areas.

In the Laurentian Channel, the spring index fluctuated at a relatively low level during the 1970s and early 1980s then increased rapidly (Fig. 13). The index leveled off and stabilized until the mid-1990s. Since that time, it has declined, perhaps reaching stability in recent years. Average weight of fish (set weight/numbers caught) at that location fluctuated without trend over that period. The multi-year average during that period was 0.4 kg. Using the length-weight relationships of Jakobsdottir (2001), average length of fish captured in the Laurentian Channel was estimated at 46 cm while average size at maturity is about 60 cm Yano (1995). Thus, the black dogfish in the Laurentian Channel comprise primarily juveniles. Along the slope waters of the Grand Banks to Labrador Shelf and including the NRA (NAFO Div. 2J+3KLNO), the index fluctuated between 1995 and 2005: the values in the first two years of the series was very similar to the last two years. Thus, it appears that the adult (spawning stock) segment of the population, the primary portion of the slope fish was stable after 1995 while juveniles in the Laurentian Channel declined.

Yano (1995) noted that size of fish increased with depth off Greenland and at <1 000 m, the fish were mainly juveniles. In Canadian waters, there is also a separation of juveniles from adults. However, the depth at which the changeover occurred was considerably shallower, at about 550 m (Fig. 14). In terms of thermal associations, juveniles were located in both the coldest and warmest temperatures while adults were largely constrained to locations where temperatures were mid-range, 2.1-3.7°C.

The size of black dogfish recorded in the trawl surveys on the Grand Banks ranged from 15 to 90 cm and varied in size composition by area and depth (Fig. 15) Yano (1995) from his study off Greenland showed that near term embryos were 16-19 cm in length corresponding with the smallest (new born) juveniles that he observed off west Greenland. The smallest mode of (15-30 cm) fish in our study area occurred almost exclusively in the Laurentian Channel. This young of the year (YOY) mode was observed primarily at depths <600 m in the Laurentian Channel. A small number of these <30 cm fish were also observed on the slope in 401-600 m (Fig. 15) but in close proximity to the outer extent of the Laurentian Channel. As well, there is a substantial proportion of mature females in the shallowest portion of the Laurentian Channel. Thus, it appears that the Laurentian Channel is a pupping ground for this species in the northwest Atlantic.

Most of the older juveniles (30-60 cm fish, see Yano 1995 for a description of maturity) were also concentrated in the Laurentian Channel and to a lesser extent the southern portion (Grand Banks portion) of the slope in shallower (<800 m) depths. Male and female adults, with the exception of the mature females in the shallow part of the Laurentian Channel were distributed along the slope, mainly in depths between 400 and 1 000 m.

Thus, it appears that black dogfish in Canadian waters have a highly structured distribution with some separation by stage. Distributional evidence indicates that large (pregnant) females migrate to the shallow (<400 m) portion of the Laurentian Channel where pupping occurs (Fig. 16b). The young then move into deeper waters of the channel. As they mature they move out of the channel and onto the slope waters, apparently moving great distances to the north from the Grand Banks to the Labrador Shelf. As they grow they move into deeper waters of the slope.

The exception to the pattern described above pertains to the area west of Greenland, north of Lat 63°. There, juveniles of all sizes were found in the slope waters (Fig. 15a, lower right panel), distributing in a manner described by Yano (1995). The sizes of fish there was quite different compared to the slope waters to the south off Canada suggesting that black dogfish off Greenland may be a different stock even though the distribution is continuous between the two areas.

Based on these observations, it is expected that most of the fish that would be captured in the fisheries in the NRA slope waters would be large juveniles or adults. Samples from the Russian Greenland halibut fishery in the NRA contained black dogfish in the range of 45-77 cm, a mix of older juveniles and adults (Fig. 15 b).

Mortality due to fishing has been estimated for black dogfish in Canadian waters. There is no directed fishery in the area but black dogfish are taken incidentally in a number of fisheries, primarily in Greenland halibut (Div. 2G to 3O), crab (pots) in 2J to 3Ps, halibut, redfish, monkfish and witch (Div. 3NOP) fisheries. Removals averaged 68 t annually between 1996 and 2005 (Table 4, Fig. 10). No data are available form the NRA but it is expected that bycatch there would be significant as this species overlaps with the Greenland halibut fishing grounds.

Other Small Sharks

Other species of small demersal sharks in Canadian waters are far less common than spiny and black dogfish. Bathydemersal species are deepsea cat shark (Fig. 16), Portuguese shark and rough sagre (Fig. 17). One shelf species, smooth dogfish is very rarely encountered in the trawl surveys of the Grand Banks (one record comprising two fish). A summary of depths, temperature range and areas captured is given in Table 1.

The deepsea cat shark was the most widespread of the three bathydemersal species, continuously distributed in slope waters from the southern Grand Banks north to Lat 55° on the Labrador Shelf, with occasional records north of this latitude (Fig. 16). A total of 900 individuals were recorded in 405 sets (from 80 704 survey sets prosecuted from 1947-2005). Many of the larger catches were observed along the western slope of the Grand Banks and Flemish Pass in the NRA and thus, this are may be at or near the centre of (north-south) distribution for the species. Depth range of encounters was 132-1685 m (the deepest depth surveyed). However, 83.7% of the captures occurred at depths >1 000 m (Table 2). The increasing abundance with depth out to the maximum depth sampled suggest that a significant proportion of the population of this species, likely >50% occurs at depths greater than the area surveyed (Fig. 5). Deepsea cat shark occurred in a very narrow range of bottom temperatures; 96% of individuals captured occurred where the bottom temperature was between 3 and 5°C (Fig. 6). Only 1.7% of the specimens were taken in >5°C.

Deepsea cat shark have also been recorded occasionally in USA Atlantic waters (Bigelow and Schroeder 1948, Compagno 1984). The IUCN designation for this species is "data deficient" and the species summary notes that "This species is known with certainty only from the holotype, a 51 cm TL adolescent male caught on the continental slope off Delaware Bay at 1 492 m depth. Nominal records at 1 300-1 600 m depth in the Eastern Atlantic (are possibly *A. manis*)". Scott and Scott (1988) also note some uncertainty in the taxonomy of this genus. The 900 specimens reported here, based on identifications made by Fisheries and Oceans scientific and technical staff at sea represent the by far largest sample of this species. This relatively large sample size may be a result of the great depths regularly surveyed compared to other areas of the northwest Atlantic. The distribution of this previously rarely reported species in the NRA suggests that it may constitute a significant bycatch in the Greenland halibut fishery prosecuted along the slope within the depth range where the species was observed.

The Portuguese shark is uncommonly encountered in Canadian waters. Only 155 specimens from 47 sets were recorded from 80 704 NL survey sets, 1947-2005 (Table 1). Depth of catch was 904-1 975 m (Fig. 5). Maximum depth recorded globally for the species globally is 3 675 m (Fishbase) therefore it is likely more abundant in the Canadian Atlantic at depths exceeding the locations surveyed. This species is globally distributed and far more abundant is other areas. In the northeast Atlantic and parts of the Pacific, they are targeted commercially and have been designated as "Near threatened" by IUCN (Baillie *et al.*, 2004; ICES, 2005).

The great lantern shark or rough sagre is rare in Canadian waters. Only 12 specimens have been encountered in 3 sets at depths between 549 and 1426 m (Table 1). It is far more common in the northeast Atlantic and in the south Pacific where they are part of a commercially exploited deep water shark complex (ICES 2005).

Smooth dogfish is shallow water warm-temperate vagrant with only a single record from the Grand Banks. It is largely distributed south of Cape Cod, USA and off South America (Bigelow and Schroeder, 2003).

Conclusions

With the exception of spiny and black dogfish, species of small sharks are relatively uncommon and of no little or commercial value in Canadian waters in comparison to the northeast Atlantic at least 13 bathydemersal and at least 2 shelf species are taken in substantial amounts in a variety mixed or directed fisheries. This catch, which is often poorly reported is a conservation concern to ICES and NEAF.

With the exception of spiny dogfish, none of the species in the northwest Atlantic are of commercial value although they are taken as bycatch in a wide range of demersal fisheries. Spiny dogfish are at the extreme fringe of their distribution in the NRA. Conservation concerns for this species relate to fisheries farther to the south, on the Scotian Shelf, Georges Bank and mid-Atlantic Bight where the species is the basis for a substantial directed fishery. Only black dogfish are common and taken in substantial numbers a bycatch in the Greenland halibut fishery within Canadian waters. As yet not quantified, incidental catch in the NRA may be substantial. However, recent population trends of adults of this species have been stable.

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Table 1. Number of specimens captured, NAFO Divisions, depth range and temperature range for six species of small shark from the Grand Banks to Arctic waters (NL demersal trawl surveys).

Common name	**# specimens (sets) observed**	**NAFO Divisions**	**Depth range (m)**	**Temperature range (deg. C)**
Black dogfish	190,384 (2597)	0B to 5Z	71-1504	-1.0-8.7
Spiny dogfish	11,524 (656)	0B to 5Z	57-896	-0.9-10.5
Deepsea cat shark	900 (405)	0B to 4V, 5Z	132-1685	2.9-13.8
Portuguese shark	115 (47)	2H to 3O, 4W, 5Z	904-1975	2.5-4.9
Rough sagre	12 (3)	3K, 43X, 5Z	549-1426	3.4-4.3
Smooth dogfish	2 (1)	3O	620	4.1

Table 2. Proportion of fish captured in the NL trawl surveys (1971-2005) in various depth and temperature ranges for six species of small shark.

Range	**Spiny dogfish**	**Black dogfish**	**Deepsea cat shark**	**Portuguese shark**	**Rough sagre**	**Smooth dogfish**
% of individuals in 500-1000 m	0.1%	4.7%	14.6%	90.5%	41.7%	100.0%
% of individuals in depths > 1000	0.0%	2.0%	83.7%	4.8%	58.3%	0.0%
% of individuals in depths > 500 m	0.1%	6.7%	98.3%	95.2%	100.0%	100.0%
% of individuals in 3.8-4.9^{O} C	3.0%	29.8%	10.2%	7.32%	75.0%	100.0%
% of individuals in > 5^{O} C	91.4%	60.0%	1.7%	0.00%	0.0%	0.0%
% of individuals in 3.8^{O} C	94.4%	89.8%	11.8%	7.3%	75.0%	100.0%

Table 3a. Spatial extent and relative abundance of spiny dogfish on the Grand Banks with respect to the NRA.

Year	Area Occupied (sq km)	Area inside 200 mi limit (sq km)	Area outside 200 mi limit (sq km)	% of extent in the NRA	% of abundance in the NRA
1996	56,727	49,357	7,370	13.0%	0.3%
1997	34,520	32,719	1,801	5.2%	0.0%
1998	26,942	19,994	6,948	25.8%	1.0%
1999	27,443	23,846	3,597	13.1%	0.1%
2000	31,599	27,991	3,608	11.4%	0.2%
2001	18,385	17,191	1,194	6.5%	0.0%
2002	18,687	16,886	1,801	9.6%	0.1%
2003	12,216	10,414	1,802	14.8%	0.6%
2004	12,108	12,108	0	0.0%	0.0%
2005	10,680	10,680	0	0.0%	0.0%
Avg	24,931	22,119	2,812	9.94%	0.22%

Table 3b. Spatial extent and relative abundance of black dogfish on the Grand Banks with respect to the NRA.

Year	Area Occupied (sq km)	Area inside 200 mi limit (sq km)	Area outside 200 mi limit (sq km)	% of extent in the NRA	% of abundance in the NRA
1996	73,925	49,002	24,923	33.7%	0.4%
1997	65,636	44,135	21,501	32.8%	0.3%
1998	81,872	46,848	35,024	42.8%	0.7%
1999	64,741	43,903	20,838	32.2%	0.2%
2000	92,155	40,448	51,707	56.1%	6.0%
2001	75,331	40,448	34,883	46.3%	0.7%
2002	87,913	46,886	41,027	46.7%	1.3%
2003	30,554	29,035	1,519	5.0%	1.5%
2004	51,371	27,620	23,751	46.2%	0.6%
2005	61,196	40,959	20,237	33.1%	0.6%
Avg	68,469	40,928	27,541	37.48%	1.23%

Table 4a. Commercial bycatches of spiny dogfish and black dogfish in Canadian fisheries on the Grand Banks, 1996 to 2005.

	Observed Catch (t)		Total Estimated Catch (t)	
Year	Black Dogfish	Spiny Dogfish	Black Dogfish	Spiny Dogfish
1996				
1997				
1998	8.822	1.178	52.939	9.453
1999	8.868	0.084	115.130	1.313
2000	42.166	3.733	74.258	24.710
2001	18.853	0.995	75.760	6.429
2002	21.933	0.461	50.000	10.000
2003	15.168	0.823	44.417	7.752
2004	42.816	4.281	86.930	42.521
2005	17.131	1.382	40.822	7.383
2006				
2007				
Average	21.970	1.617	67.532	13.695

Table 4b. Commercial bycatches of spiny dogfish in Canadian fisheries on the Grand Banks, 1996 to 2005 by fishery.

Year	Fishery (Directed Species, Gear, Vessel Class, Area)	Estimated Spiny dogfish Bycatch (t)	% Annual Total
1998	Cod Gillnet 1-3 3Ps	2.7	28%
	Atlantic_Halibut Longline 1-3 3Pn	1.7	18%
	Shrimp Shrimp Trawl 1-3 2J3K	1.6	17%
	Crab Pot 1-3 3LNOPs	1.2	13%
	Greenland_Halibut Gillnet 4-7 north	1.0	11%
	All Others	1.3	13%
	All 1998	9.5	100%
1999	Crab Pot 1-3 3LNOPs	0.5	40%
	Cod Gillnet 1-3 3Ps	0.4	30%
	Skate Gillnet 1-3 3LNOPs	0.2	16%
	All Others	0.2	14%
	All 1999	1.3	100%
2000	Atlantic_Halibut Longline 1-3 3LNOPs	7.6	31%
	Scallop Dredge 1-3 3LNOPs	5.9	24%
	Cod Longline 1-3 3Ps	4.9	20%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	2.4	10%
	All Others	3.8	15%
	All 2000	24.7	100%
2001	Crab Pot 1-3 3LNOPs	3.0	46%
	Redfish_Seb.Sp. Gillnet 1-3 3LNOPs	1.7	27%
	Cod Gillnet 1-3 3Ps	1.4	22%
	All Others	0.3	5%
	All 2001	6.4	100%
2002	Redfish_Seb.Sp. Gillnet 1-3 3LNOPs	1.2	57%
	White_Hake Longline 1-3 3LNOPs	0.4	17%
	White_Hake Gillnet 1-3 3LNOPs	0.2	10%
	All Others	0.3	16%
	All 2002	2.1	100%
2003	Crab Pot 1-3 3LNOPs	3.8	49%
	Shrimp Shrimp Trawl 1-3 3LNOPs	1.2	16%
	Monkfish Gillnet 1-3 3LNOPs	0.7	9%
	Cod Gillnet 1-3 3Ps	0.6	8%
	All Others	1.4	18%
	All 2003	7.8	100%
2004	White_Hake Gillnet 1-3 3LNOPs	18.6	44%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	16.8	39%
	Cod Gillnet 1-3 3Ps	3.3	8%
	All Others	3.9	9%
	All 2004	42.5	100%
2005	Cod Gillnet 1-3 3Ps	6.3	85%
	White_Hake Gillnet 1-3 3LNOPs	0.6	8%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	0.3	4%
	All Others	0.5	7%
	All 2005	7.4	100%

Table 4c. Commercial bycatches of black dogfish in Canadian fisheries on the Grand Banks, 1996 to 2005 by fishery.

Year	Fishery (Directed Species, Gear, Vessel Class, Area)	Estimated Black dogfish Bycatch (t)	% Annual Total
1998	Greenland_Halibut Gillnet 4-7 north	16.8	32%
	Crab Pot 1-3 2J3K	12.0	23%
	Greenland_Halibut Gillnet 1-3 2J3K	5.5	10%
	Crab Pot 1-3 3LNOPs	3.8	7%
	Shrimp Shrimp Trawl 1-3 2J3K	3.4	6%
	All Others	11.4	22%
	All 1998	52.9	100%
1999	White_Hake Longline 1-3 3LNOPs	37.8	33%
	Crab Pot 1-3 2J3K	36.4	32%
	Crab Pot 1-3 3LNOPs	20.4	18%
	All Others	20.5	18%
	All 1999	115.1	100%
2000	Greenland_Halibut Gillnet 4-7 3LNOPs	19.9	27%
	Crab Pot 1-3 2J3K	17.9	24%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	12.8	17%
	Crab Pot 1-3 3LNOPs	7.5	10%
	All Others	16.1	22%
	All 2000	74.1	100%
2001	Greenland_Halibut Gillnet 1-3 3LNOPs	15.6	22%
	Greenland_Halibut Gillnet 4-7 3LNOPs	11.7	16%
	Greenland_Halibut Gillnet 1-3 2J3K	11.3	16%
	Crab Pot 1-3 3LNOPs	10.6	15%
	Greenland_Halibut Gillnet 1-3 north	7.5	10%
	All Others	15.0	21%
	All 2001	71.7	100%
2002	Greenland_Halibut Gillnet 1-3 2J3K	19.5	28%
	Crab Pot 1-3 3LNOPs	12.7	18%
	Shrimp Shrimp Trawl 4-7 3M	7.8	11%
	Crab Pot 4-7 3LNOPs	6.3	9%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	4.7	7%
	Greenland_Halibut Otter Trawl 4-7 2J3K	3.0	4%
	Greenland_Halibut Gillnet 4-7 north	2.5	4%
	All Others	12.9	19%
	All 2002	69.5	100%
2003	Greenland_Halibut Longline 1-3 3LNOPs	9.0	20%
	Greenland_Halibut Gillnet 1-3 2J3K	8.7	20%
	Greenland_Halibut Longline 4-7 3LNOPs	7.6	17%
	Monkfish Gillnet 1-3 3LNOPs	4.2	10%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	4.2	10%
	Crab Pot 1-3 3LNOPs	2.1	5%
	All Others	8.6	19%
	All 2003	44.4	100%
2004	Shrimp Shrimp Trawl 4-7 3M	21.9	25%
	Atlantic_Halibut Longline 4-7 3LNOPs	13.9	16%
	Shrimp Shrimp Trawl 1-3 2J3K	8.4	10%
	Witch_Flounder Otter Trawl 4-7 3LNOPs	8.4	10%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	7.4	8%
	Greenland_Halibut Gillnet 1-3 3LNOPs	6.6	8%
	All Others	20.3	23%
	All 2004	86.9	100%
2005	Greenland_Halibut Longline 4-7 3LNOPs	21.8	53%
	Greenland_Halibut Otter Trawl 4-7 north	4.0	10%
	Redfish_Seb.Sp. Otter Trawl 4-7 3LNOPs	2.6	6%
	Greenland_Halibut Gillnet 4-7 2J3K	2.5	6%
	Greenland_Halibut Gillnet 4-7 north	2.4	6%
	All Others	7.6	19%
	All 2005	40.8	100%

Table 4d. Catches of dogfish reported in NAFO STATLANT, in 3LMNO, 2000-2005.

Spiny Dogfish

Year	3L	3M	3N	3O	Total
2000					0
2001	1				1
2002					0
2003	6	3	22		31
2004	5	2	1		8
2005					0
				Average	7

Dogfish ns

Year	3L	3M	3N	3O	Total
2000	107	133	152	10	402
2001	194	114	357	11	676
2002	152	91	188	43	474
2003	248	89	256	19	612
2004	145	43	157	20	365
2005	3	0	6		9
				Average	423

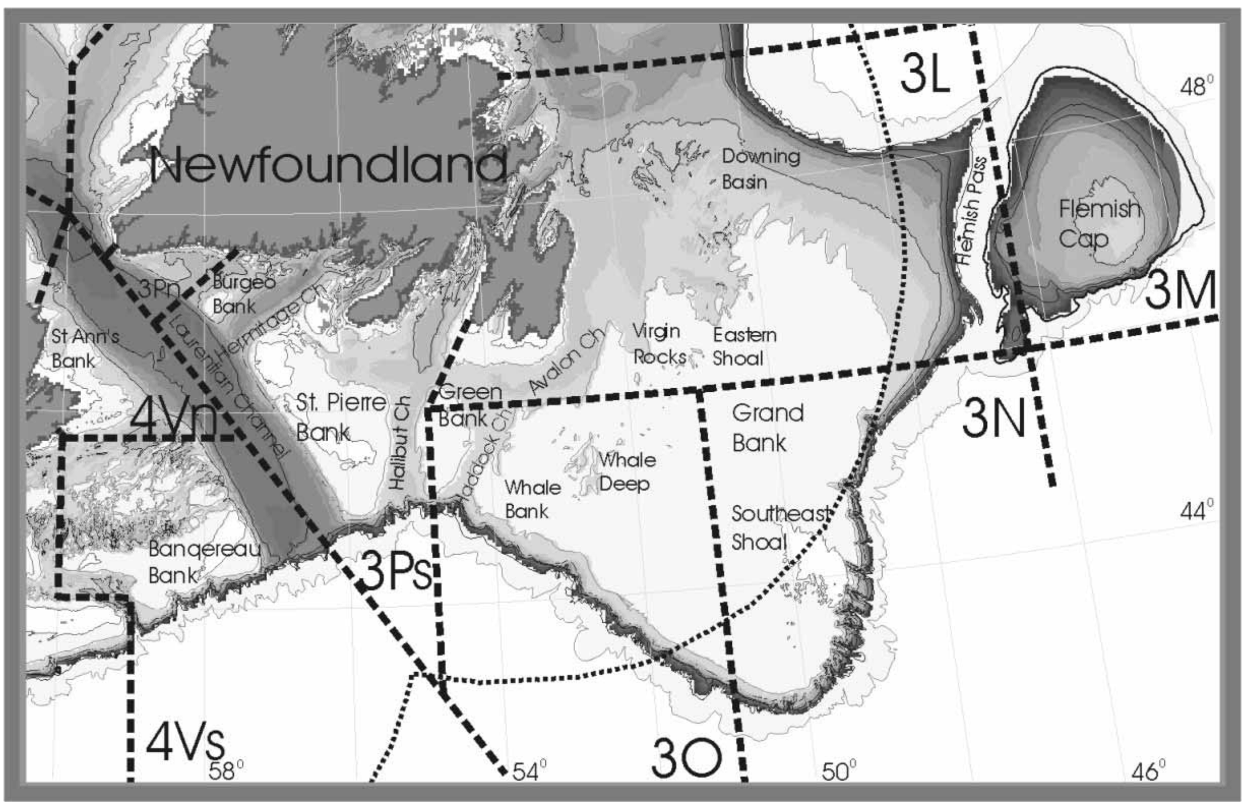

Fig. 1. Map of the Grand Banks showing various banks, basins and NAFO Divisions.

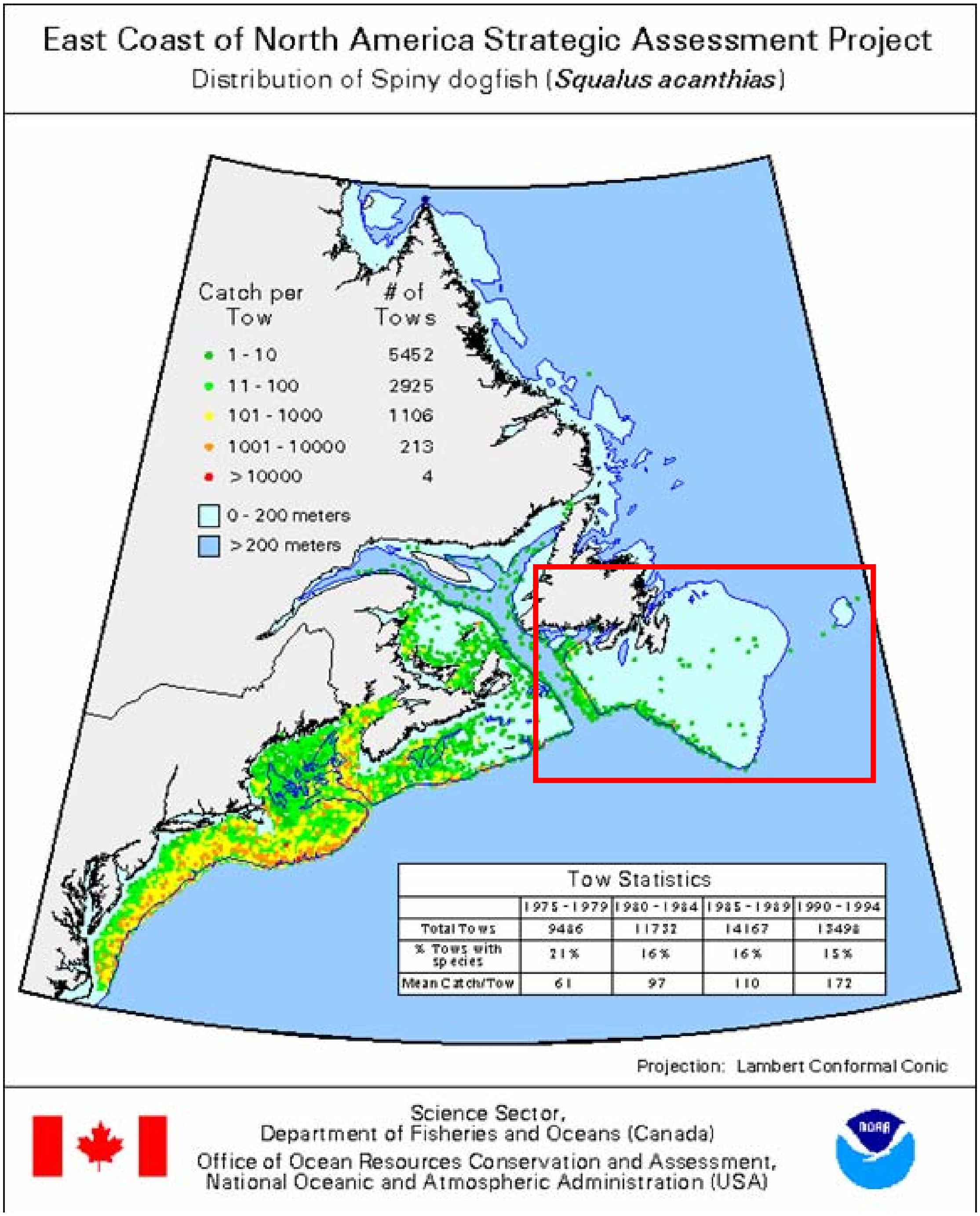

Fig. 2. East Coast of North America Strategic Assessment Project (ECNSAP) map of spiny dogfish distribution Data comprise combined, unadjusted survey data from the various regions of Canada and from the USA. Catch per tow is not directly comparable between surveys but provides an overview of the distribution of the species. Red boxed area is expanded in detail in Fig. xx.

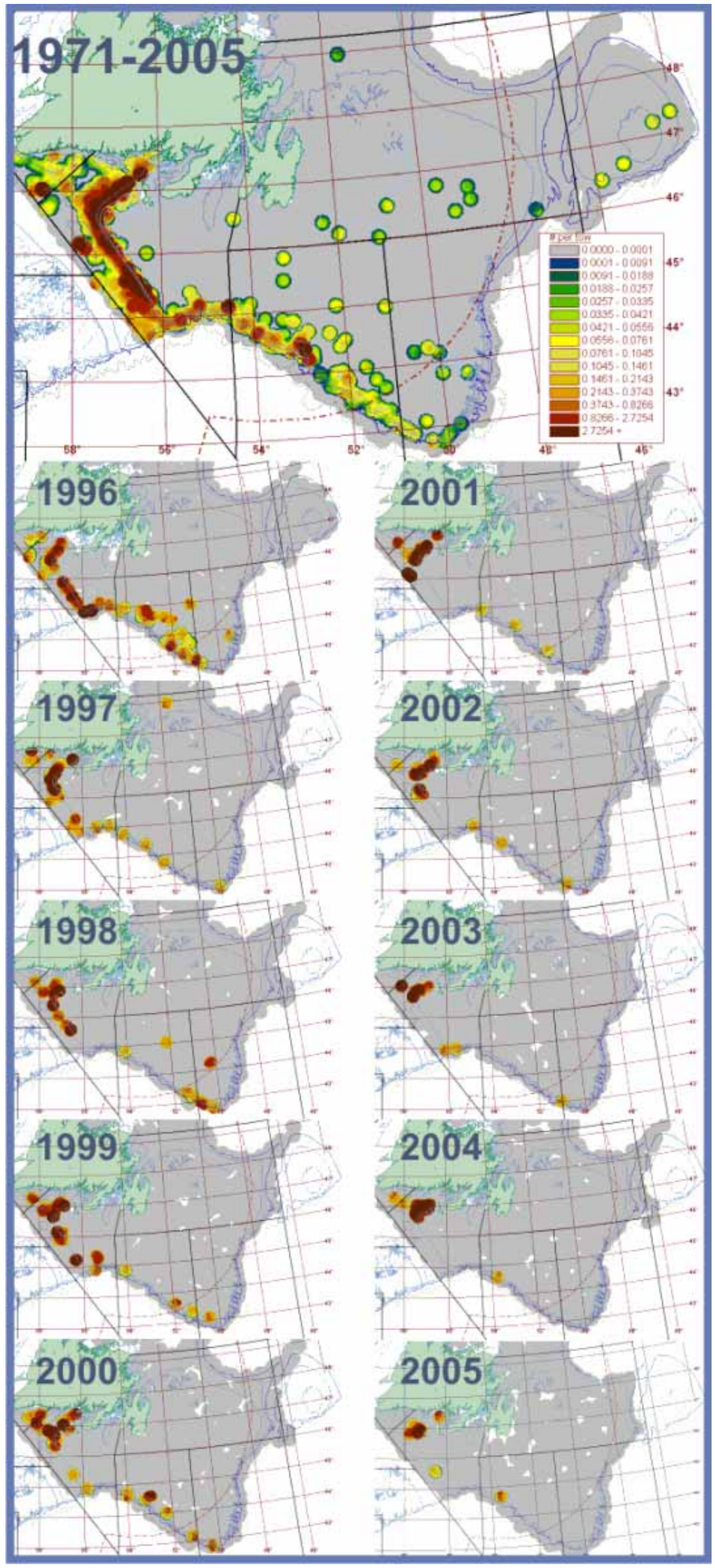

Fig. 3. Map of the distribution of spiny dogfish on the Grand Banks. Upper panel: NL trawl surveys, 1971-2005. Lower panels are recent annual maps, from 1996 to 2005.

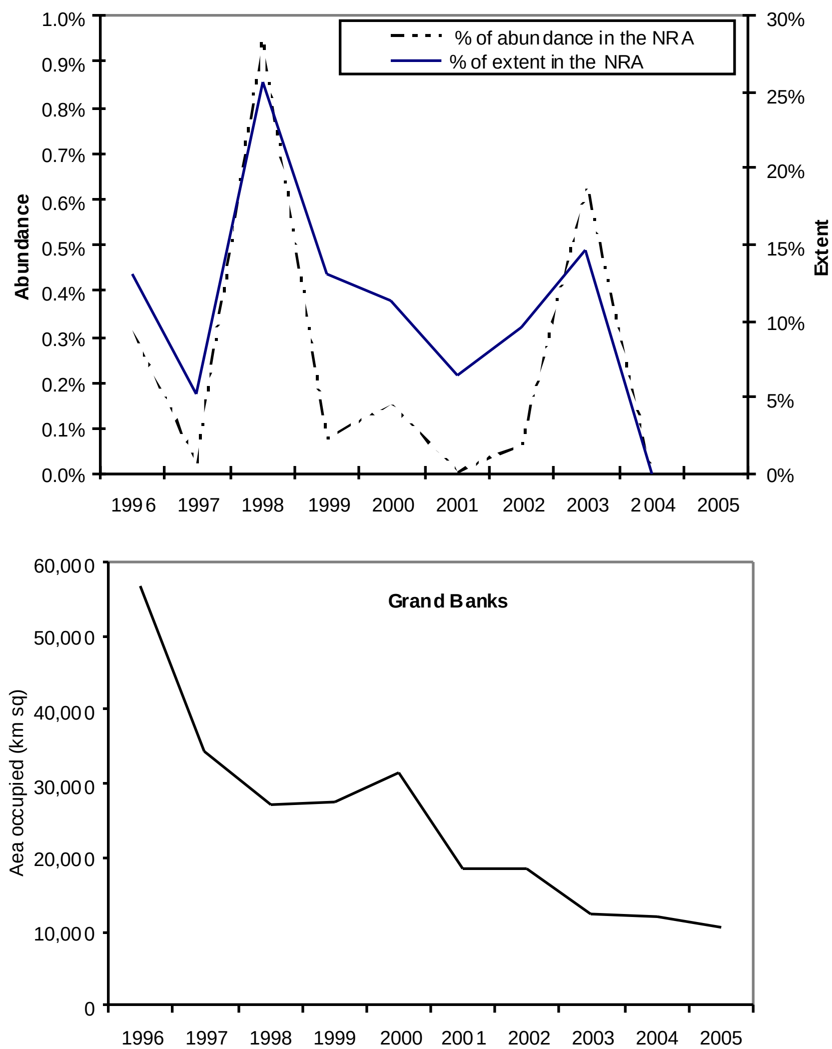

Fig. 4. Upper: Proportion of the abundance and of the area occupied (extent of distribution) of spiny dogfish on the Grand Banks (NAFO Div. 3LNOPs, see Fig. x) that is located within the NRA. Lower: Area occupied by spiny dogfish on the Grand Banks. Note that spiny dogfish on the Grand Banks are a seasonal northern fringe of a larger population located to the south.

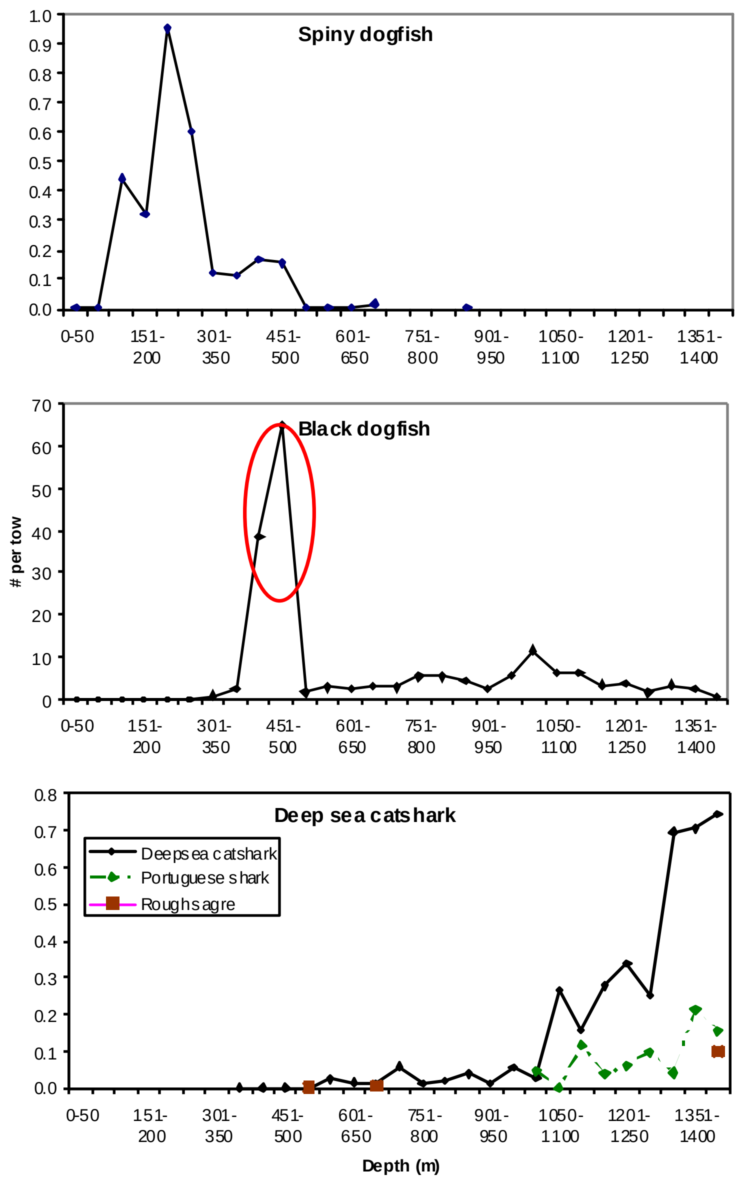

Fig. 5. Distribution of shark species by depth, Grand Banks to Labrador Shelf. Data are from NL trawl surveys, 1971-2005. The two large values within the red circle all occur in the Laurentian Channel.

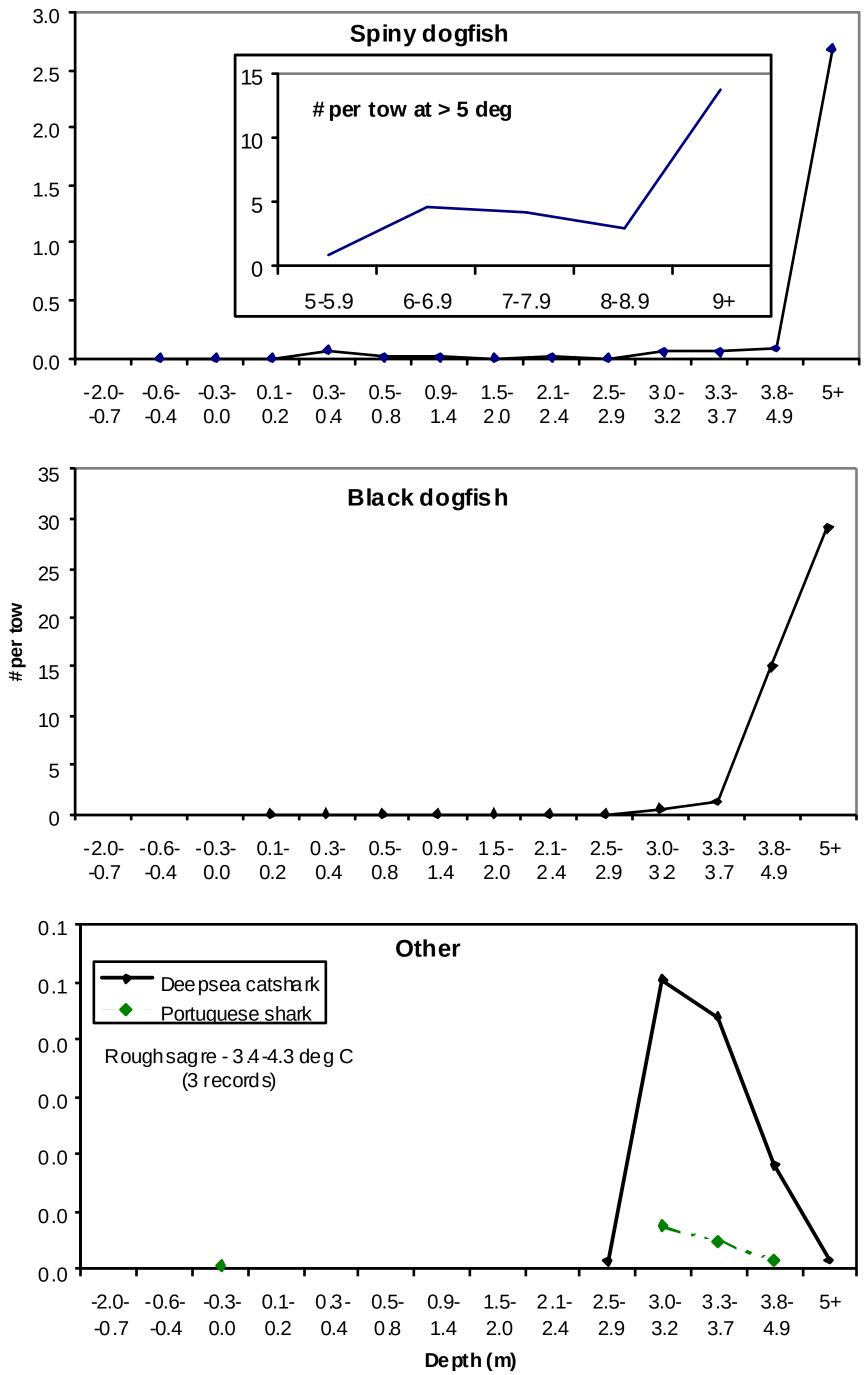

Fig. 6. Distribution of shark species with respect to bottom temperature, Grand Banks to Labrador Shelf. Data are from NL trawl surveys, 1971-2005.

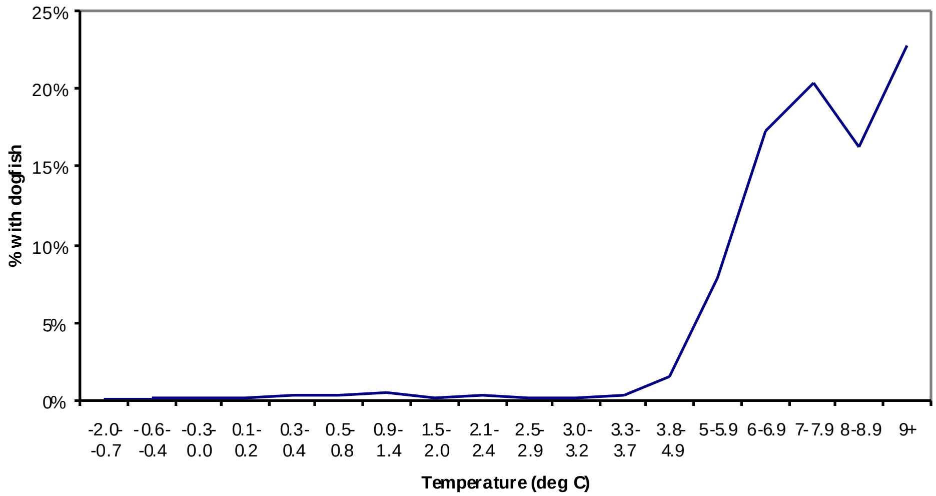

Fig. 6b. Proportion of sets containing spiny dogfish with respect to bottom temperature, Grand Banks to Labrador Shelf. Data are from NL trawl surveys, 1971-2005.

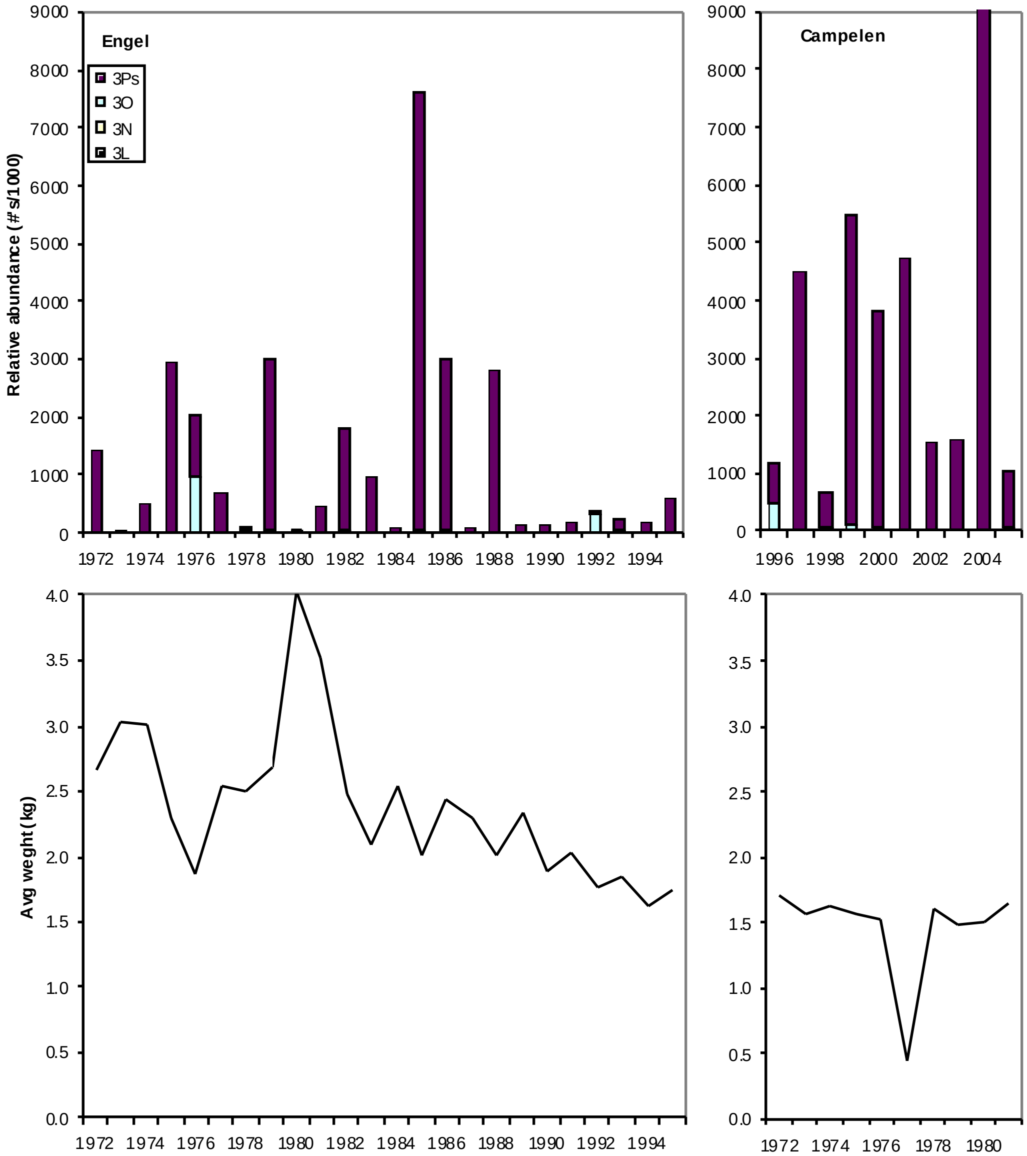

Fig. 7. Relative abundance index for spiny dogfish on the Grand Banks based on spring surveys. Engel and Campelen are independent series (not standardized) thus are illustrated in separate graphs.

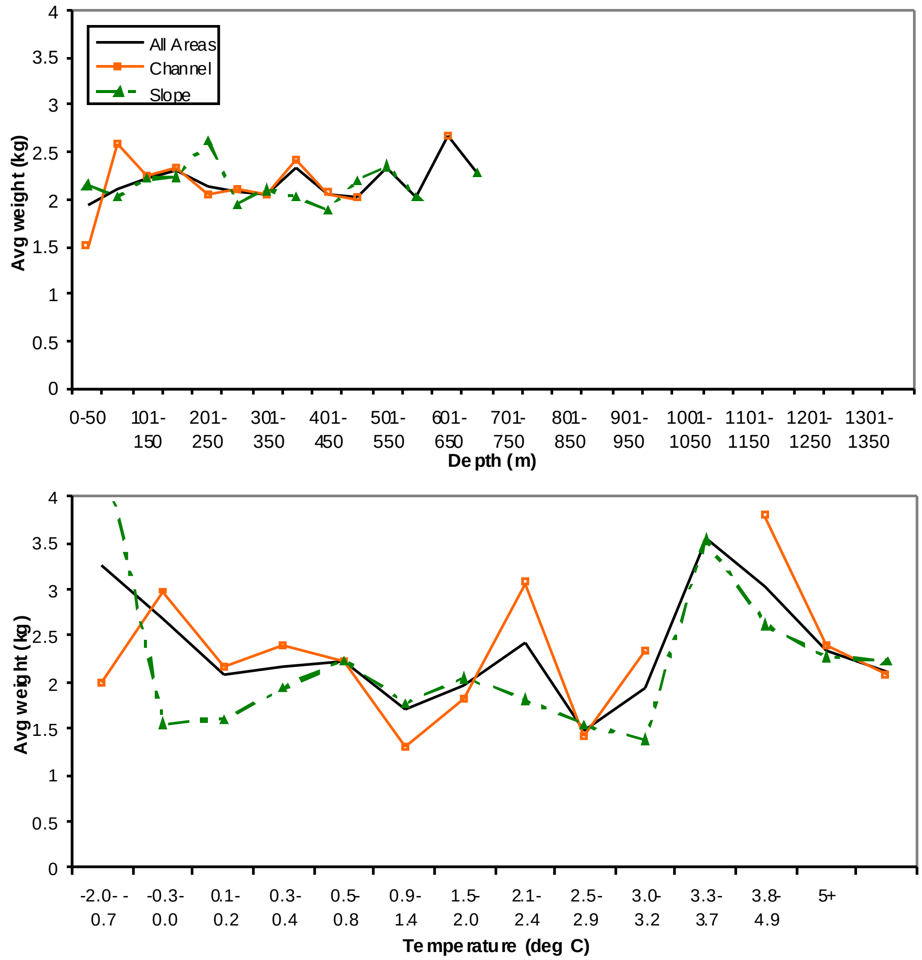

Fig. 8. Average size of spiny dogfish with respect to depth and bottom temperature based on NL survey data from 1971-2005.

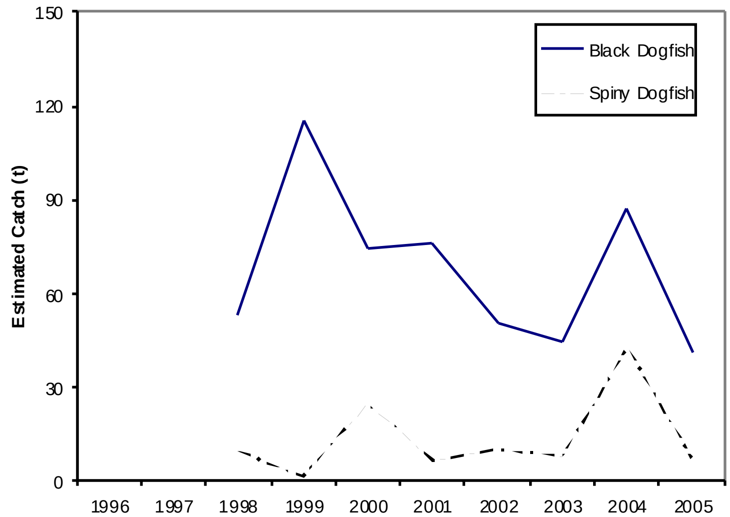

Fig. 9. Estimates of catches of spiny dogfish and black dogfish in commercial fisheries occurring on the Grand Banks, northeast Newfoundland and Labrador Shelf.

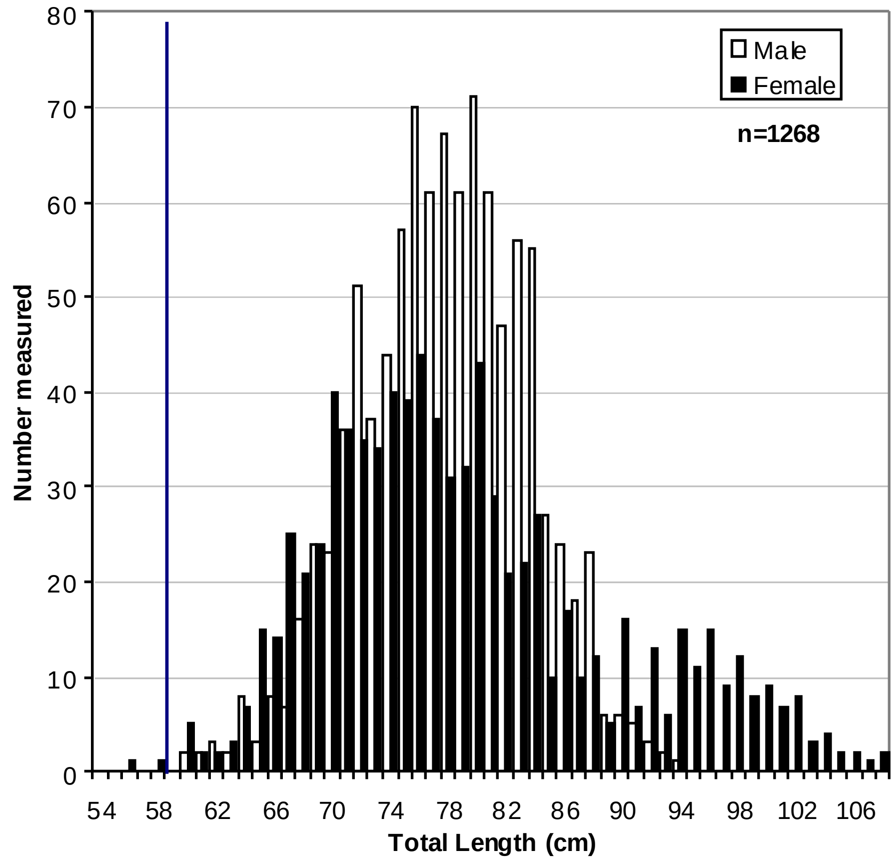

Fig. 10. Spiny dogfish measured from 1 268 sets from RV trawl surveys from 1974-2002. Most of these records come from the St. Pierre Bank (Div. 3P) where dogfish are concentrated within the study area. Samples were taken with both Engel and Campelen gear. Blue line is length at 50% maturity according to Nammack *et al*. (1985).

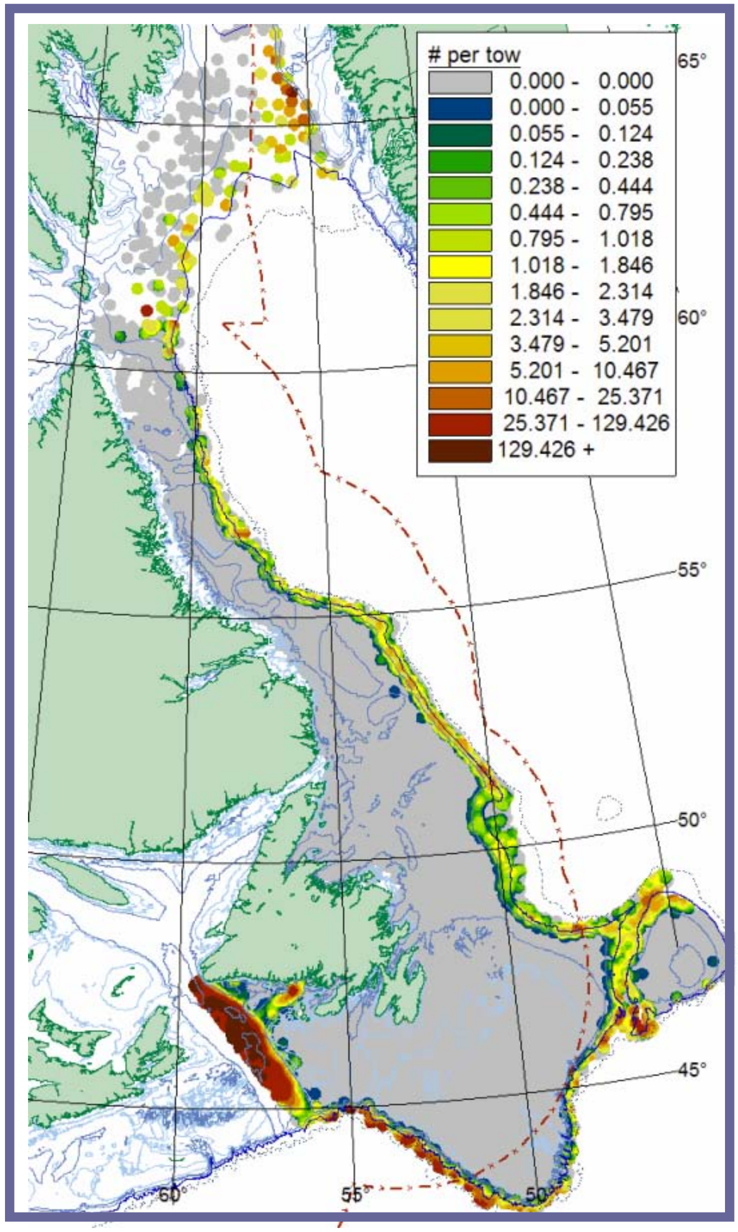

Fig. 11a. Distribution of black dogfish from the Grand Banks to Davis Strait based on NL trawl survey data from 1971-2005.

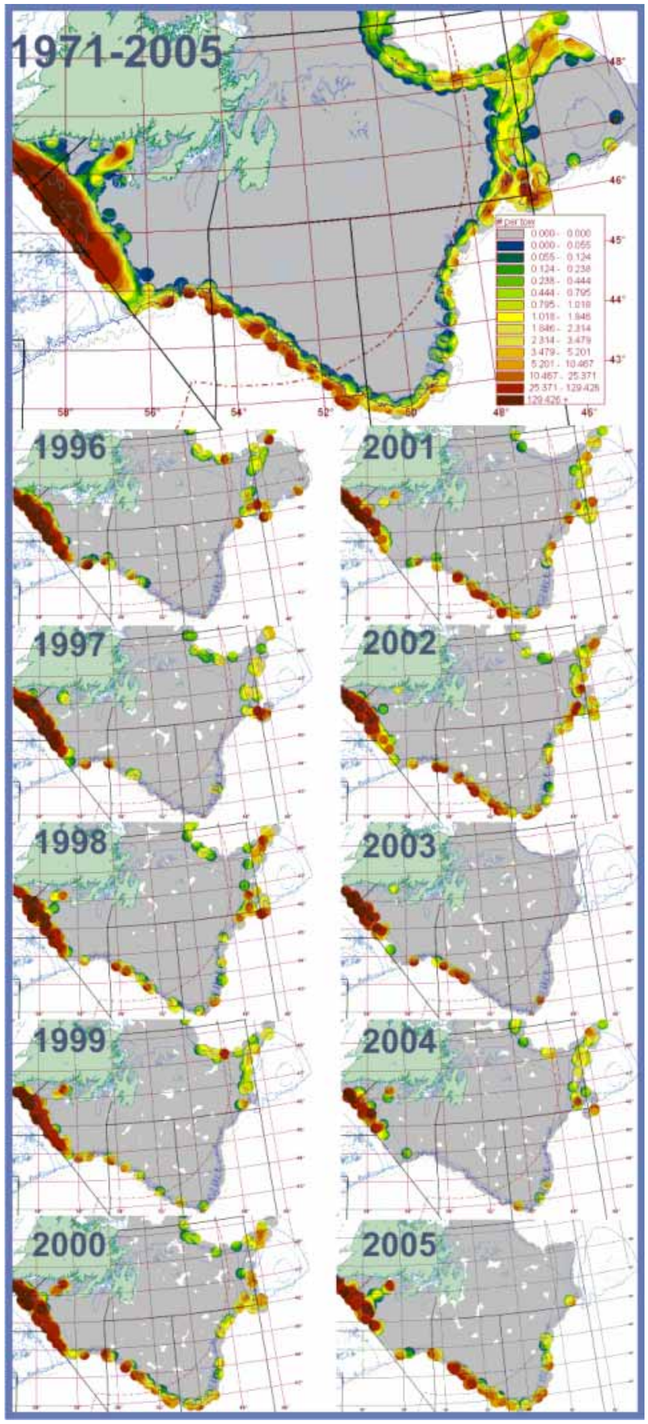

Fig. 11b. Map of the distribution of black dogfish on the Grand Banks. Upper panel: NL trawl surveys, 1971-2005. Lower panels are recent annual maps, from 1996 to 2005.

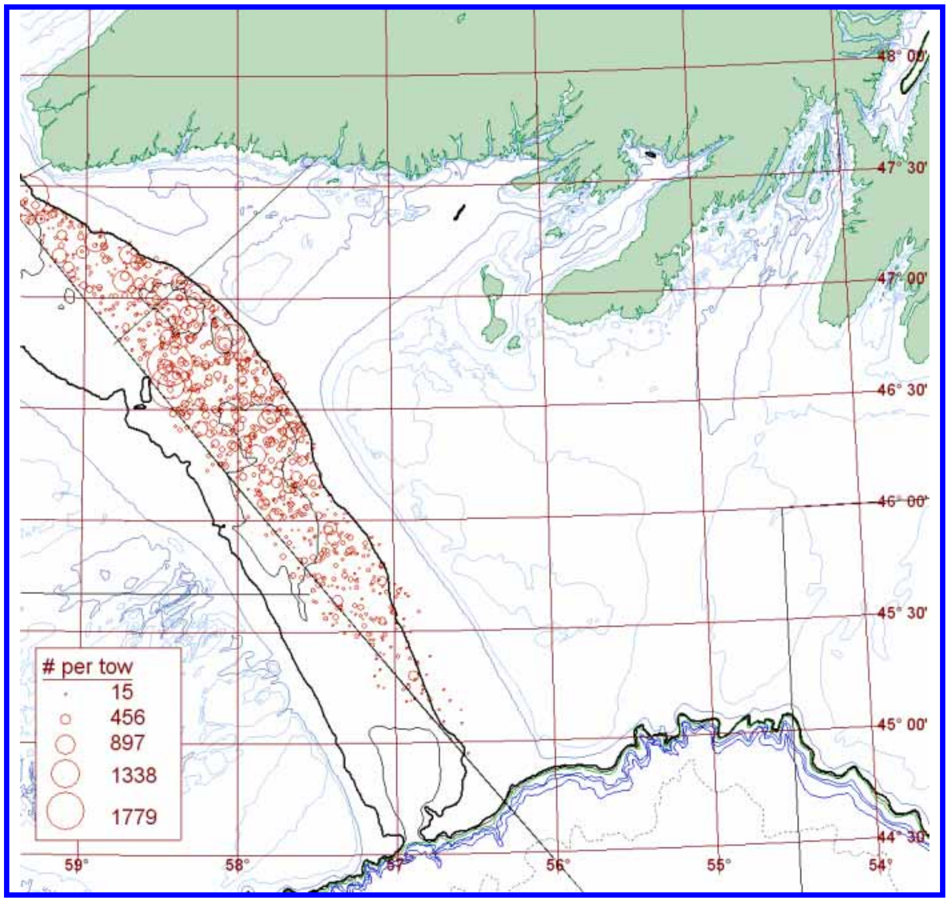

Fig. 11c. Location of all sets with large number s of black dogfish. Large sets are defined as >15 individuals per tow.

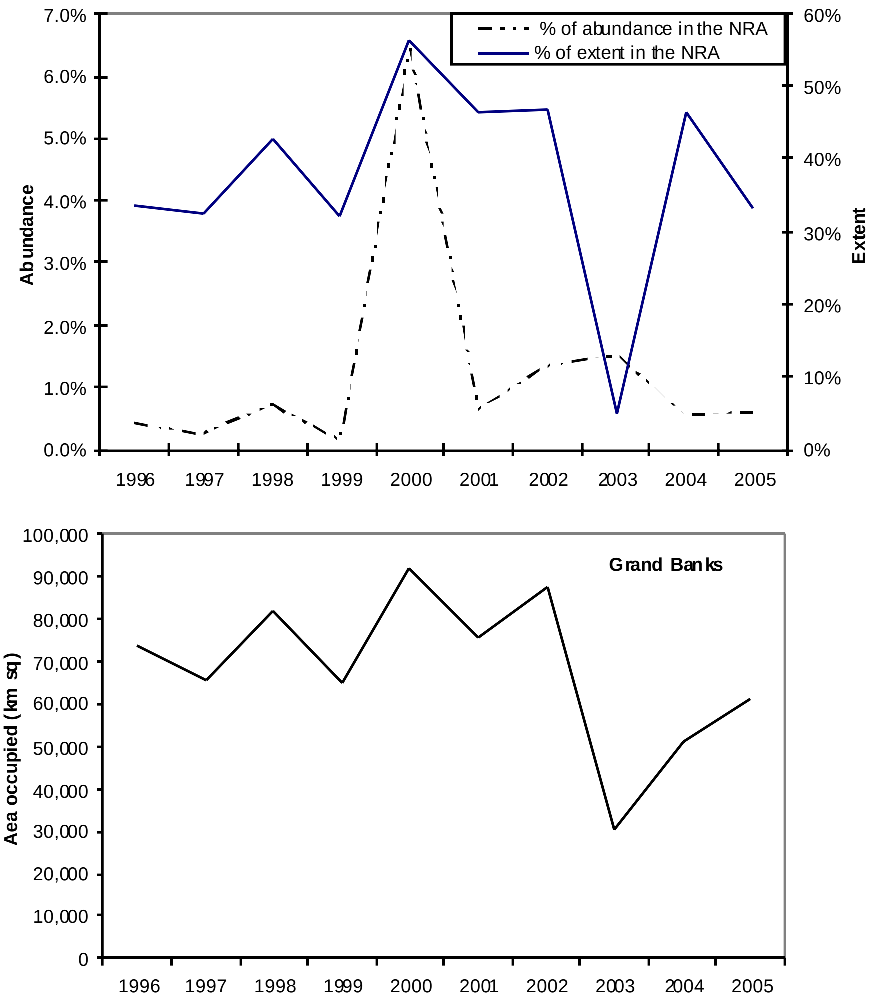

Fig. 12. Upper: Proportion of the abundance and of the area occupied (extent of distribution) of black dogfish on the Grand Banks (NAFO Div. 3LNOPs, see Fig. 10) that is located within the NRA. Lower: Area occupied by black dogfish on the Grand Banks. Note that black dogfish on the Grand Banks are a part of a larger population in Canadian waters.

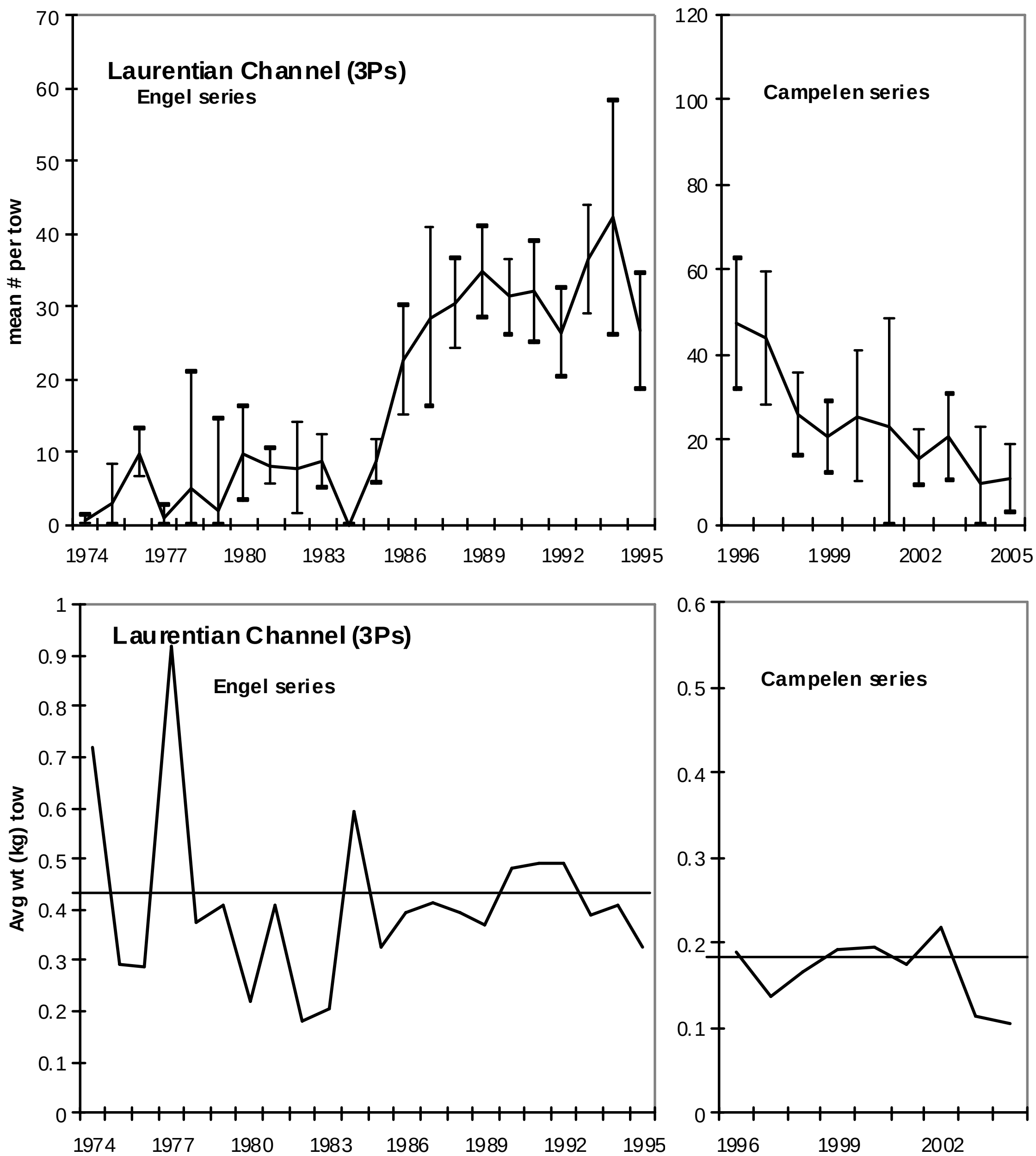

Fig. 13a. Number per tow for black dogfish on the Grand Banks based on spring surveys, with confidence intervals. Engel and Campelen are independent series (not standardized) thus are illustrated in separate graphs.

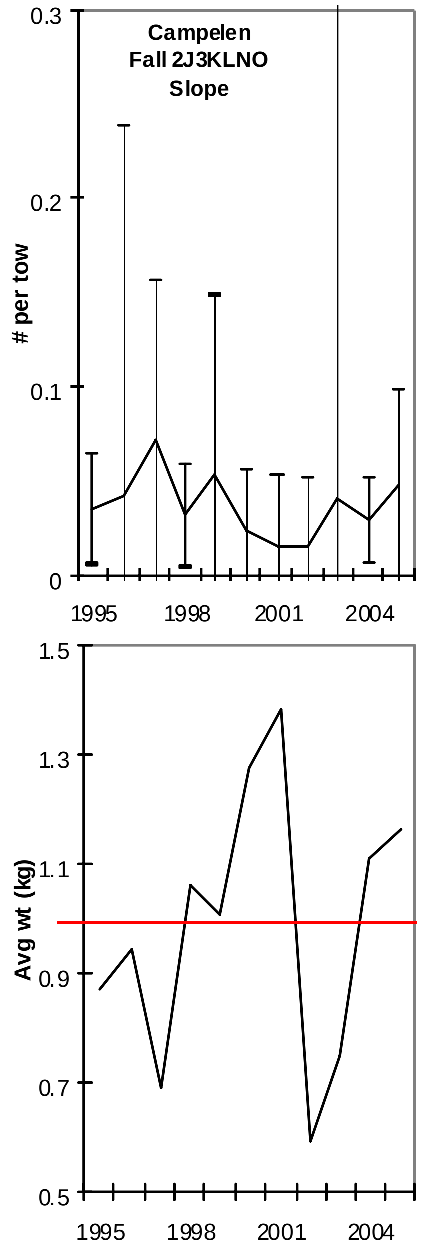

Fig. 13b. Number per tow (upper panel) and average weight (lower panel) for black dogfish on the Grand Banks based on autumn surveys.

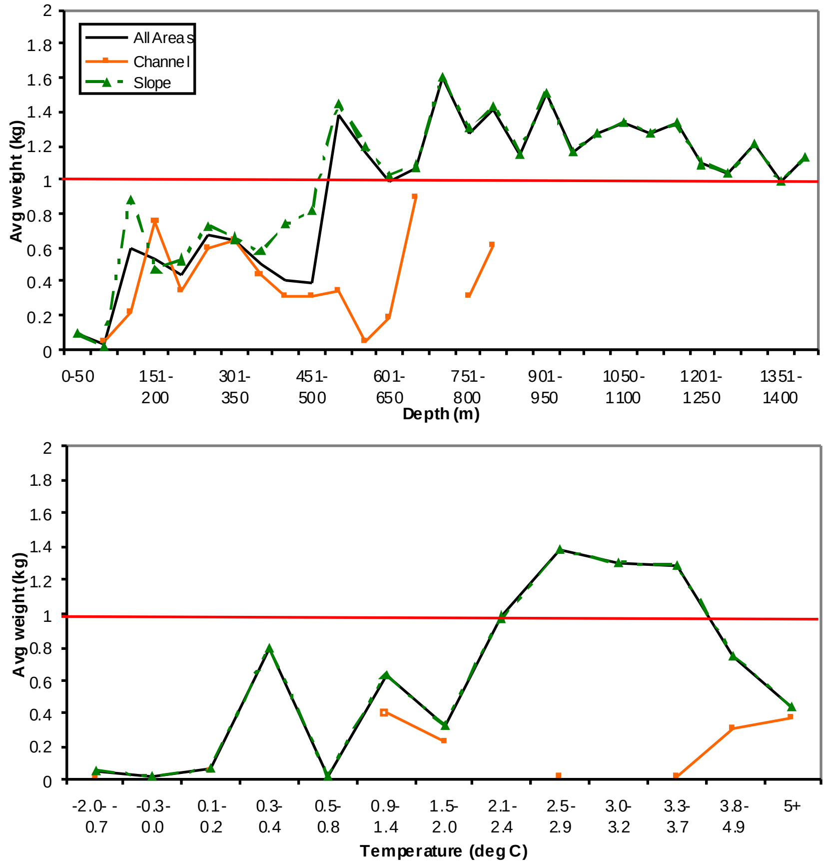

Fig. 14. Average weight of black dogfish with respect to bottom temperature and depth based on NL surveys, 1971-2005.

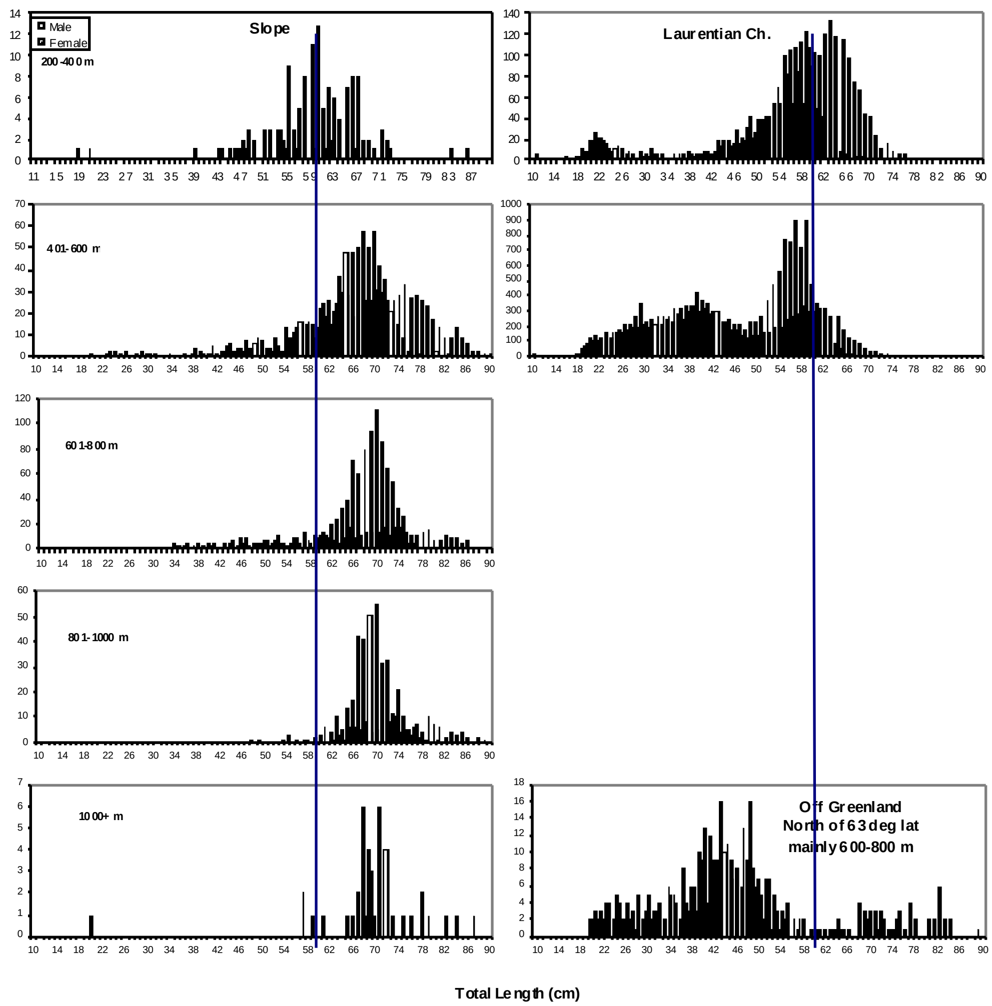

Fig. 15a. Length frequencies of black dogfish by depth intervals. Left column is fish from the slope waters from the Grand Banks to Labrador Shelf, Right column is from the Laurentian Channel. Samples were taken only with Engel gear. Blue lines are length at maturity according to Yano (1995) off Greenland.

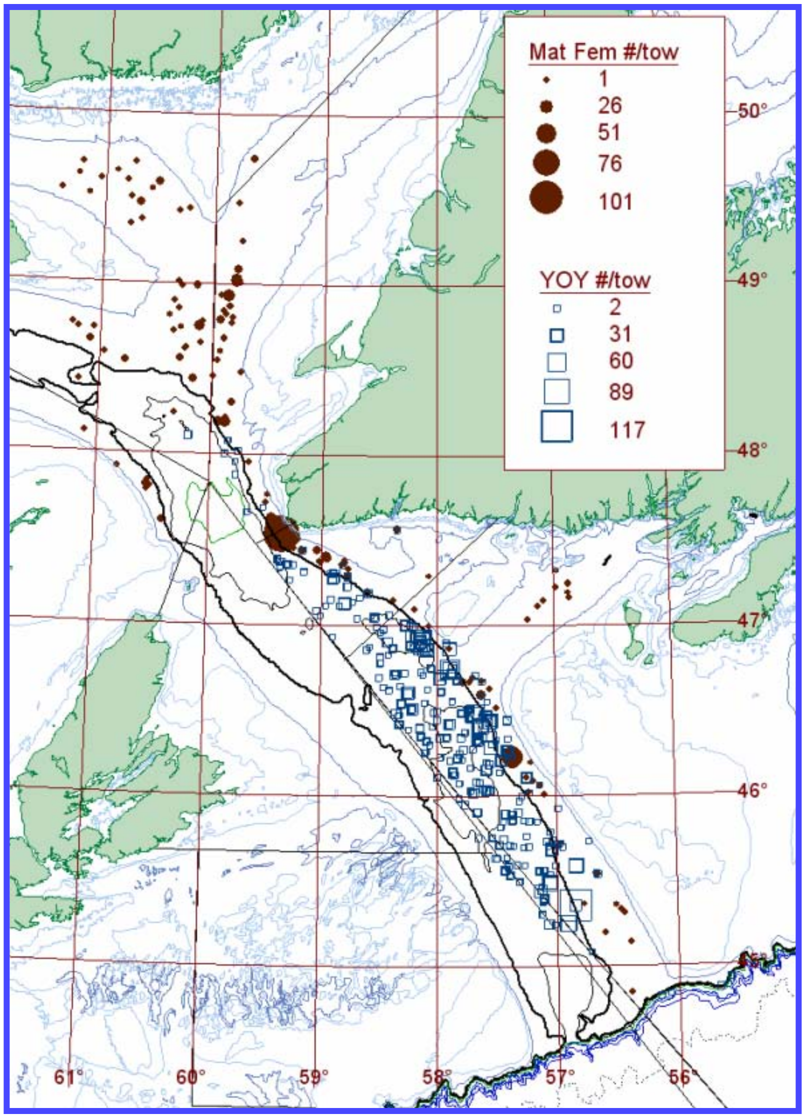

Fig. 15b. Distribution of large mature female (filled circles) and YOY (young of the year, open squares) black dogfish in Canadian waters.

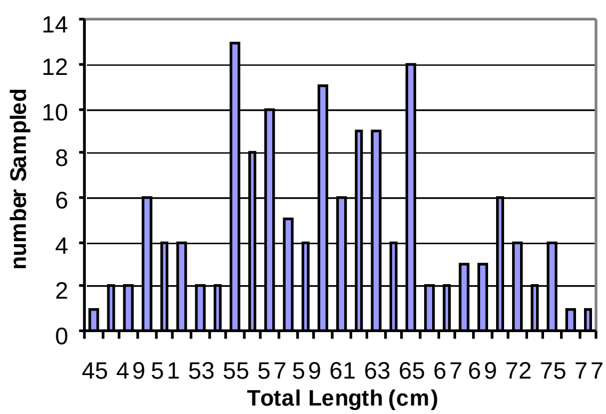

Fig. 15c. Length frequency of black dogfish taken in the Russian Greenland halibut fishery in 2005.

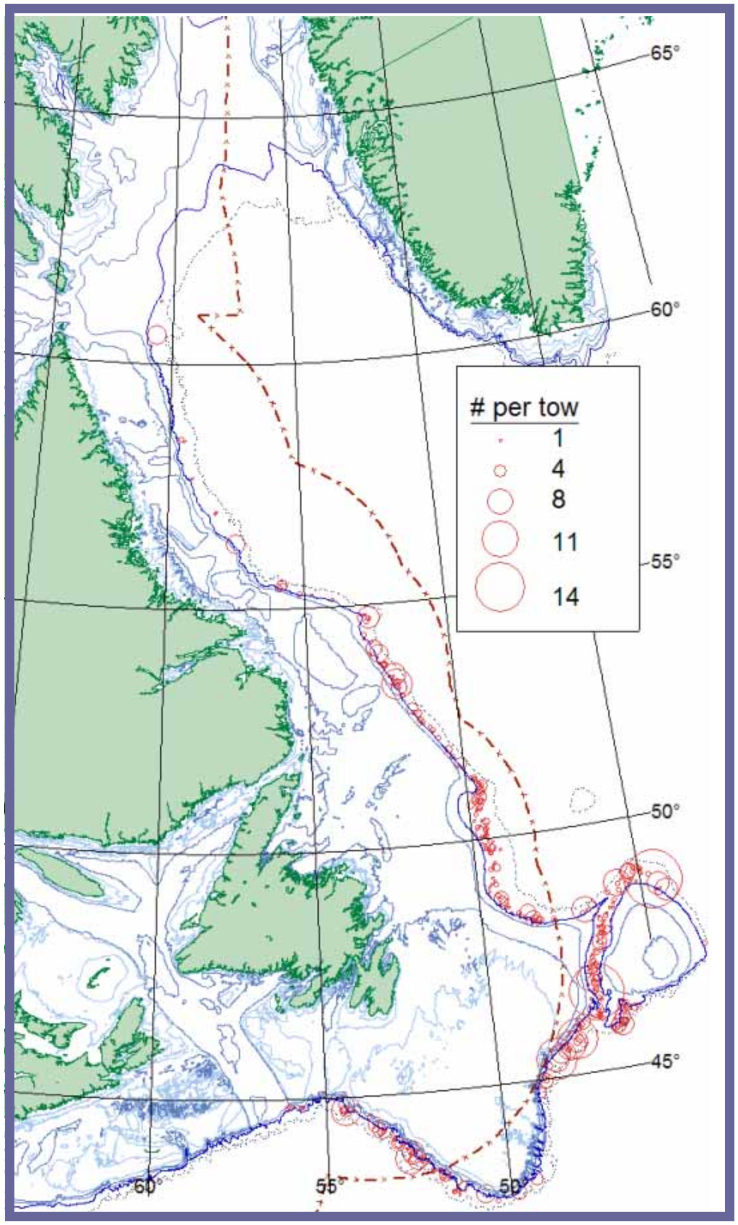

Fig. 16. Distribution of deepsea cat shark on Canadian waters based on NL demersal trawl surveys 1971-2005.

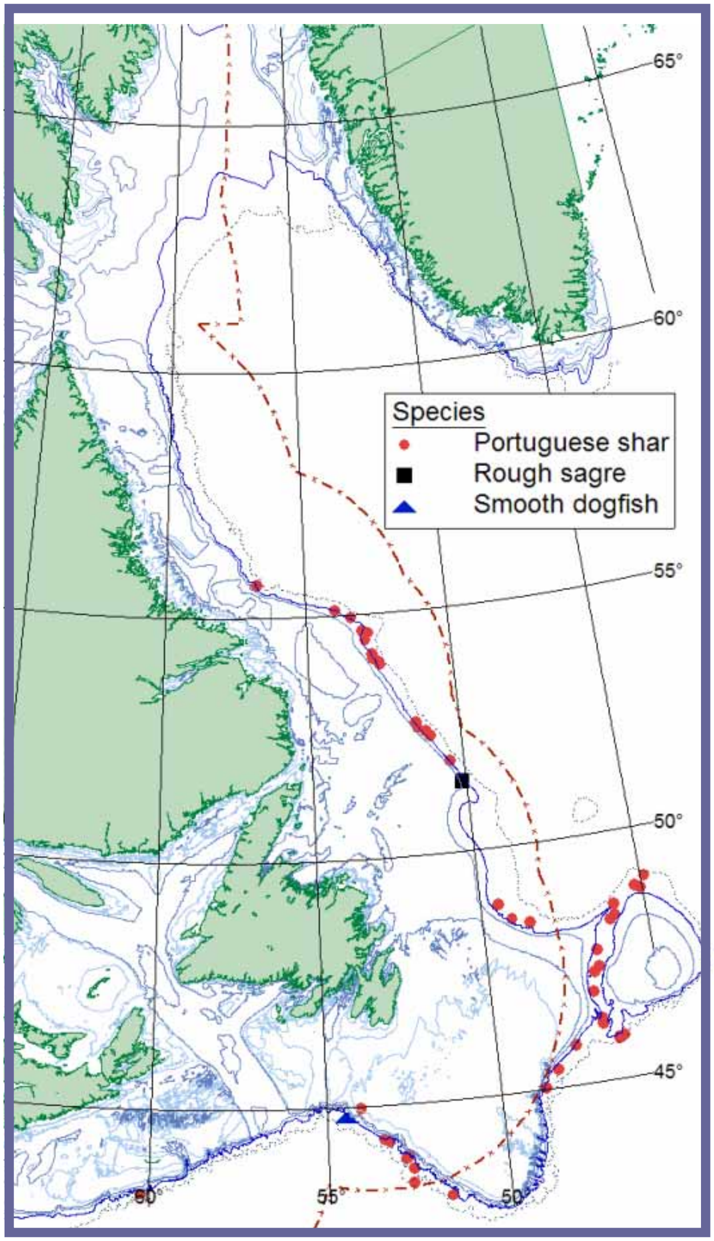

Fig. 17. Distribution of three rare species of shark in Canadian waters, Portuguese shark, rough sagre (lantern shark) and smooth dogfish based on NL demersal trawl surveys 1971-2005.