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The Status of Thorny Skate (*Amblyraja radiata* Donovan, 1808) in
NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps

by

D.W. Kulka and C.M. Miri

Department of Fisheries & Oceans Canada, Northwest Atlantic Fisheries Centre
P. O. Box 5667, St. John's, NL, Canada A1C 5X1

Abstract

This evaluation of thorny skate (*Amblyraja radiata*) represents the fourth assessment of this relatively new fishery. The stock biomass indices, following a decline to their lowest historic level in the early-1990s have stabilized since the mid-1990s. However, a change in research survey gear (in the fall of 1995) with different catch characteristics has created a discontinuity in the survey time series, thereby preventing a comparison between two periods: 1986 to 1994, and 1995 to date. The spring survey, previously used to estimate biomass and abundance, may not include a substantial portion of the population, and thus represents only the portion of the stock that occurs within the surveyed area. On average (1990-2002), fall survey estimates of biomass for the comparable area (NAFO Divisions 3LNO) were 41%. Analysis of lengths taken during research surveys have covered a consistent range since 1985, with main modes occurring at 15-32 cm and 65-83 cm in both spring and fall, the latter mode comprising mature skates. Since 1996, a single mode in the 30-60 cm range (a mix of mature and immature fish) has been observed. A recent increase in the proportion of larger skates in survey catches is noted. Since the mid-1980s, Spain, Portugal, and Russia have prosecuted a directed fishery for skate (*Raja* sp.) outside Canada's 200-mile-limit on the Tail of the Grand Banks. However, Canada only established a limited directed fishery for skate on the southwestern Grand Banks and southern St. Pierre Bank after the decline of traditionally exploited groundfish resources. Prior to 1993, skates in Canadian waters were taken only as by-catch, most of which were discarded. Reported catches of all countries combined have averaged 12 191 tons (23 948-7 626 tons) since 1985. In 2002, the (preliminary) reported catch was 9 838 tons (3 342 tons for Canada, including discards). A comparison of skate distribution from research survey data with commercial grounds indicates that the Canadian fleet fishes about one third of the area where skate are greatly aggregated in the spring, primarily along the shelf edge where skate are largest. Non-Canadian fleets fish a separate area on the Tail of the Grand Banks (outside 200 miles) in the fall, catching smaller skates.

Introduction

Skates (Family Rajidae) are commonly taken in research and commercial catches in waters off Atlantic Canada. Thirteen species of skate are found in Atlantic Canadian waters (Scott and Scott, 1988), five of which are fairly common on the Grand Banks of Newfoundland (comprising Grand, Whale, Green, and St. Pierre Banks inclusive, Fig. 1). Of these, thorny skate (*Amblyraja radiata*) is dominant, comprising about 90% of the skates caught in research survey trawls on the Grand Banks during 1951-1998, and about 80% of skate species taken in commercial offshore catches on the Grand Banks and northeastern Shelf to the north, 1981-1998 (Kulka *et al.*, MS 1996; Kulka and Mowbray, MS 1998). More skate species were taken as by-catch in commercial fisheries than in research surveys, because commercial activity occurred over a wider range of depths, thereby capturing deeper water species in greater abundance (prior to 1994, research surveys did not extend beyond 500 m in depth for most years).

The Grand Banks mix of skate species differs from that of the Scotian Shelf to the southwest, where < 50% of skate in commercial catches are thorny, and the predominant skate species is winter, *Leucoraja ocellata* (Simon and Frank, 1996, MS 2000). Winter skate is only taken occasionally in research survey or commercial gears on the Grand Banks. The second most common species on the Grand Banks (and on the northeast Newfoundland and Labrador Shelves) is smooth skate (*Malacoraja senta*), comprising about 5% of the catch while other species are taken only occasionally. Spinytail (*Bathyraja spinicauda*) and Barndoor (*Dipterus laevis*) skates, two deeper water species, were also common in commercial offshore catches of the 1980s (Kulka *et al.*, MS 1996).

Review of the Distribution and Biology

Thorny skate is a boreal to arctic species distributed in the north Atlantic. In the eastern Atlantic, they are distributed from western Greenland, around Iceland to the Barents Sea, including the English Channel, the North Sea, the western Baltic, and as far south as Cape Town, off of South Africa (Froese and Pauly, 2003). Details of its distribution in the North Sea have been reported by Shreman and Parin (1994). In the western Atlantic, thorny skate is widely distributed from Greenland to South Carolina, with its centre of distribution on the Grand Banks (Kulka *et al.*, MS 1996; Kulka and Mowbray, MS 1998, 1999). Historically more widespread on the Grand Banks, thorny skate presently reaches its greatest density on the shallower southwestern Bank in late fall and winter, and along outer sections of the Banks in spring and summer.

On the Grand Banks, thorny skate has been observed in a wide range of depths near shore to 1 700 m (the deepest depths surveyed and commercially fished) with most of its biomass between 50-150 m, and shallowest in the fall (refer to the discussion on migration below and Kulka and Mowbray, MS 1998). They are observed on both hard and soft bottoms (Scott and Scott, 1988; Kulka and Mowbray, MS 1999), and are primarily associated with muddy, sandy and pebbly substrates (which constitute the majority of the Grand Banks; Prena *et al.*, 1999). To the north, they are found on muddy and possibly rocky locations.

A limited tagging study on the Grand Banks (Templeman, 1984) suggested that thorny skate is mainly a sedentary species, and generally does not undergo long migrations. However, Templeman did not attempt to examine seasonal patterns, and most of the tagging took place nearshore. Kulka and Mowbray (MS 1998, 1999) suggested that thorny skate on the Grand Banks undergo a seasonal migration, concentrating toward the Bank edge from December to June, and onto the Bank in the remaining months. Several distributional observations support this theory: a change in spring and fall distributions such that a higher density and greater proportion of biomass are found in deeper waters during spring; on-bank aggregations are 30% more dense in the fall versus spring research surveys; high concentrations located in greater than 1 100 m in Spanish research surveys during spring; estimates of biomass on average 40% lower in spring than in fall; and double the by-catch rates of skate in December-June versus July-November in deep slope Spanish fisheries. Based on reproductive condition, del Rio *et al.* (MS 2002), suggested that thorny skate were congregating on the Bank in the fall and winter to spawn before moving off the shelf. Further evidence is given by del Rio *et al.* (*ibid.*) indicating that catch rates consistently decreased at the end of November every year, thereby terminating fishing activity for the Spanish fleet directing for thorny skate on the shallow section of the Tail of the Grand Banks.

Kulka and Mowbray (MS 1998) compared cumulative area and biomass in relation to ambient temperature (resembling Smith and Page's CDF technique in 1996), and further illustrated the seasonal differences of thorny skate: neither spring nor fall distributions of skate were thermal neutral. The densest aggregations were found on the warmer sections of the Banks. In spring, the percent of biomass was far below the percent of available habitat over almost the entire temperature range, indicating a strong association with the warmest waters. Thorny skate were most densely aggregated where bottom temperature was 4.5-5.2°C (near maximum temperatures of the Grand Banks). However, biomass in the fall was proportionately distributed over temperatures exceeding 2.4°C with skate density peaking at 1.1-2.9°C. No skate were found in waters <0°C at any time of the year. Thus, skate preferentially distribute in warmer waters on the Grand Banks, especially in the spring. Whether thorny skate are differentially selecting warmer habitat between spring and fall, or the differences relate more to its migration to deeper (and warmer) waters, is unclear. In Atlantic waters of the United States, thorny skate was reported in a wide range of ambient temperatures, -1.4-14°C (McEacheran and Musick, 1975).

No genetic work has been done to determine whether thorny skate in Canadian waters comprise one population or more. However, the distributional work of Kulka and Mowbray (MS 1998) indicates that they are widely distributed

forming fairly dense concentrations on the southern Grand Banks and, historically, on the northern Grand Banks and northeast Newfoundland Shelf. Thorny skates are also distributed as far north as Davis Strait at lower concentrations. Within the managed area of the Grand Banks, NAFO (Northwest Atlantic Fisheries Organization) Div. 3L, 3N, 3O, and Subdiv. 3Ps), a relatively continuous distribution and lack of physical barriers suggest that they constitute a single reproductive entity concentrating on the shallow section of the Grand Banks and extending from the Tail of the Banks outside of Canada's 200-mile-limit to the southern edge of St. Pierre Bank (NAFO Subdiv. 3Ps). However, in recent years, thorny skate on the northern section of the Banks and northeast Newfoundland Shelf have become increasingly separated from those on the south.

A number of studies have investigated selected aspects of the biology of thorny skate. Topics include migration and abundance (Templeman, 1984a), length/weight and morphometrics (Templeman 1984b, 1987a), egg development (Templeman, 1982a), and feeding on the Grand Banks (Rodriguez Marin *et al.*, 1994; Templeman, 1982b) and in the Barents and Norwegian Seas (Antipova and Nikiforova, 1983, 1990; Berestovskii 1989a, 1989b). Age and growth of thorny skate have not been studied, although these parameters are critical to understanding its population structure and the effect of fishing mortality on the population. However, other skate species have been aged with otoliths (Simon and Frank MS 1996) for winter skate (*L. ocellata*) on the Scotian Shelf, vertebrae (Correia *et al.*, 1997) for Northeast Atlantic species and thorns (Gallagher and Nolan, 1999) for various Northeast Atlantic Rajids.

Some aspects of thorny skate biology have been examined on sections of the Grand Banks outside Canada's 200-mile-limit, and on the Flemish Cap. Del Río and Junquera (MS 2000) examined catch rates, length composition, sexual maturity, sex ratios, discards, and by-catch of thorny skate taken in Spanish commercial catches on the Tail of the Grand Banks (NAFO Div. 3N). Del Río and Junquera (MS 2001) and del Rio (MS 2002) studied reproductive aspects in the same area. Vinnichenko *et al.* (MS 2002) also investigated size, maturity, food and feeding in the same area, based on by-catch in the Russian skate fishery on the Nose of the Grand Banks. Skates examined in those studies are likely from the same stock examined in this paper.

Knowledge of the reproductive biology of thorny skate in the Northwest Atlantic, until recently, was limited. Templeman (1984b) first indicated that size at maturity was considerably larger for thorny skate on the Grand Banks (NAFO Div. 3LNOPs), as compared to those in northern areas (northeast Newfoundland Shelf). Templeman (1987b) later reported that male thorny skate on the Grand Banks mature at smaller sizes (68-83 cm TL) than females (65-74 cm). Junquera and del Rio (MS 2001) and del Rio (MS 2002) found that, for thorny skate on the Grand Banks (NAFO Div. 3N) in 1997-2000, length at 50% maturity was 43-51 cm for males and 54-60 cm for females. Varying within the 3 years examined, males first matured at 36 cm and were 100% mature at 64 cm, while females first matured at 41 cm and were 100% mature at 77 cm.

Based on Templeman's (1987b) data, Atkinson (MS 1995) also noted that female thorny skate in Div. 3L and 3N (northern and eastern part of the Grand Banks) mature at a slightly smaller size than those further south and west in 3O and 3Ps. However, these differences were slight. It appears that size at maturity of thorny skate on the Grand Banks is quite similar to that of winter skate on the Scotian Shelf, as reported by Simon and Frank (MS 1996, 2000).

Templeman's papers (1984b, 1987b) suggest that reproduction occurs year round on the Grand Banks, and del Rio and Junquera (2001) indicate that peak spawning occurs in the fall and winter. Templeman (1982, 1987) first reported the occurrence of thorny skate egg capsules (purses) in the Northwest Atlantic, and Berestovskii (1994) looked at reproductive aspects under experimental conditions in the southern Barents Sea. Ovaries of sexually mature females were shown to usually hold 10-12 pairs of eggs in different developmental stages with synchronous formation of capsule pairs in the oviducts (Hobson 1930; Chinarina and Troshicheva 1980; Templeman 1982). Two mature eggs are liberated from the ovaries, fertilized in the upper part of the oviduct, then enclosed with yolk and albumen in a capsule (formed by a shell gland prior to release; Clark 1922). Templeman (1982, 1987b) reported that thorny skates deposit 6-40 egg cases per year with each containing a single embryo. Larger thorny skates produce larger eggs. However, it is not known if egg case size is related to survival rate.

In NAFO Div. 3N (southeast Grand Bank), del Rio (2002) examined thorny skate females for presence of egg capsules in the oviduct, numbers and sizes of eggs in the ovary, and variations in shell gland width. His results confirmed the low reproductive potential of Northwest Atlantic thorny skate. Both number and size of oocytes developing in the ovaries increased in maturing fish. In fully mature skates, number of eggs in the ovaries was 40-45, and egg diameter was approximately 12 mm. The majority of adult females from August to December had mature ovaries, but active

uterine stages were almost absent. In contrast, most males were mature during that time. Del Rio suggested that thorny skate concentrations in shallow waters of the Shelf during August to December could be mating aggregations. This observation supports the seasonal migration pattern observed by Kulka and Mowbray (MS 1998), who indicated that thorny skate were concentrated on shallow sections of the Shelf from July to November, but otherwise remained off the Shelf.

Knowledge of early life history of thorny skate is also limited. Berestovskii (1994) hatched out Barents Sea thorny skate from egg cases under laboratory conditions. He speculated that, at low temperatures, embryonic development in extruded egg capsules could extend over 2-2.5 years in the Barents Sea. At hatching, these skates were 10.4-11.4 cm TL with body (disk) widths of 62-69 cm, and total weights of 7.8-10.5 g. Newly hatched individuals had an internal yolk sac, a site of umbilicus attachment, and a tail piece (approximately 8 mm in length). Conditions in the Barents Sea are similar to those on the Grand Banks.

The exact life span of thorny skate in Newfoundland waters (or other areas) is not known, as there has been no attempt to age this species. Preliminary ageing and maturity studies for winter skate on the Scotian Shelf (Simon and Frank, MS 1996, 2000) indicates that 50% are sexually mature at 65-70 cm TL, which correspond to ages of approximately 6-7 years. Templeman's tagging/recapture study (1984a) of a limited number of thorny skates suggests that thorny skate can live at least 20 years. A similarly sized species, winter skate (*L. ocellata*) on the Scotian Shelf appears to have a life span of about 20 years (Simon and Frank, MS 2000). Little is also known about survival of thorny skate from egg release to maturity.

Stomach analyses suggest that thorny skate feed on a variety of items, which include invertebrates and fish (Templeman, 1982b; Rodriguez Marin *et al.*, 1994; Vinnichenko, MS 2002). Invertebrate food items include marine worms (Cl. Polychaeta), crabs (SO. Reptantia) and whelks (F. Buccinidae). Berestovskii (1994) noted that juveniles in captivity ate pieces of fish (cod, capelin) and live crustaceans (amphipods), but did not consume bivalve (mussel) meat. Increasingly important for the diet of larger skates, fish prey includes sculpins (F. Cottidae), redfish (*Sebastes* sp.), sand lance (*Ammodytes* sp.), and small haddock (*Melanogrammus aeglefinus*). At sites of commercial fishing activity, significant amounts of fish offal have been found in skate stomachs. Coupled with the ventral location of their mouths, this information suggests that thorny skates are opportunistic bottom feeders. Limited information on predators of thorny skate in Newfoundland waters suggests that they are consumed primarily by large predators such as seals, sharks, and Atlantic halibut (*Hippoglossus hippoglossus*).

The Fishery

The thorny skate stock management area encompasses the Grand Banks (NAFO Div. 3L, 3N, 3O, and Subdiv. 3Ps), and hereafter is referred to as 3LNOPs (Fig. 1). Thorny skates are also distributed in other areas in significant densities particularly on the northeast Newfoundland Shelf (Fig. 1) where there is also a limited fishery for thorny skate (NAFO Div. 3K). However, for the purpose of managing this fishery, the stock is defined only on sections of the Grand Banks where this species has been targeted by Canadian vessels since 1994 as well as non-Canadian fleets since the mid-1980s and where thorny skate are most densely concentrated.

Kulka and Mowbray (MS 1998) reported that significant by-catches of skates have probably been taken since commencement of offshore fishing in the late-1940s, initially by non-Canadian fleets and later by Canadian vessels. Before the mid-1980s, non-Canadian fleets comprised the largest component of offshore fisheries on the Grand Banks, and kept several thousand metric tonnes (t) of skate for their markets each year. In contrast, the Canadian fishing industry was unable to profitably market skate in Canada although limited amounts of Canadian skate wings were exported to European countries in the 1970s. In the early- to mid-1980s, Kulka (1982, 1984, 1985, 1986a, 1986b, 1989) reported that about 3 000 tons of skate were taken annually as by-catch in the Canadian offshore fisheries, but were mostly discarded. Kulka and Mowbray (MS 1998) subsequently estimated that an average of about 5 000 tons was discarded annually by the Canadian fleet during the 1980s and early-1990s although only a few hundred tons were recorded in Canada's annual landings statistics during that period.

Although often kept by non-Canadian fleets, skates were taken only as by-catch until the mid-1980s. In 1985, Spain began targeting skate in a non-regulated fishery outside Canada's 200-mile-limit on the Tail of the Grand Banks (Junquera and Paz, MS 1998; del Río and Junquera, MS 2000, 2001), where it was found in sufficient concentrations in the fall at depths less than 100 m. By-catches of thorny skate in other fisheries outside 200 miles (primarily

Greenland halibut, *Reinhardtius hippoglossoides*) have also contributed significantly to skate catches reported to NAFO (Northwest Atlantic Fisheries Organization) by non-Canadian countries.

Catch history presented by Kulka and Mowbray (MS 1998) indicated that the Spanish skate fishery occurred almost entirely (98.7%) on the Tail of the Grand Banks in NAFO Div. 3N using otter trawl gear although mesh size was unknown. Since July 2002, the minimum mesh size is 280 mm for skate-directed fishing in the NAFO Regulatory Area (NRA: outside Canada's 200-mile-limit). Kulka and Mowbray (*ibid.*) reported that the total area covered by Canadian and Spanish fisheries (in two separate areas) was 15 000 km² with about 9 000 km² comprising Spanish grounds. Sixty-five percent of skate-directed sets occurred between 51-100 m, and the maximum depth fished was 250 m. While the Canadian skate fishery inside 200 miles is regulated by quota (3 000 tons in 2003), skate fisheries in the NRA are unregulated. This has allowed Spain to increase its skate catches from 4 700 tons in 1999 to 10 700 tons in 2000 (del Rio and Junquera, MS 2000) and possibly maintain catches >10 000 tons since then. Catch per hour averaged 519 kg/hr in 1997 and 691 kg in 2000. Skates in Spanish catches were 30-85 cm TL with a mode of 48-49 cm in 1997 for unsexed skates, and modes of 50-51 cm for males and 46-47 cm for females in 2000. Skates of 42-49 cm TL dominated these catches. Del Rio and Junquera (MS 2001) noted that skate fisheries in August-November are targeting spawning concentrations.

In 2000, Russia commenced a directed fishery for thorny skate. Catches were 3 600 tons in 2000 and 2 600 tons in 2001 during May to December in NAFO Div. 3N in the vicinity of the Spanish skate fishery (Vinnichenko *et al.*, MS 2002). Reported fishing depths were 40-80 m shallower than those of the Spanish fishery. Skates in Russian catches were 25-92 cm TL, and primarily 32-60 cm. Mesh size varied widely over the two years reported: 136 cm in 2000 and 320 cm in 2001. Other countries, especially Portugal, continue to report skate catches to NAFO. However, these values appear to be primarily by-catch.

With the collapse of major groundfish stocks in Canada over the early-1990s, attention was turned to "non-traditional" species. Since thorny skate was a common by-catch (particularly on the Grand Banks), and was potentially marketable in Europe, it became a candidate for increased exploitation. Potential markets were investigated (Day, 1991), and the Newfoundland Provincial Department of Fisheries initiated an experimental fishery for this species in 1993. In 1994, the Canadian Department of Fisheries and Oceans (DFO) continued this fishery, in order to find commercial concentrations of skate, while limiting catches of prohibited species (Anon., 1994). Suitable fishing grounds were found on the southwest slope of the Grand Banks, and effective gear types and configurations were determined. Further marketing studies (Anon.1992; Day 1994), and experimentation with skate processing techniques and machinery resulted in local buyers and processors becoming inclined to process skate. Interest in fishing skate grew as markets in Europe were developed particularly in France and Belgium. In 1993 and 1994, experimental fishing resulted in the first significant skate landings appearing in Canadian statistics. In 1995, Canada established a regulated skate fishery inside its 200-mile-limit with gear and by-catch policies, a licensing system, and Total Allowable Catch (TAC).

Kulka *et al.* (MS 1996) and Kulka and Mowbray (MS 1998) examined by-catch of skates in individual catches from 1988-1998, as recorded by fisheries observers. They reported that otter trawls yielded the greatest proportion of by-catch skates, while gillnets caught the least. Excluding thorny skate, rajid by-catch was small and variable among areas. Regardless of gear type, other skate species were spinytail (*Bathyraja spinicauda*), averaging 10% of the skate by-catch; barndoor (*Dipturus laevis*) at 4%; smooth (*Malacoraja senta*) at 2%; and winter (*Leucoraja ocellata*) at 1%. Thorny and smooth skates were mostly concentrated on the Grand Banks at locations where skate-directed fisheries presently occur. Spinytail and barndoor skates were more typically taken in deep water fisheries, such as those directing for Greenland halibut and grenadiers (*Coryphaenoides sp.*) primarily along the slope of the northeast Newfoundland Shelf. Since 1992, closures of several groundfish fisheries have greatly reduced by-catch of all skates by trawl gear in Canadian waters especially more northern and deepwater species. Trap fisheries for crab and trawling for shrimp have greatly increased in recent years, and commonly catch skates. However, skates caught in crab traps are generally released alive, and since 1994, mandatory use of the Nordmore grate in shrimp trawls has reduced skate by-catch in that fishery. Therefore, mortality due to fishing north of the Canadian regulated area has been lower during the early to mid-1990s, relative to previous years. However, since skates are not speciated in Canadian landings statistics, thorny skate is over-reported as a result of less common skate species in the catch.

Purpose

This paper updates biological and fishery data to 2002, information necessary for a current assessment of Div. 3LNOPs skate. Similar to previous assessments of this stock (Atkinson, MS 1995; Kulka *et al.*, MS 1996; Kulka and Mowbray, MS 1998), an age dis-aggregated analytical analysis for estimating stock size was not conducted for three reasons: 1) data from research vessel surveys do not contain ages of thorny skate, although lengths are recorded; 2) biological sampling of commercial catches continues to be inadequate for VPA (Virtual Population Analysis) or most other traditional stock assessment methodologies; and 3) landings for this species appear to be consistently under-reported, especially prior to 1994. However, since 1998, available data on thorny skate have been enhanced (for example, maturity studies by del Rio, 2002; more commercial information on skate catch sizes from Canadian Fishery Observers), and more comprehensive stage dis-aggregated analyses have been applied in this paper to the existing data.

Participants at the **Symposium on Elasmobranch Fisheries: Managing for Sustainable Use and Biodiversity Conservation (NAFO, September, 2001)** requested that the NAFO establish effective management measures for thorny skate in NAFO waters. In addition, with a mandate to provide information and advice for Elasmobranch species that occur in the NAFO Regulatory Area (thorny skate is one of two species directed for on the Grand Banks in the NRA) NAFO has asked for detailed information with eight focused questions. The **Fisheries Commission** subsequently requested **Scientific Council** to provide the following with respect to **thorny skate in NAFO Div. 3LNO**:

1. Information on exploitation rates in recent years, as well as information on by-catches of other groundfish in the 3LNO skate-directed fishery.
2. Information on abundance indices, and the distribution of the stock in relation to groundfish resources particularly for the stocks which are under moratoria.
3. Information on the distribution of thorny skate in Div. 3LNO, as well as a description of its relative distribution inside and outside the NAFO Regulatory Area (NRA).
4. Advice on reference points and conservation measures that would allow for exploitation of this resource in a precautionary manner.
5. Information on annual yield potential for this stock in the context of (3) above.
6. Identification and delineation of fishery areas and exclusion zones where fishing would not be permitted, with the aim of reducing the impact on groundfish stocks which are under moratoria particularly juveniles.
7. Determination of an appropriate level of research required to monitor the status of this resource on an ongoing basis, with the aim of providing catch options that could be used in the context of management by Total Allowable Catch (TAC).
8. Information on skate size composition in the current catches, and comment on these sizes in relation to the size of thorny skate at sexual maturity.

This paper attempts to address most of the issues raised by the Fisheries Commission, using information from Canadian research surveys, fishery statistics of all countries, and information in national Research Reports or other papers. Information on relative exploitation, population indices for various life stages, distributional changes for thorny skate, and size composition in the population and commercial catches are examined. Consideration is given to provision of advice in the form of reference points, and determination of an appropriate level of research required to monitor the status of this resource on an ongoing basis, with the aim of providing catch options that could be used in the context of management by Total Allowable Catch (TAC).

In the absence of age data and other life table parameters for thorny skate, this paper focuses on its relative biomass, distribution dynamics, and directed fishery. An update of biological information and abundance indices is presented for 1971-2002 (spring) and 1977-2002 (fall) as well as current skate distributions. Similar to the 1998 assessment, spatial and temporal characteristics of the directed fishery are compared to the distribution of thorny skate, an important analysis, because this is a relatively new fishery and recent biological studies are few. Given a continued paucity of commercial samples from this fishery, coupling of size-dependent spatial distributions (from research survey data) with locations of commercial skate catches appears to be the only method of determining which part of the stock is being targeted by fishers. Impacts of these removals on the stock are discussed. This paper presents information for the improved management of 3LNOPs skate. These analyses also provide the fishing industry with new information on skate distributions that could assist more effective exploitation strategies, while safeguarding important marine ecological areas.

A review of fishery regulations and recent catches (1985-2002) are also provided, based on ZIF (Zonal Interchange Format) data for Canada and NAFO statistics for other countries. Reliability of reported catches is discussed, and two different sets of landings data are investigated for the Spanish skate fishery: one reported to NAFO, and one adjusted with Canadian C&P commercial inspections data (Department of Fisheries and Oceans Canada – Fisheries Management Branch – Conservation and Protection Division) up to 1998. However, Canadian C&P estimates are not available after 1998.

Methods

Research vessel survey data

Data on thorny skate have routinely been collected during Department of Fisheries and Oceans Canada (DFO) research surveys in NAFO Div. 3LNO and Subdiv. 3Ps. Doubleday (1981) summarizes the stratified random design adopted by DFO - Newfoundland region after 1970 for spring surveys, and after 1976 for fall surveys. Spring surveys of NAFO Div. 3LNO commenced in 1971 with the inclusion of Subdiv. 3Ps (comprising St. Pierre Bank) since 1972. Fall surveys of NAFO Div. 3L began in 1981, and then commenced for Div. 3NO in 1990. Subdivision 3Ps is not surveyed in the fall. While survey design has remained constant over time, both inshore and deepwater strata have been added to the survey area in recent years (beginning in 1993), along with modifications to some of the original strata. A summary of early modifications is in Bishop (1994).

In addition, there was a change in survey gear after the spring 1995 survey from an Engels 145 groundfish trawl to a Campelen 1800 shrimp trawl. Although both are bottom trawls, configuration and mesh size differ significantly, as described by Bishop (1994). Size and age based conversion factors for amounts and sizes of fish caught were derived for major commercial species, but not for thorny skate. Thus, catch rate data and biomass and abundance indices are on a different scale as of fall 1995. This gear change also affected selectivity by fish size as determined for major commercial species. However, a comparison of skate frequency data before and after this gear change suggests that size selectivity differences between gears may not be so significant for skate. This change in gear is delineated on various tables by a dashed line or space, and on figures by a vertical bar. A conversion factor was derived from the knife-edge change in biomass and abundance over the time of the gear change, an average of the 1996 and 1997 biomass and abundance estimates was divided by an average of the same estimates for 1994-1995. This conversion factor was then applied to survey estimates to “Campelenize” them prior to 1995, and thus provide continuity over the full time series. Normally, trawl gear conversion factors are based on results of comparative trawling experiments, which account for changes in the sizes of fish caught by the different trawls. Catchability varies among fish sizes between these two trawls. For many fish species, the Campelen trawl tends to catch a larger proportion of smaller fish when compared to Engels gear (Walsh, 1995). However, for thorny skate, an examination of length frequencies and average size caught suggests that proportions of various sizes of thorny skate are similar between both survey gears. Thus, a simple ratio of weight and number between adjacent years of the survey gear change probably yields a reasonable conversion factor.

Research data from stratified random surveys in NAFO Div. 3LNO and Subdiv. 3Ps were used to estimate biomass and abundance, and examine trends in average size (biomass/abundance) of thorny skate in spring 1971-2002 and fall 1981-2002. Not all areas were surveyed every year for both time series; the missing data are denoted by blank cells on biomass and abundance tables. The total area surveyed in 1996-2002 was 294 589 km² in 1994-96 was 283 321 km² and in 1986-93 was 255 542 km².

STRAP2 is an areal expansion of survey tracks to the total area within a series of predefined strata related in part to depth (Smith and Somerton, 1981). This technique was used to estimate biomass and numbers of skates. These strata estimates are then added over the survey area. Similarly, STRAP1 (Smith and Somerton, 1981) was used to estimate numbers at length for predefined depth strata. Total abundance at length was then the addition of these estimates over the research vessel survey area. Due to the absence of length-weight data from DFO stratified random surveys in NAFO Div. 3LNOs, sexed length-weight relationships of thorny skate generated by del Rio *et al.* (2002 from Spanish spring trawl surveys in 2001 for Div. 3NO) were utilized in STRAP1 calculations. These calculations assumed that weight at length remained constant throughout the entire survey period.

Changes in the proportion of three life stages of thorny skate were examined in this study: young of the year (YOY); immature; and mature individuals referred to here as Spawning Stock Biomass (SSB). Research survey frequency

numbers at length were partitioned with information reported by del Rio *et al.* (2002) regarding the proportion of mature fish at length for thorny skate in NAFO Div. 3N and 3O, and information reported by Berestovskii (1994) concerning hatch size of thorny skate. In the present paper, young of the year (YOY) is defined as the smallest, narrow mode of fish less than 22 cm TL. Berestovskii (1994) determined that size at hatching from the egg case for thorny skate in the Barents Sea was approximately 10.4-11.4 cm. This hatching size compared closely to the starting size of the smallest mode apparent in both spring and fall Canadian research surveys averaging 15-16 cm (males and females), and ranging to about 22 cm. Thus, this smallest mode observed in all survey years was designated as YOY, and was used to derive a recruitment index. All thorny skates up to 17 cm TL, and an increasingly smaller proportion of skates 18-22 cm long were designated as YOY.

The ogives of del Rio (2001) for 1997, 1999, and 2000 were used to estimate the proportion of mature males and females in Canadian spring survey catches, in order to derive an index of spawning stock biomass (SSB). The year 2000 ogive was applied to surveys in 2000-2002 the year 1999 ogive to 1998 and 1999 and the year 1997 ogive was applied to 1997, and all years earlier. If size at maturity varied in years prior to 1997, then the spawning stock index could be over or under-estimated for those years. Information from Templeman (1987b) suggests that this may be the case although the bias is not large. The remaining thorny skates were defined as immature excluding young of the year.

SPANS GIS (Anon., 2003) was used to investigate spatial distribution of thorny skate with research vessel survey data. A detailed description of this potential mapping technique is in Kulka (1998). The DFO survey trawl gear change (mentioned previously) resulted in the scale of maps representing a different catch rate after fall 1995. In addition, extra sets that were not part of standard surveys have been added to some strata in 1985-1994 for a diurnal study in Div. 3LNO. Although these diurnal sets are a deviation from the proportional allocation of sets, they use the same sampling protocol as standard survey sets, and are included in the present mapping of thorny skate distributions.

Using potential mapping, maps depicting species distribution and abundance over the whole surveyed area were generated separately for spring and fall. To reduce the volume of maps produced, spring and fall surveys were grouped into three-year intervals except for data collected in spring 1995, which were grouped with spring data from 1992-1994 (using the same survey gear). This grouping of years assumes similar distributions within each group.

When creating species distribution maps, a single legend is set for a baseline year for each species, then used across all years to show inter-annual variation (Kulka, 1998). Such a legend was created here to represent biomass on a single scale throughout the twenty-three year period examined (1980-2002). All legends were devised using fifteen density strata. To smooth the surface transition from one density stratum to another, a linear decay function was applied to this potential mapping thereby giving points on the periphery of scanning circles less weight in the averaging function.

For the resultant maps, darkest (red) areas represent highest densities of skate (highest catch per tow), which fade to green, representing the lowest catch rate. Grey depicts sampled areas with no skate catches, and white depicts unsampled areas. Points overlaying each map's surface indicate where research survey sets occurred. Area of occupancy for thorny skate was calculated annually. Changes in proportion of biomass occupying 20% of the area was calculated for 1980-2002, by setting the highest legend value to correspond to 20% of the surveyed area.

Skates taken during research surveys in 3LNOPs were usually identified to species, and total length of thorny skate was measured in approximately 60% of the sets (more in recent years). Since skate catches were usually small, the entire catch was measured for length in nearly all sampled sets. However, no measurements of wing width or maturity stages were done. Thorny skate length frequencies were plotted by NAFO Division and year from 1986-2002, and separately for spring and fall surveys. These length frequencies represent actual skates caught in sampled sets and have not been weighted by stratum area or extrapolated to survey abundance estimates.

The individual research survey length frequencies were partitioned into three life stage; YOY, immature and SSB, using ogives derived by del Rio (2002) in the same manner described previously. For partitioning annual aggregated frequencies, maps of the distribution of YOY and SSB were produced for selected years, using the resulting survey catch rates for those specific population components and potential mapping.

The Fisheries

Commercial landings data for skates inside Canada's 200-mile-limit are not specific to species. However, approximately 90% of landed skates are *Amblyraja radiata*. Information on skate removals was obtained from four sources: Zonal Interchange Format (ZIF) data files for Canadian landings; Canadian Fishery Observer database for species composition and discards; NAFO STATLANT-21A for reported non-Canadian landings; and C&P (Department of Fisheries and Oceans Canada (DFO) - Fisheries Management Branch - Conservation and Protection) commercial inspections data.

Canadian landings were compiled using Canadian statistical records in the ZIF database available since 1985. Discards from Canadian fisheries were calculated by applying the proportion of skate catch to groundfish landings (kept fish, all species) in the Fishery Observer database to the reported groundfish landings in Canadian statistical files. In addition, skate catches (kept fish plus discards) of non-Canadian vessels in Canadian waters were extracted from Fishery Observer records. Canadian Fishery Observers have covered 100% of non-Canadian fishing effort since the inception of the Canadian Observer Program in 1978, and approximately 8% of Canadian effort since the skate-directed fishery began in 1994. 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). Total lengths of thorny skate in commercial catches from various gears were measured only sporadically since 1994 with most of the sampling done in 2000-2002. Observer data were utilized to examine distribution of fishing effort and skate catch rates. The potential mapping technique described previously was used to create distribution maps of observed fishing activity (catch rate by NAFO Division and gear). Fishing grounds were then compared to skate distributions derived from DFO research survey data.

Fishing log data recorded for each set in 1999-2002 were used to examine spatial distribution of fishing grounds by gear type. The fishery along the southwest slope of the Grand Banks is a mixed fishery for monkfish (American angler, *Lophius americanus*), white hake (*Urophycis tenuis*), Atlantic halibut (*Hippoglossus hippoglossus*), and thorny skate. Thus, data used to map the fishing grounds included sets that were designated as directed for each species. Catch per set was used to categorize various densities of skate. Maps of fishing grounds were generated with the potential mapping technique described previously.

Non-Canadian catches outside 200 miles (and inside 200 miles before 1992) are comprised of information reported to NAFO and data collected by Canadian Fishery Officers (DFO - Conservation and Protection Division) during commercial vessel inspections at sea in the NAFO Regulatory Area (NRA). The latter were combined with NAFO data to derive an adjusted estimate, which is considered more accurate (see Discussion for justification). These C&P-adjusted estimates were used for 1992-1998, but were not available thereafter. NAFO statistics were then used for non-Canadian countries in 1999-2002. Maps of non-Canadian fishing grounds outside of Canada's 200-mile-limit were also generated from C&P estimates for 1995-1999. This information represents about 60% of the total skate catch in the NRA.

By-catch in the Canadian skate fishery was estimated by adjusting the proportion of each species taken in the observed skate-directed fishery, using a ratio of landed to observed skate (all skate species combined, because all species are landed). In addition, proportions of each by-catch species in the skate-directed fisheries in the NRA were estimated from Canadian Fishery Officer reports (information on the species mix in catches from non-Canadian logbooks). For consistency with other authors reporting on by-catch, a "skate-directed" set was defined in this study as one in which skate was the most caught species (by weight) in a catch. These by-catch proportions were then compared to other published studies. Another approach used here was to calculate by-catch proportions for sets inside the 100 m contour in NAFO Div. 3NO. All published literature indicated that the skate-directed fishery occurred at depths less than 100 m. The Canadian C&P data from vessel inspections at sea contained no information on fishing depth, but did have a geo-reference, latitude and longitude. These data were imported into the SPANS Geographic Information System, and a depth category was assigned to each catch. Estimates of total by-catch were derived by multiplying recorded amounts of each species by the ratio of reported skate catch to C&P-recorded totals of skate.

An Index of Exploitation was calculated for each NAFO Division and all areas combined, using a ratio of reported catch to spring research survey biomass index. Indices for the Canadian fleet inside 200 miles (NAFO Div. 3LOPs) were then compared to indices for non-Canadian fleets fishing outside 200 miles (NAFO Div. 3N).

Results

Trends

Spring and fall research survey biomass and abundance indices derived using STRAP2 are presented in Table 2 and Fig. 2 (spring and fall biomass for Engels and Campelen time series, by NAFO Division), Fig. 3 (spring and fall abundance for Engels and Campelen time series) and Fig. 4 (spring biomass and abundance for Campelen adjusted time estimates). The fall series does not include data from Subdiv. 3Ps for any year, or from Div. 3N and 3O before 1990. Thus, they are not comparable to spring results which extend over the entire area and time period. Since the fall series was not spatially complete over the designated stock area, spring surveys were used as the primary estimator of biomass and abundance trends of the stock. However, fall estimates are also used, because that survey is conducted when a greater proportion of thorny skate are available to trawl gear. During that time, skates are concentrated on the shelf, whereas in the spring, part of the population has moved to the shelf edge, a proportion apparently outside of where spring surveys occur (see discussion on migration below). Thus, in using spring estimates of biomass and abundance to examine trends in the population, it is assumed that the proportion of skate that moves outside of the surveyed area is consistent among years. Figure 6 indicates that proportion within the spring survey area changed over time, and thus spring biomass/abundance estimates also reflect changes in degree of migration.

The spring index of biomass (Fig. 2) indicates a fluctuation in the relative population size over time. It appears that relative biomass increased between 1971 and 1976. However, the 1971 estimate is missing data from NAFO Div. 3O and Subdiv. 3Ps. Assuming 1973 values for the missing areas in 1971 and 1972, the trend would be flat or increasing slightly to 1975. The 1976 value is the highest on record well above any other year. This high value was the result of three very large sets (508, 428, and 243 kg skate per standard tow), and thus the estimate for that year in Div. 3O may be anomalously high. Only Subdiv. 3Ps was surveyed in 1983, and some other areas were only partially surveyed. Given the missed survey areas and the anomalous year, it appears that the biomass index increased from 1971-1985, before declining rapidly to its lowest level in 1993-1995. Relative biomass in 1993-1995 was $1/3^{\text{rd}}$ of that observed in the early-1970s. Most of this decline occurred in Div. 3L on the northern part of the Grand Banks, and to a lesser extent in Div. 3O. Biomass in Div. 3O and Subdiv. 3Ps appeared to fluctuate without a pattern until 1992. Biomass in those areas was smaller in 1993-1995, but the reduction was not to the same extent as in Div. 3L. Thus, declines in relative spring biomass on the Grand Banks were largely attributable to the northern extent of the Banks.

After the change in research survey gear (denoted by a grey bar and a separation in the time series on the x-axis) to Campelen, relative biomass was approximately 2.8 times greater (comparing the average of 1994-1995 and 1996-1997) indicating that the Campelen trawl was considerably more efficient in capturing thorny skate. Although a length/aged-based conversion factor was not derived for thorny skate (as was done for major commercial species), application of the conversion factor described above indicates that the relative skate biomass likely remains low, as compared to the mid-1980s and earlier (Fig. 4, upper panel). The index increased moderately between 1996 and 1999, but has since been flat or in decline. Biomass in 2002 may not be significantly different from 1993-1995, when it was at its lowest.

The relative spring abundance trends mirrored the biomass indices, both spatially and temporally (Fig. 4, lower panel). The index increased between the early-1970s and mid-1980s, then declined rapidly in 1990-1995 mostly in Div. 3L and 3O. Skate abundance increased from 1996-1999, then declined afterwards. These changes appear to be relatively small. Most of the thorny skate were found in Div. 3N, 3O, and Subdiv. 3Ps, approximately 60% in the 1970s, and 90% following its decline in the early-1990s.

For comparable years and areas (1981-2002 in NAFO Div. 3L, 1990 in NAFO Div. 3LNO), spring and fall survey estimates of biomass showed similar trends. However, fall estimates were more variable, and consistently higher within each NAFO Division. The decline observed in the spring series during the early-1990s also appeared in the fall series. After 1995, the fall index fluctuated without a pattern, and 85-90% of the skate biomass in Div. 3LNO was found in 3NO.

The trend in proportion of biomass between the northern part of the Grand Banks and the southern portion (the NAFO Div. 3L line used as the dividing point) is illustrated in Fig. 5. For spring (upper panel) in the 1970s, about 60% of thorny skate biomass was found below the NAFO Division line separating 3L from the southern areas. This analysis utilized only years when all areas were surveyed. The proportion increased during the 1980s, then stabilized at approximately 90% by 1992. For fall (lower panel, a very short time series), the pattern was very similar. The proportion in 3NO was about 85% as compared to 3L after 1993. This suggests that the decline in biomass since the

late-1980s occurred mainly on the northern Grand Banks (Div. 3L). The decline was relatively smaller in Divi. 3N and 3O, and biomass appears to have been relatively stable in Subdiv. 3Ps.

A comparison of spring and fall biomass estimates (a ratio of estimates in NAFO Div. 3LNO, the only three Divisions surveyed during both seasons) indicates that fall estimates are consistently higher (Fig. 6). Both seasons were surveyed consistently since 1990. However, limited data in Div. 3L suggests that, prior to 1990, the fall/spring ratio may have been lower. From 1990-1995, this ratio increased from approximately 50% to 80-90%, concurrent with the period of decline. The ratio declined to about 40% by the late-1990s, and has remained relatively stable. However, in 2002, it increased to approximately 65% in all areas except Div. 3L.

Concurrent with the decline in biomass of thorny skate, a reduction in average weight was observed in both spring and fall during this period with a greater change in the spring (Fig. 7 and Table 2). The trend has been downward since the beginning of spring surveys in 1971 to the mid-1990s. In the early to mid-1970s, average weight of skate (spring surveys, all Divisions) was about 2 kg, equivalent to an average total length (TL) of approximately 61 cm, and a wing width (ww) of 45 cm (refer to Table 3 in Atkinson 1995 for conversions, and Fig. 8). By the mid to late-1980s, average weight of thorny skate in Engels catches was 1.3 kg (49 cm TL, 39 cm ww). This decline in size differed between areas, less pronounced in NAFO Div. 3O, greatest in Div. 3L and 3N. During the early- to mid-1990s, average size of skate in those areas was about 0.5 kg. Average sizes from fall surveys in Div. 3L declined steadily from 2 kg in 1984 to 0.5 kg in 1992 after which it seems to have stabilized at the lower level. After research surveys in Div. 3NO began in 1990, average size in Div. 3O appeared to decline steadily from about 2.5 kg in 1991 to 1.0 kg in 1994 similar to the trend observed in spring. In Div. 3N, the fall trend was similar to that in spring, except that the skates were slightly larger.

Since 1995, this decline in mean weight of skates in research survey catches has reversed. From 1995 (fall) or 1996 (spring) to 2002, the trend in average size has consistently increased in all Divisions (Table 2 and Fig. 7). Between spring and fall, the relative increases were different among areas. For example, the largest increase was observed in NAFO Div. 3O in the fall, but the largest average weight was in Div. 3N in fall 2000. During the period of decline, the largest (mature) skates were found on the southwestern Grand Banks and southern St. Pierre Bank (Division 3O and Subdiv. 3Ps). At other times, mean weight was generally similar among all areas.

With the change in survey trawls to Campelen in fall 1995, most of the fish species captured by that gear were smaller compared to those caught by Engels gear. Comparing the last year when Engels gear was used to the first year of Campelen, average weight (biomass/abundance) is very similar over all Divisions (Fig. 7). For thorny skate, it appears that there is no break across survey gears in terms of mean weight. This is expected given that Campelen gear appears to catch 2.8 times more weight per tow than Engels, and seems to catch 2.4 times more skates than the latter trawl.

Length composition of thorny skate in research surveys by year (1986-2002) and by NAFO Division is presented in Fig. 9a (spring) and Fig. 9b (fall). By Division, the shapes of frequencies were generally similar between spring and fall. A large range of lengths were present (11-101 cm TL), and this range varied slightly from year to year. There was some inter-annual variation in the mix of sizes. In addition, observed peaks usually matched among areas within a given year suggesting similar size compositions between Divisions. For most areas and years, a peak of smallest skates was between 10-20 cm, and averaged 15 cm. The next largest peak of (immature) skates occurred between 20-30 cm, sometimes merging with the 10-20 cm mode. The 20-30 cm mode was much reduced after the mid-1990s. A peak of large (mature) skates of approximately 65-83 cm is apparent, particularly from 1986-1989. This peak re-appeared during 1997-1999 especially in the fall. Until 1990, large skates were also found on the northern part of the Grand Banks (Div. 3L). In Div. 3L, these large fish are nearly absent in 1992-94 then increased in number after 1994 in the fall, and after 1998 in the spring.

On the northern Grand Banks (NAFO Div. 3L), the mode of young skates averaging about 25 cm (ranging from 10-35 cm, probably year-class-1 fish) dominated both spring and fall survey catches until 1994 or 1995 (Fig. 9). This suggests that recruitment was occurring there on a yearly basis, or that young skates were consistently moving into that area. Since 1995, these young skates have been largely absent or low in number. A small mode was apparent in 2001-2002 (fall), but it appears that recruitment in this area has remained low following the decline in biomass there. For the southern Grand Banks (Div. 3N and 3O), this mode of young fish was also small or largely absent after 1995 in spring and fall. However, a mode of 10-35 cm skates was present since 1996 although narrower in range (10-20 cm).

This suggests that, after 1995, recruitment (presence of substantial numbers of small fish) occurred mostly on the St. Pierre Bank (Subdiv. 3Ps).

Numbers of thorny skate at length amalgamated across the entire stock were partitioned into young of the year (YOY), immature and mature (SSB) components as illustrated for 2002 in Fig. 10. Partitioning thorny skate life stages was based on results of other studies (see Methods). These partitioned frequencies were then used to examine trends in young of the year (YOY) and mature (SSB) components of the thorny skate population (Fig. 11-14).

A minimum estimate of recruitment (YOY) and mature fish (SSB) for thorny skate males and females are illustrated in Fig. 11. Trends in both components of the population were fairly similar, and mirrored those observed for the entire population (see Fig. 4). Beginning in the early-1990s, both YOY and SSB declined until about 1997. Recruitment apparently remained low since the mid-1990s, while SSB has been stable or increasing slightly.

Figure 12 indicates that the proportion of thorny skate YOY (young of the year as proportion of total abundance) remained fairly constant between 0.1 and 0.15 for males and females until the late-1980s. Increasing slightly to 0.2 mid-1990s. The proportion of YOY then returned to values previously observed during the 1980s. In contrast, the percent of the skate population that was mature declined for both sexes during the early-1980s to 1999 and have remained low since. Values for immature skates increased during the early to mid-1980s and have declined since about 1997.

Figure 13 shows that ratio of males to females in the sampled population over time has been relatively consistent, with some fluctuations over time (1980-2002) for all three population components, YOY, immature and SSB. YOY averaged close to 1 (1:1 males to females) while the ratio of immature males to females was lower averaging about 0.75 and SSB averaged 1.5. Why there are proportionately fewer immature males in the sampled population than mature males and YOY males is unclear. This pattern suggests changes in the catchability perhaps due to differential migration in and out of the sampled area.

Distribution

Within the designated stock area (NAFO Div. 3LNO and Subdiv. 3Ps), the distribution of thorny skate has undergone significant changes since the early-1980s (Fig. 14 spring, Fig. 15, fall). In 1980-1982, skates were widely distributed over the entire Grand Banks in moderate to high concentrations. Only a very small area along the western extent of Div. 3L (around the southern extent of Newfoundland's Avalon Peninsula: Fig. 1) seemed to have low concentrations in spring and fall, and there was a significant concentration of skates in the eastern portion of Div. 3L. By 1983-88, this area of low concentration in western 3L had expanded to surround the Avalon Peninsula, and half way across the northern part of the Grand Banks. During this period, 2-3% of the surveyed area (around the Avalon Peninsula) contained no thorny skate (Fig. 14). By 1989-1991, 6% of the surveyed area (near the Avalon Peninsula) was devoid of skates, and areas of high concentration were found more on the periphery of the Banks as compared to previous years. The area without skates increased steadily in the late-1990s to about 10% then to almost 25% of the surveyed area in 2001-2002. The greatest changes were observed on the northern Grand Banks by 2001-2002, where a large portion was devoid of skates and dense concentrations were largely absent. Remaining concentrations stretched from the Tail of the Banks onto St. Pierre Bank and along the edge of the Laurentian Channel.

These reductions in the distribution of thorny skate are largely reflected in the biomass changes described previously, with one exception. Biomass has been relatively stable since the early to mid-1990s, but during that period the area of high concentration has increasingly diminished. Thus, the area occupied by thorny skates has substantially decreased, and the population has become increasingly more concentrated in a smaller area. Approximately 80% of the biomass is presently concentrated within 20% of the area on the southwest edge of the Grand Banks (including Subdiv. 3Ps). Thirty-five to forty percent of the surveyed area now contains little or no biomass mostly adjacent to the Avalon Peninsula where bottom temperatures are the coldest.

Comparing Fig. 14 with Fig. 15 indicates that thorny skates were distributed differently in the spring than in the fall and these differences were consistent over the years. Differences were less pronounced in earlier years, when thorny skates were more widespread during spring and fall. In spring, skates were distributed deeper, with moderate to high concentrations forming a nearly continuous band along the periphery of the Banks (outer limits of the surveyed area). This concentration extended from the Nose and Tail of the Grand Banks, across the outer Haddock Channel, Green Bank, Halibut Channel, along the edge of the Laurentian Channel, and ending in the Hermitage Channel. The band of

thorny skates was most dense and wider along the southwestern slope of the Grand Banks and up into the Laurentian Channel. Compared to the fall, this large (southern) spring concentration was located further west across the NAFO Div. 3NO line, and into Subdiv. 3Ps. A second concentration of thorny skate was also located in the centre of the Banks, straddling the line between Div. 3L and 3N in the early years of this study. However, this concentration has largely disappeared over time.

In contrast, the main concentration of thorny skate in the fall was distributed more on the Banks, inhabiting shallower waters. Concentrations of skate along the shelf edge were diminished while an aggregation on (and westward of) the Southeast Shoal and, to a lesser extent, one straddling the Div. 3LN border, were larger. The latter aggregation was distributed more to the east, and was denser in the fall (by approximately 30%) than in spring. The St. Pierre Bank (NAFO Subdiv. 3Ps) is not surveyed in fall. Research surveys conducted in August in southern and western 3Ps, and into 4Vn, found little or no aggregation of thorny skate along the shelf edge although a large aggregation was readily observed in spring.

Figure 16 shows that between 1980 and 2002, the percent of the surveyed area containing no skates increased from about 3% in 1980-1988 to 25% in 2001-2002. At the same time, the biomass became increasingly more concentrated. During 1980-1988, about 57% of the biomass was located within 20% of the survey area and the concentrations of skate could be found over several parts of the Grand Banks (see Fig. 14 and 15). By 2001-2002, 83% of the biomass was concentrated into 20% of the surveyed area, primarily along the southwest slope of the Grand Bank.

Various life stages of the thorny skate stock distribute in a different manner, and these population components have also changed over time. Young of the year (YOY) were observed to distribute around the periphery of the Bank (Fig. 17), and a similar distribution pattern was apparent in both spring and fall research surveys (Fig. 17a and 17c) except that they were distributed more onto the Bank in the fall. The extent of this distribution (total area occupied by YOY) was similar over time. Area occupied by YOY in spring was 142 100 km² in 1980-1981, and 132 500 km² in 2001-2002 (only spring surveys cover the entire stock area). However, some of the occupied area had shifted from the north and east to the south and west. The greatest change in thorny skate distribution was observed in the reduction of area containing dense concentrations. In the 1980s and early-1990s, relatively dense concentrations of YOY were found along the entire periphery, the Laurentian Channel to the northern Grand Banks. In 2001-2002, although low numbers of YOY persisted over the entire periphery, dense concentrations of thorny skate were seen only in the western part of its stock area. Areas where YOY abundance was highest (exceeding 5.2 skates per tow) diminished from 5 960 km² in 1980-1981 to less than 1 700 km² in 2001-2002. The large majority of YOY abundance/biomass is now located in the most western part of the stock area along the Laurentian Channel in NAFO Subdiv. 3Ps. Refer also to Fig. 9 showing the near absence of a YOY mode in NAFO Div. 3LNO frequencies.

Mature thorny skates (males and females) were more widely distributed across the shelf, particularly in early years (Fig. 17b and d). In 1980-1981, mature thorny skates occupied most of the stock area, covering 320 350 km². By the mid-1990s, most mature skates (and immature fish) were absent from the northern part of the Bank except for small concentrations along the shelf edge (occupying 229 000 km², a 29% reduction in area occupied by the SSB).

Derived from Canadian spring research survey data, the relationship between female spawning stock biomass (SSB) and recently hatched skate (YOY) is illustrated in Fig. 19. The upper panel shows that the ratio of YOY/SSB was constant between 1980 and 1986 increased between 1989 than declined after the early-1990s stabilizing at levels previously observed in the mid to early-1980s. This increase in YOY relative to SSB is concurrent with the period of decline of the stock. Figure 18, middle panel plots YOY against SSB. The trajectory indicates that there is a relationship between spawning stock biomass and recruitment for this K-selected species. The lower panel shows that the trends in relative biomass of YOY and SSB are quite similar, suggesting a stock/recruitment relationship. The average of the highest three years in the series was 24 444 tons, the lowest three years of female relative SSB averaged 6 906 tons and the last three years of female relative SSB averaged 10 149 tons.

The Fisheries

Thorny skate are caught in a wide variety of fisheries over an area extending well beyond the managed 3LNOPs stock. Figure 19 illustrates skate catch per set from all commercial fishing activity observed in 1992-2002 (DFO-NL Region: Fisheries Observer Program). This period was subsequent to the collapse of some demersal fish stocks entailed a corresponding reduction in groundfish fishing effort, and increases in shrimp and crab fishing and occurred after non-

Canadian fleets stopped fishing within Canada's 200-mile-limit. Thorny skate are taken as by-catch as far north as the Davis Strait. North of Lat. 52°, skate catch rates were generally lower, but skates were reported as a relatively common by-catch as far north as Lat. 70°N in NAFO SubArea 0A. Directed fisheries in this area were primarily targeting shrimp (*Pandalus* sp.), crab (*Chionocetes opilio*), and Greenland halibut. Shrimp trawls are equipped with Nordmore grates, which exclude larger fish thereby decreasing by-catch of larger skates. Most by-catch in the Greenland halibut fishery is discarded, but survival rates of discarded fish are unknown. South of Lat. 52°, higher skate catch rates were observed as far south as Lat. 48°, on the northern section of the Grand Banks. Between Lat. 46° and 48°, a large area was not fished, or skate by-catch was low to nonexistent except along the shelf edge, where Greenland halibut is targeted. Highest skate catch rates occurred on the southern Grand Banks (in the vicinity of the Canadian directed fishery (compare Fig. 14 and 15 to Fig. 20), and also on the northern part of St. Pierre Bank.

There is also a very limited fishery for skate north of the management stock area (3LNOPS) in NAFO Div. 3K. However, catches have not exceeded 100 tons there. Whether thorny skates occurring north of NAFO Div. 3L comprise a different ESU (Evolutionary Significant Unit) is unknown.

In terms of areas fished, skate catches in Canadian waters occurred primarily in NAFO Div. 3L and Subdiv. 3Ps prior to 1992 (by-catch), but have shifted to 3O in addition to 3Ps in recent years after the Canadian skate-directed fishery began in 1994. Figure 20 (upper panel) shows that directed sets for skate occurred along the shelf edge in 1999-2002 from the Laurentian Channel in NAFO Subdiv. 3Ps to Canada's 200-mile-limit in NAFO Div. 3N. Fishing effort distribution was similar among years, clustered in southern 3Ps, and in two locations in 3O. Most of the effort occurred in depths of 100-300 m for otter trawls and gillnets, and 50-150 m for longlines (Fig. 20, lower panel). However, catch rates (catch per set) tended to be similar across a wider range of depths: 50-800 m.

Locations of the Canadian gillnet (Fig. 21 upper panel), longline (middle panel), and otter trawl (lower panel) skate/monkfish/white hake/Atlantic halibut mixed fisheries in 1999-2002 were similar. The same areas were fished consistently between years; therefore, 1999-2002 are presented on a single map. Fishing effort was concentrated on the southwest slope of the Grand Banks, and extended onto the slope of St. Pierre Bank (along the Laurentian Channel). Skate catch rates with all gears were higher on the inner extent of these grounds (in primarily 50-200 m), where sets targeting thorny skate occurred. However, skate by-catch was substantial at greater depths, where sets were targeting other species.

A spatial representation of non-Canadian effort outside of Canada's 200-mile-limit is presented in Fig. 22. These data were recorded from Spanish and Portuguese fishing logbooks by Canadian Fishery Officers during vessel inspections at sea in 1995-2002. On the Tail of the Grand Banks, fishing effort encompassed most of the available shallow Bank where the most dense skate concentrations straddle the NAFO line in fall. For 1995-1997 and 1998-1999, catch rates were substantially higher on the portion of the Bank less than 200 m deep, than along the shelf break (Fig. 24a). Average catch of skate within the 200 m contour, corresponding to the "skate directed fishery", was 534 kg per hour (10.7 tons per day) in 1995-1997, and 669 kg per hour (13.4 tons per day) in 1998-1999 (Fig. 22a, circled area). These shallow sets comprised primarily a skate-directed fishery. This on-shelf effort occurred mainly in June-December when thorny skates were aggregated on the shallow section of the Bank, which extends outside the 200-mile-limit. Both time periods reflected very similar spatial patterns except that in 1998-1999, the area fished extended slightly further west, and on-shelf catch rates were higher. Fishing effort along the shelf edge yielded significant skate by-catch in a fishery mainly targeting Greenland halibut.

Locations fished in 2000-2002 were similar to previous years (Fig. 22b). However, spatial patterns of skate catch rates did not resemble previous years. Skate catch rates on the Tail of the Grand Banks (circled area) was 157 kg per hour (3.2 tons per day), only 24% of that recorded in the previous time period. In addition, average skate by-catch rate in the Greenland halibut fishery was considerably higher than that in previous years: 113 kg per hour, as compared to 40 kg per hour in 1995-1999.

Skate catches of all countries after 1984 are illustrated in Fig. 23, and summarized by country in Table 4 (statistics are incomplete for 2001 and 2002). Combined catches are categorized in three periods: 1985-1991, when total skate catch was 16 000-23 000 tons (peak catches) 1992-1996, when skate catches dropped under 12 000 tons and declined to less than 7 000 tons in 1996 and 1997-2002, when the directed efforts of several countries increased outside of 200 miles. The 2002 estimate was 13 054 tons (based on ZIF for Canada, and STATLANT-21A or Research Reports for other countries whichever was considered a more reliable source).

The Canadian portion of skate catches during 1985-1991 was 30%, but 99% of that was discarded. However, almost all non-Canadian skate catches were retained. Approximately 90% of non-Canadian catches was reported by Spain, Portugal, and Russia (USSR) (Fig. 24). After 1993, almost 100% of non-Canadian skate catches was taken by those three countries. Commencing in 1994, Canada retained most of its skate catches in a new directed fishery (Fig. 25). Average annual catch of skate in the last 6 years was 13 298 t: 67% taken by Spain, and 24% taken by Canada.

Non-Canadian countries are thought to retain most of their skate catches. However, there are no statistics available to confirm this. In the Canadian fishery, skate discards (common before its skate-directed fishery began in 1994) are presently negligible. Regulations dictate that all skates must be landed. Thorny skates were only discarded because of spoilage. In 1985-1993, all reported Canadian skate landings were by-catch, averaging 61 tons per year (Fig. 25). Much of this by-catch came from mixed fisheries for Atlantic halibut/monkfish/white hake, and the redfish fishery. In 1994-2002, the skate-directed fishery accounted for 74% of the total skate landings for Canadian vessels, and average total catch was 2 848 tons. In 2002, the total skate catch was 2 486 tons, slightly higher than the previous four years.

Since the late-1980s, 100% of skate caught by non-Canadian countries has been from trawls, with 86% (1997-2002) taken in NAFO Div. 3N on the Tail of the Grand Banks (where the skate-directed fishery occurs; Fig. 24). Most of that directed fishery is prosecuted in August-December. The remaining non-Canadian skate catches were by-catch in the Greenland halibut fishery, which occurs throughout the year. However, Canada utilized gillnets, longlines, and otter trawls in the Canadian skate fishery. In the first four years of the Canadian skate fishery (1994-1997), otter trawls took most of the skate catch (46-75%). Since 1998, skate catches have been fairly evenly distributed between the three gears (Fig. 26).

In 1994, the first year of the directed Canadian skate fishery, most of the skate catch were taken in the fall (Fig. 27). Since then, most of the trawl catches were taken in spring occurring in NAFO Div. 3O and Subdiv. 3Ps near the dividing line. Canadian gillnet catches of thorny skate occurred in all months of the year, but were mainly concentrated in March-September in past years, and May-September in recent years (Table 5). Gillnet catches, primarily from Div. 3O in spring, were highest near the NAFO Div. 3O/3Ps line. Skate catch rates for gillnets averaged 2 500 kg per 100 nets. Longline catches also occurred in all months of the year, but were mainly during March-August in 2001-2002. The activity was more spread out over spring, and skate catch rates were generally approximately 180-200 kg per 1000 hooks.

Although most of the reported Canadian catches were in spring (March-June as compared to non-Canadian fishing on the Tail of the Grand Banks primarily after August), trawl catch rates (750 kg per hour) recorded by Canadian Fishery Observers were approximately the same as that reported in the fall Spanish skate fishery. The best Canadian skate catches were taken at the mouth of Haddock Channel (Fig. 1) in fall. All gears were fished in a narrow range of depths averaging 140 m. However, skate by-catch in the mixed fishery occurred at greater depths although at lower catch rates. Both spring and fall research surveys indicated that skates along the southwestern edge of the Banks were more densely aggregated at depths greater than where they were fished by Canada (see Fig. 14 and Fig. 15).

Annual Canadian catches have remained fairly stable, being regulated by quota. In 1997-2002, the Canadian allocation was set at 45.8% for mobile gear (otter trawl), and 54.2% for fixed gear (gillnets and longlines). Canadian skate fishery policies and regulatory measures for 2002 are summarized in Table 6. In contrast, the skate fishery outside Canada's 200-mile-limit is prosecuted by non-Canadian countries, and has been unregulated by quota limits. However, since July 2002, a minimum codend mesh size of 280 mm is required when directing for thorny skate in the NRA.

Size of thorny skate in commercial catches varied with gear type. Commercial skates must be measured for total length by Fishery Observers at sea, because landed products of the Canadian fleet are only wings (pectoral fins). As a result of low observer coverage of the Canadian skate fishery, length frequencies have been sparse since it began in 1994 (Table 1) and not all gears were sampled every year. Figure 28 provides a summary of 25 864 thorny skate total lengths in 1994-2002 collected by Canadian Fishery Observers indicating that shape of the commercial catch frequency varied with gear type. Gillnet and longline fisheries caught a similar size range of skates longer than 55 cm TL. Trawls captured skates as small as 30 cm TL with approximately 25% less than 55 cm TL. Figure 30, annual commercial length frequencies indicates that, where data were available, average length of commercial skates was similar over all years for each of the gear types.

Figure 30 compares the sizes of thorny skate taken in Canadian, Spanish, and Portuguese trawl fisheries. On average, Canadian trawls caught larger skates (approximately 25% were smaller than 55 cm TL consisting of immature fish) than in the Spanish trawl fishery. Skate size in Spanish commercial catches was between 30-85 cm TL, with a mode at 50 cm, and consisted of about 55% immature skates. Skate size in Russian catches ranged from 25-92 cm TL, with the majority between 32-60 cm (similar to Spanish skate sizes).

Minimum and maximum size and percent mature thorny skate in the commercial fisheries varied by year and country (Table 7). Median size at maturity used to determine proportion of mature fish in the catches was 54 cm based on ogives developed by Spain. Canada fished for thorny skate in the western part of NAFO Div. 3O while the remainder of the countries fished primarily in NAFO Div. 3N and to a lesser extent in 3O. The Portuguese length information is taken from a mix of fisheries, not just a directed fishery for thorny skate.

By-catch in the Canadian skate-directed fishery was derived from Canadian Fishery Observer data in 2002 (Fig. 32a and b). Gillnets took a larger proportion of by-catch (36-44%), than trawls or longlines (1-16%). In NAFO Div. 3O (adjacent to the NRA), the proportion of skate observed in the Canadian trawl fishery was 84%. The major by-catch was monkfish at 11%, and Atlantic halibut at 4%. However, the sample size was very small: only thirteen sets were observed in this fishery.

Figures 32c and d illustrate species composition in the non-Canadian skate-directed fishery of 2002, as recorded from fishing logbooks by Canadian Fishery Officers during vessel inspections at sea. Corresponding to depths less than 1 000 m within NAFO Div. 3NO (see Fig. 22), the area within the oval represents the skate fishing grounds. These data show a species composition that is very different from what was observed for Canada in the adjacent NAFO Div. 3O. For Spain, the percentage of skate was 20% in 3N, and 33% in 3O. The majority of the reported catch was Greenland halibut at 47% in 3N, and 44% in 3O. Other reported by-catch that was significant included white hake, and roundnose grenadier. Russian fishing logbooks indicated 17% skate, 30% Greenland halibut, 27% roundnose grenadier, and 14% roughhead grenadier. Portuguese logbooks indicated that catches in Div. 3N and 3O (respectively) contained 70 and 71% Greenland halibut, and 15% and 13% roundnose grenadier. Skates comprised only 5% and 3% in Div. 3N and 3O, respectively. Estonian logbooks showed 42% skate in 3N with a 25% by-catch of Greenland halibut, and a 12% by-catch of white hake.

An Index of Exploitation or relative F (reported commercial catch/spring research survey biomass index) was used to examine relative changes in the impact of fishing mortality (Fig. 33). The dotted line represents the Index with unconverted Engels survey biomass as the denominator. The solid line illustrates the Index with a “Campelenized” estimate of biomass as the denominator. The Index indicates that the exploitation of thorny skate tripled, from approximately 5% in the mid-1980s to about 15% in 1996-2002. This period of increased exploitation is concurrent with the period of thorny skate decline in NAFO Div. 3LNOPs.

The Index of Exploitation was highest in NAFO Div. 3N corresponding to the majority of the skate fishery being prosecuted primarily by Spain, Portugal, and Russia in the NAFO Regulatory Area. The Index increased from about 0.2 in the early-1980s, and fluctuated around 0.5 after 1995. Approximately 80% of reported skate catches was attributable to Div. 3N during the 1980s, and increased to about 90% in the 1990s. The Index was lowest in NAFO Subdiv. 3Ps, never exceeding 0.1. Skate biomass in 3Ps underwent the smallest decline, and commercial catches have remained relatively small.

Figure 34 shows that there is a relationship between relative spring survey biomass and commercial catch (upper panels) and exploitation index and relative biomass. This suggests that higher catches result in lower biomass indices.

Discussion

Across comparable areas, the fall estimate of biomass of thorny skate on average is about 40% higher than spring estimates, because skates have migrated to deeper water during the spring research survey period (Kulka and Mowbray, 1998). Therefore, a portion of the skate population is not available to survey trawls. However, the spring survey is used as a relative measure of changes in skate population size, because it surveys the entire stock management area while the fall series does not. In addition, the relative difference between spring and fall estimates has changed over time because of changes in skate patterns of migration. An increase in the spring/fall ratio of survey

indices during the early to mid-1990s indicates a change in the degree of migration (less onto the shelf in the fall, Kulka and Mowbray, 1998). This increase in degree of migration was concurrent with the period of decline. Thus, the thorny skate decline in the late-1980s and early-1990s may not be as great as the spring index suggests, because the degree of migration was greater in those years. For this reason and those stated above, the spring research survey greatly underestimates actual thorny skate biomass especially during the period of decline. However, the relative trend reflected in the survey indices (a decline in the late-1980s and early-1990s), and stability at the thorny skate's lowest historic level is valid.

Walsh's (1992) escapement experiments with Engels trawls compared thorny skate and three other groundfish species on the Grand Banks. He noted that escapement from the trawl for almost all sizes of skate was high unlike that of Atlantic cod, American plaice, and yellowtail. Maximum catching efficiency for thorny skates longer than 35 cm TL was about 40% (typically 80% or more for large sizes of the other three species). For all species tested, Engels gear appeared to be least effective in capturing thorny skate. Skates of all sizes were observed to escape under the trawl's footrope. Similar studies have not been conducted with Campelen trawls. However, a sudden increase in biomass (2.8 times) and abundance estimates (2.4 times) in both spring and fall research surveys after the change in trawl gear, coupled with a very similar average size and frequency composition of skate taken (comparing the first two Campelen years with the last two Engels years), indicates that Campelen gear is more efficient than Engels gear in capturing skate of all sizes. Given the observed avoidance behaviour of thorny skates when encountering research survey gear and their flattened body shape, catchability (q) of skate is lower in survey trawls as compared to other groundfish species.

Also, relative q of skates of different sizes in Engels versus Campelen gears is quite different to that of other demersal species. There is no apparent difference in average size of skate caught in both trawls, as observed with most other species. Thus, the value of q and an Engels to Campelen biomass/abundance conversion factor for thorny skate may be quite different than those for other demersal species. Estimates of biomass and abundance derived for thorny skates of all sizes from research surveys must be viewed as minimum values. Biomass and abundance indices presented in this paper likely represent considerably less than half of the actual skate biomass, and exploitation rates are maximum estimates.

Examining trends in relative biomass and abundance (the traditional method for investigating population trends) however, does not encompass all of the population dynamics of thorny skate. The analyses of spatial dynamics have revealed changes in the skate population that would otherwise be difficult or impossible to detect, using aggregated statistics from commercial or survey sources. In addition to changes in relative biomass, thorny skate has also undergone substantial changes in its distribution, starting in the 1980s (before the beginning of its decline in biomass). More evenly distributed over the entire stock area in the 1980s and even back to the 1950s (Kulka *et al.*, 1996), thorny skate are becoming increasingly aggregated on the southern part of the Grand Banks, and sections of the northern Bank are now devoid of skate. More than 50 years of data suggest that this is a relatively recent phenomenon. The rate of aggregation has accelerated in recent years, even when thorny skate biomass has been stable. The result is a decreasing area of occupancy and increasing catch rates in the commercial skate fishery which is prosecuted where the skates are aggregating.

A very similar pattern of aggregation was observed for northern cod just prior to its collapse (Rose and Kulka, 1999). Similar to skate, 64-75% of the Atlantic cod biomass in 1983-1988 occurred in 20% of the habitat. In contrast, during the decline of northern cod (1989-1991), hyper-aggregation (87-89% in 20% of the area) was observed. Aggregation and reduced area of occupancy led to the cod being increasingly more vulnerable to exploitation, because they became more densely concentrated where fishing occurred. This is very similar to what is now happening to thorny skate. Whether these spatial dynamics are an indication of a skate stock under stress is unknown. Distributional dynamics need to be monitored closely.

Canadian commercial inspection data indicated that Spanish catch rates increased between 1995-1997 and 1998-1999, and del Rio and Junquera (2001) noted a further increase in skate catch rates on the Tail of the Grand Banks in 2001. This increasing rate corroborates the spatial contraction and increasing density observed in spring research surveys following the period of decline. Therefore, thorny skates are becoming more vulnerable to the commercial fishery. The same level of fishing effort captures greater amounts of skate. Reported skate catches have risen sharply in 2000-2002, placing more fishing pressure on this species. Furthermore, most of the current fishing pressure is in the last area where thorny skates are found in dense concentrations. Thus, hyper-aggregation could result in a further

reduction of the 3LNOPs stock, given that thorny skates are aggregating into the area which is commercially fished. Commercial catch-per-unit-effort (CPUE) will probably remain steady or increase in the short term, even if the thorny skate population declines. Commercial catch rates provide no indication of a stock decline or even suggest an increase. Thus, non-spatial information could be misleading, and examination of thorny skate distribution dynamics constitutes an important component in understanding the status of the 3LNOPs stock.

Distributional changes were somewhat different for the various thorny skate life stages. Formerly occupying nearly the entire survey area, mature skates are now found in only half the available area, and are more densely concentrated there. Young of the year distributed around the entire edge of the Grand Banks, from the Laurentian Channel to the northern slope, and as deep as Canadian research surveys fished. As a result of the reduced area occupied by reproducing adults, area of occupancy for the early life stage of thorny skate has significantly diminished in the 1990s, and remains restricted. Recruitment has been very low since the mid-1990s in all NAFO Divisions, except Subdiv. 3Ps.

Both areas occupied and biomass of thorny skate on the Grand Banks have declined but causes for the decline in the mid-1980s to early-1990s are unclear. Most of the decline occurred on the northern Grand Bank in the area surrounding Newfoundland's Avalon Peninsula, where there was little or no commercial fishing effort (presently or historically). Thus, a commercial skate-directed fishery did not locally deplete thorny skate in areas where its decline was greatest. However, Kulka and Mowbray (1998) demonstrated that thorny skates undergo a seasonal migration moving to the shelf edge in December, and staying in deep water until June. Along the Nose of the Grand Banks, skates are taken as by-catch in a large fishery targeting Greenland halibut. Skate by-catch rates in that shelf-edge fishery (at depths of 700-1 400 m from Canadian Fishery Officer inspection reports) were approximately 70 kg per hour in December-June, when skates were dispersed offshore. In contrast, these by-catch rates were 40 kg per hour in other months when thorny skates were concentrated on the Bank (Kulka and Mowbray 1998). Actual amounts taken in that fishery is unclear. A larger proportion of skate removals comes from the Tail of the Grand Banks outside Canada's 200-mile-limit (NAFO Div. 3N), where skate are most densely concentrated during June to November a period coinciding with the skate-directed fishery.

The decline of thorny skate, particularly on the northern Grand Banks (NAFO Div. 3L), is also concurrent in space and time with the decline of many other demersal species (Atkinson 1994), and occurred during a period when bottom water temperatures were below average. The coldest section of the Grand Banks (north) corresponds to where thorny skate underwent its greatest decline. Thorny skates appear to select warmer areas of the Bank throughout the year (Kulka and Mowbray, 1998), and thus these cooler bottom temperatures may have been a factor in this decline. As with other Newfoundland groundfish species, it remains unclear what proportion of the skate decline can be attributed to fishing mortality, as opposed to natural mortality related to environmental effects. Simon and Frank (1996) have shown that thorny skate on the Scotian Shelf has also declined since 1982 and, similarly for this stock, the reasons are unclear.

By-catch estimates in the non-Canadian skate-directed fishery varied by reporting source. Information collected by Canadian Fishery Officers from fishing logbooks during vessel inspections at sea showed some unexpected patterns from the shallow section on the Tail of the Grand Banks. The species mix appeared to be more representative of shelf-edge species compositions. They varied significantly with those reported by other authors in previous years. Vinnichenko *et al.* (2002, Table 5) reported that in the Russian skate-directed fishery in the NRA, presumed to be NAFO Div. 3N, but not specified in that paper, skates dominated catches at about 88% in 2001 and 2002. With a codend mesh size of 240-320 mm in 2001, the predominant by-catch species was yellowtail flounder, American plaice and Atlantic cod, with very small amounts of redfish and "other" species were also specified. These authors also indicated that the proportions of different by-catch species were very similar in 2000, when a codend mesh size of 136 mm was used. This suggests that increasing codend mesh size to 240-320 cm has no significant effect on by-catch composition in the skate-directed fishery although such a large change in mesh size would be expected to make a substantial difference.

Del Rio and Junquera (2001) also indicated that American plaice and yellowtail flounder were the two main by-catch species in the Spanish skate-directed fishery in 1997 and 2000, with a 240 mm codend mesh. However, proportions of both species were much larger than those reported in the Russian fishery: American plaice at 14-31% of the by-catch, yellowtail flounder at 15-18% in 1997 and 2000, Greenland halibut 7% in 2000 and Atlantic cod 3% in 1997. Spanish reported slightly greater fishing depths (51-100 m) than those reported in the Russian fishery (40-80 m).

The Portuguese Research Report for 2002 (Vargas *et al.*, 2003) did not mention mesh size of the codend used in the Portuguese skate-directed fishery in NAFO Div. 3LNO, and only reported the dominant by-catch species. In Div. 3N, American plaice was the most common by-catch species at 22%, at depths of 160-252 m (this depth range would encompass that area of the Grand Banks where fishing effort targeted skates). Atlantic cod comprised 20% of the by-catch at depths of 93-1 100 m; Greenland halibut was 31% at depths of 675-1 299 m; and roughhead grenadier was 32% at depths of 1 023-1 121 m. In Div. 3O, by-catch of commercially important species remained significant at depths of 93-750 m: American plaice was 22.9-27.7%; Atlantic cod was 25.5%; and white hake was 19.4-24.4% (*ibid.*). In Div. 3L at greater depths (684-1 094 m), Greenland halibut was consistently the main by-catch species at 25-30% (*ibid.*). Thus, by-catch reported by countries fishing in the NRA were generally quite high, suggesting a mixed fishery rather than one directed for skate.

Conclusion and Prognosis

In managing a commercially exploited species, it is important to have some knowledge of the stock structure, reproductive biology, spatial distribution (and where commercial catches are taken in relation to this distribution) and nature of commercial catches in terms of amounts, skate size and age. Templeman (1884a, 1984b, 1987b) provided information on some of these topics, indicating limited movements (although the tagging experiments were very limited), demonstrating substantial differences in thorny skate size at maturity (one indicator of stock structure) in NAFO Div. 3LNOPs versus areas to the north. This maturity work has been updated by del Río and Junquera (2001), del Río (2002), and del Río *et al.* (2002), but their analyses were restricted to the southern Grand Banks.

Differences in stock structure within 3LNOPs are less than clear. Analyses of distribution in this study indicate that a single concentration of thorny skate on the southern Grand Banks (straddling the NAFO dividing lines between 3N and 3O, and between 3O and 3Ps) shifts seasonally relative to the Division lines, and between years. Whether this concentration of thorny skates constitutes a portion of a larger stock, a single stock, or several stocks, remains unclear. Distribution dynamics presented in this paper, and some of the earlier morphometric studies (such as in Templeman, 1987a), suggest a single stock. However, thorny skates distribute beyond the arbitrary boundary that has been designated for this stock. In addition, analyses of biomass, abundance, and average size per NAFO Division (as generated by STRAP methods) are confounded by seasonal distributional dynamics of thorny skate in relation to NAFO Divisional borders. This makes it difficult to interpret inter-annual trends in biomass, when analysed by NAFO Division. Stock definition, including determination of spatial boundaries, remains to be done.

Elasmobranchs (skates and sharks) in general, and thorny skates in this study, have a low reproductive potential due to slow growth rates, late sexual maturation, low fecundity, and long reproductive cycles (referred to as K-selected). These characteristics result in low intrinsic rates of increase for the species (Smith *et al.*, 1998), which are thought to have very low resilience to fishing mortality (Hoenig and Gruber, 1990). Frisk *et al.* (2002) with their analyses for several northwest Atlantic skates, supported the notion that long-lived, slower growing, late maturing species are vulnerable to exploitation (see discussion below).

However, although elasmobranchs are not as fecund as most teleosts, it does not immediately follow that they have a lower reproductive capacity, because newly hatched skates have a much higher probability of survival. A more appropriate comparison would be the number of juveniles produced per female per year. It may be that the effective yield per recruit for many elasmobranchs is not greatly different from more fecund teleost species. Nonetheless, as for any species, thorny skates are susceptible to over-exploitation.

Perhaps the more important issue is the recovery of elasmobranch population(s) from depletions, (caused by both natural phenomena and human activities). Due to low reproductive potential, recovery could require many years. The population of thorny skate on the Grand Banks is at its lowest historic level. Thus, even if environmental conditions were favourable and commercial fishing pressure was low, recovery of thorny skate in 3LNOPs may take much longer than more fecund demersal species. This issue must be considered when considering management options.

Frisk *et al.* (2002) in their study of the population dynamics predicting exploitation limits using matrix analyses of little skate *Leucoraja erinacea*, winter skate and barndoor skate *Dipturus laevis*: also suggested that conservation measures should focus on juvenile and adult stages of these northwest Atlantic elasmobranch species (and perhaps elasmobranchs in general). Our approach is consistent with this proposed strategy. Our stage based analyses show

that the greatest variation, both spatially and in the population dynamics occurred in the young of the year and the mature components. Thus, it is these stages that should be the focus of an assessment of the status of the stock should focus.

The analyses of spatial dynamics have revealed changes in the thorny skate population that would otherwise be difficult or impossible to detect with standard analytical (non-spatial) analyses. Hyper-aggregation was observed after the mid-1990s, skate population size had stabilized. A continuation of this trend could result in a further reduction of the stock, given that thorny skates are concentrating in the area that is commercially fished. Commercial catch rates will probably remain steady or increase in the short term even if the thorny skate population declined further. These rates would give no indication of a stock decline. Thus, examination of thorny skate distribution dynamics constitutes an important component in understanding the status of the 3LNOPs stock, and must be closely monitored. This approach would benefit any assessment where geo-referenced data were available.

In determining an appropriate level of exploitation for thorny skate, research survey indices represent a minimum estimate of skate population size, and must be balanced with the knowledge that thorny skate biomass index has declined to its lowest historical level (presently showing no signs of recovery). The average total skate catch for 1996-97 was 8 930 tons, representing approximately 13% of the average spring survey estimate over the same period. This constitutes a substantial reduction from the 20% exploitation rate observed in 1995. However, if there was change in skate catchability due to the change in survey gear in fall 1995 (which appears to be the case), then a comparison of exploitation rates between periods is not valid.

Whether the current level of exploitation of thorny skate is sustainable is uncertain. Biomass has remained stable, but thorny skate distribution dynamics suggest that the 3LNOPs stock may decline at the current rate of exploitation. The Index of Exploitation outside of Canada's 200-mile-limit (which is fished exclusively by non-Canadian fleets), averaged 6.5 times higher than in areas fished by Canada inside 200 miles. Regardless, spatial dynamics in the form of hyper-aggregation suggest that current exploitation rates may be too high to affect recovery of the stock. Even if fishing mortality is sufficiently low to allow recovery, the k selected reproductive strategy likely means a protracted recovery process.

Deficiencies

There remain a number of important limitations to our knowledge of thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps. Most importantly, information is lacking on such characteristics as individual growth rate and details on the age structure of skate population(s). No ageing of thorny skate has been attempted; therefore, age disaggregated analyses are not possible.

Information on maturity has recently been updated by Junquera and del Rio (MS 2001), and del Rio (MS 2002) but there is a long gap when maturity information is unavailable (1972-1997). Biological sampling of commercial skate catches continues to be inadequate, and information on commercial catches is restricted to gross removals by weight although sampling has improved in recent years.

There are still uncertainties with respect to reported skate landings although this study attempted to determine a more accurate account of skate catches. Non-Canadian catches of skate outside Canada's 200-mile-limit constitute the largest component of removal and remain unregulated. There has also been some concern about the accuracy of non-Canadian skate catches reported to the Northwest Atlantic Fisheries Organization (NAFO). DFO's Conservation and Protection Division (Fisheries Management Branch – NL Region) has suggested that, during the 1980s, up to about 60% of reported skate catches in some years may have been unreported catches of other important groundfish species. Canadian Fishery Officer inspection estimates in 1992-1995 were lower than NAFO reported catches of skate for those years. However, C&P inspection estimates exceeded NAFO skate catches in 1996-1998. There are indications that skate catch information from outside 200 miles continues to be unreliable. Given the uncertainties in the catch data and unknown catchability of survey trawls for skates, these are carried over into estimates of exploitation, or what level is most appropriate for a sustainable thorny skate fishery. This analysis presents an Index of Exploitation as a proxy.

In addition, much of the historical baseline work (food and feeding, stock structure, morphology, reproduction) has not been updated in recent years. Ageing and stock structure research would greatly enhance knowledge of the current status of thorny skate in 3LNOPs. Tagging studies concentrating on offshore aggregations of thorny skate would lead to

a better understanding of the mechanism and timing of its migrations. Accurate records of catch and sampling of commercial skate catches at sea should be enhanced through the Fishery Observer Program and reported to NAFO in order to define removals of thorny skate by size and, preferably, by age and sex.

Prognosis

Thorny skate has undergone substantial changes in its distribution, commencing in the 1980s. It has become increasingly aggregated on the southern section of the Grand Banks, and the rate of aggregation has accelerated in recent years. The result is a decreasing area of occupancy, and increasing catch rates particularly in the non-Canadian commercial fishery (which occurs where the skate are aggregated). These concentrations are spatially concurrent with the major fishing grounds. A very similar pattern was observed for northern cod just prior to its collapse. The result of hyper-aggregation is that thorny skates are increasingly more vulnerable to exploitation, because they become more densely concentrated where commercial fishing occurs. In addition, the degree of skate migration increased during its period of decline, but has since returned to previous levels. Whether these spatial dynamics are an indication of a stock under stress is unknown. As with numerous other demersal species, the proportion of decline that is attributable to changes in fishing mortality versus environmental influences remains uncertain. Whatever the causes, the thorny skate stock in 3LNOPs has remained at its lowest level since the mid-1990s, and has undergone distributional changes that may reflect stress in the population(s). This stock is not showing any signs of recovery and is possibly even in the early stages of collapse.

Outlook

Thorny skate underwent a decline in the late-1980s to early-1990s. Since then, abundance has remained relatively constant at the lowest historic level. With the exception of the western extent of thorny skate distribution on St. Pierre Bank (NAFO Subdiv. 3Ps), information on lengths of thorny skate from research surveys indicates that recruitment has been low in all areas since 1996, except perhaps 3Ps. Recruitment on the northern Grand Banks (NAFO Div. 3L) has been absent during this period.

Analysis of research data indicates that thorny skate declined earlier and at a greater rate in the north, as compared to the southern part of its range. This decline, which began in the early-1980s, accelerated in the early-1990s. In recent years, the thorny skate stock in 3LNOPs has reached its lowest level in all areas, and its biomass shows no sign of recovery. The rate of its northern decline has also increased in recent years. As a result of its decrease in biomass, the Index of Exploitation for thorny skate has increased steadily since the 1980s.

Available evidence indicates that, at best, the thorny skate stock in 3LNOPs is stable at a low level of biomass. At the worst, recent changes in distribution have reduced its range, and made this stock more vulnerable to overfishing. Low recruitment over most of 3LNOPs in the last seven years suggests that this stock may not be fully replenishing itself. Given the historical decline in biomass indices, the lack of comparable data on current stock status, and uncertainty about the ability of the thorny skate stock(s) to rebuild, an increase in commercial harvest levels is not considered prudent.

Management Considerations

A Canadian skate-directed fishery is a relatively recent development. The Canadian Total Allowable Catch (TAC) for the thorny skate stock in 3LNOPs is 3 000 tons. Relative to other groundfish fisheries, the commercial value of this fishery has remained low (about 45 cents per lb) over the life of the fishery, and markets have been limited. The result is that the Canadian quota has not been taken. However, the majority of the catch of this stock (90% of total catch in 2000; average of 67% since 1985) occurs outside Canada's 200-mile-limit, where there are no quotas. In addition, the non-Canadian skate fishery in the NRA has expanded in recent years, although skate catch reports from this area continue to be unreliable.

The Index of Exploitation in NAFO Div. 3N, which is fished exclusively by non-Canadian fleets outside Canada's 200-mile-limit, averaged 6.5 times higher than areas fished by Canada inside 200 miles. Both Canadian and non-Canadian fleets fish the same concentration (most probably the same stock) of thorny skate. Thus, if significant reductions in skate catches are to take place, the majority would have to occur in the unregulated non-Canadian fishery outside 200 miles.

As stated in the Introduction, under Annex 1. No. 9, the Fisheries Commission of NAFO requested Scientific Council to provide Scientific Advice on Management with respect to thorny skate in Div. 3LNO in 2004 (Note that the managed stock area also includes NAFO Subdiv. 3Ps, hence the references to that area in the supporting documentation and this report). Responses to each request are as follows:

a) Information on exploitation rates in recent years, as well as information on by-catches of other groundfish in the 3LNO skate fishery.

The index of exploitation or relative F (commercial catch/spring survey biomass index) for thorny skate tripled from 0.05 in the mid-1980s to about 0.15 in 1996-2002 (refer to Fig. 33). The increasing index is concurrent with the period of stock decline. The Index varied among areas; highest in NAFO Div. 3N corresponding to the majority of the skate fishery in the NRA and lowest in Subdiv. 3Ps. The 3N Index increased from about 0.2 in the early-1980s, fluctuating around 0.5 after 1995 while the 3Ps index did not exceed 0.1. Catchability (q) of thorny skate in survey gears is low, thus the indices can be considered to be maximum estimates of the rate of exploitation. About 80% of the commercial catch was from NAFO Div. 3N in the 1980s, increasing to about 90% in the 1990s.

Reported by-catch in the Spanish 3NO skate fishery diminished with time ranging between 9.8% (2002) and 22.5% (1998). By-catch consisted of American plaice (5.4-14.1%), yellowtail flounder (1.5-6.7%) and cod (0.6-0.7%). Considerably higher by-catch rates were reported by Portugal, totaling about 79% for all species combined in a 3NO mixed fishery. Dominant by-catch species were Greenland halibut, American plaice and white hake. Reported by-catch in the Russian 3NO directed fishery amounted to 12% mainly yellowtail flounder (5%), American plaice (4%) and cod (3%). By-catch in the Canadian fishery, further to the west in NAFO Div. 3O was 16%, comprising mainly monkfish and Atlantic halibut.

Refer to Recommended Research, below indicating the need to collect and analyse commercial set by set geo-referenced data in the NRA in order to adequately address the second part of this request.

b) Information on abundance indices and the distribution of the stock in relation to groundfish resources, particularly for the stocks which are under moratorium;

The spring relative abundance of thorny skate mirrored biomass trends (refer to Fig. 4). The indices increased between the early-1970s and the mid-1980s then declined rapidly between 1985 and 1994. Most of the decline occurred on the northern part of the Grand Bank in NAFO Div. 3L and 3O. Biomass has remained low since 1994 and the trend has remained relatively flat.

Based on 2001-2002 autumn survey data on the Tail of the Bank, corresponding to the season and location of the directed fishery, areas of high abundance of thorny skate corresponded closely with areas high abundance of yellowtail flounder (refer to Fig. 31) due to a high degree of overlap in the distribution of the two species. Overlap of distribution is less for the American plaice and cod. Areas of high American plaice abundance corresponded to mid-range abundance of thorny skate and high cod abundance corresponded to both low and high skate abundance areas.

c) Information on the distribution of thorny skate in Div. 3LNO, as well as a description of the relative distribution inside and outside the NAFO Regulatory Area (NRA).

The distribution of thorny skate on the Grand Banks has undergone significant changes. In the early-1980s, they were widely distributed over the entire Grand Banks in moderate to high concentrations (refer to Fig. 14, 15 and 16). Historically, thorny skate occupied about 97% of the stock area but currently occupies about 75% and has become concentrated. In this latter period (2000-2001), corresponding to where bottom temperatures are the coldest, much of the northern Grand Bank contained no thorny skate.

The remaining biomass has become increasingly concentrated (hyper-aggregated) on the southwestern part of the Grand Banks. In the early-1980s, about 55% of the biomass of thorny skate was found in the southern half of the stock area. In 2002, >80% of the biomass is now concentrated within 20% of the total area. Although the biomass has been stable since the mid-1990s, the distribution has continued to hyper-aggregate. Areas fished correspond to where the

skate are aggregating and thus commercial catch rates have remained high during the period of decline. A very similar pattern of aggregation was observed for northern cod just prior to its collapse.

Based on spring and autumn Canadian survey data from 1995-1999, about 17% of the biomass of thorny skate was found in the NRA, mainly in NAFO Div. 3N. However, about 90% of the catch came from the NRA in the 1990s.

d) Advice on reference points and conservation measures that would allow for exploitation of this resource in a precautionary manner.

Historic levels of fishing mortality are uncertain. However, relative SSB and recruitment were related for this K selected species (refer to Fig. 18). Following the period of decline (1985-1994), the average of the lowest 3 years (1993-1995) of the female index of SSB was 6 906 tons compared to the highest 3 years in the series (1985-1987), 24 444 tons. A catch and index of exploitation corresponding to a female SSB of 10 000 tons was 15 000 tons and 0.12 respectively.

Spatial dynamics are seldom considered in the definition of reference levels for a commercially exploited stock (although it is an important consideration for species at risk). Given the changes in distribution undergone by this stock, an alternate reference level may constitute a measure of the area occupied by the stock or a measure of concentration of the biomass. An area of occupancy greater than 75%, the current level, is recommended. These analyses represent the first step toward defining limit reference points for thorny skate.

Given that the fishery in the NRA is currently not under regulation by quota, an initial conservation measure would be to institute a precautionary quota that is applicable throughout the entire stock area.

e) Information on annual yield potential for this stock in the context of (d) above.

There is insufficient information at this time on which to base predictions of annual yield potentials.

f) Identification and delineation of fishery areas and exclusion zones where fishing would not be permitted, with the aim of reducing the impact on the groundfish stocks which are under moratorium, particularly juveniles.

Analyses of distribution of juvenile cod, American plaice and yellowtail flounder in NAFO Div. 3NO indicate significant overlap with thorny skate (refer to Fig. 31). The main nursery area for yellowtail flounder was located on the southern portion of the southeast Shoal and the area just to the west. This corresponds closely with the northern part of the concentration of thorny skate and the fishery in the NRA. Cod and American plaice juvenile distributions are also associated with the Southeast Shoal and area to the west but are more variable with a lesser degree of overlap with the thorny skate fishing grounds. Nonetheless, relatively high by-catches of American plaice, yellowtail flounder and cod would be expected and this appears to be borne out by observer data and reported landings.

An area closed to fishing intended to protect juvenile yellowtail flounder and cod would constitute a significant portion of the northern extent of the thorny skate fishing grounds while one intended to protect American plaice would overlap with the southern portion of the grounds.

h) Information on the size composition in the current catches and comment on these sizes in relation to the size at sexual maturity.

Minimum and maximum size and percent mature thorny skate in the commercial fisheries varied by year and country (refer to Table 7). Median size at maturity used to determine proportion of mature fish in the catches was 54 cm based on ogives developed by Spain. Canada fished for thorny skate in the western part of NAFO Div. 3O while the remainder of the countries fished primarily in NAFO Div. 3N and to a lesser extent in 3O. The Portuguese length information is taken from a mix of fisheries, not just a directed fishery for thorny skate.

Research Recommendations

The following areas of research would be required to facilitate monitoring the status of thorny skate and providing management advice:

- Recent work on maturity has permitted the examination of life stage dis-aggregated trends such as SSB/recruitment relationships. Derivation of exploitation indices series for various life stage components, particularly the SSB, can provide some of the input required to derive reference points and conservation limits.
- Age based analyses of the population would yield more options in terms of providing management advice for the stock. Thorny skates have not previously been aged but thorns and vertebrae may provide the best materials for aging.
- Spatial dynamics of various population components should be examined in relation to environmental and fishery related influences to better understand the factors that affect the population status.
- Thorny skate extend over a wide area. Research is required to determine stock structure of the species.
- Fishing mortality and its effects on the population are not well understood. Continued and enhanced collection of information on size, sex and maturity of commercial catches of thorny skate is required to define the effects of fishing on the population.
- Analysis of detailed, geo-referenced commercial fishery data for NAFO Div. 3NO corresponding to the directed skate fishery in the NRA is required to quantify by-catch levels and to spatially define species interactions.
- Information on annual yield potential and reproductive potential is required to provide quantitative fisheries management advice.
- The application of assessment models that may facilitate quantitative fisheries management advice for this stock should be examined.

Summary

- The abundance of thorny skate increased from the early-1970s to the mid-1980s, then declined to its lowest level in the mid-1990s. The population has since become stable at this low level.
- Thorny skates on the Grand Banks undergo a seasonal migration. They are concentrated along the outer Bank in December-June, and on the Bank in July-November. The degree of offshore migration (proportion of skates off the Bank in the winter/spring) appears to have intensified during the period of population decline (mid-1980s to the early-1990s).
- Thorny skates have become increasingly concentrated in a smaller area (hyper-aggregation). The extent to which this is occurring increased, following the decline in biomass. Once densely concentrated on the northern Grand Banks, thorny skates are now absent from much of this area. Approximately 90% of thorny skate biomass is presently concentrated in 20% of the area (near the edge of the southwestern Grand Banks).
- The southwestern edge of the Grand Banks is where the skate-directed fishery occurs, and commercial catch rates (inside and outside 200 miles) have increased, because thorny skates have become increasingly more aggregated.
- Concurrent with the decline in thorny skate biomass, a reduction in average weight was observed, 2 kg in the mid-1970s, 1.3 kg in the mid to late-1980s and 0.5 kg in the mid-1990s. Since 1994, the average weight of thorny skates has increased to about 1.5 kg.
- Small thorny skates (10-30 cm TL) have been largely absent from the northern Grand Banks (NAFO Div. 3L) since 1996. The largest occurrence of small skates is presently found in NAFO Subdiv. 3Ps.
- Since the mid-1990s, 16.5% of thorny skate biomass has been outside Canada's 200-mile-limit, while 72% of skate catches were taken outside 200 miles.
- Reported commercial catches increased substantially in 2000, as compared to the previous five years. This increase occurred outside 200 miles.
- The Exploitation Index (commercial catch/spring research survey biomass index) increased from approximately 5% in the mid-1980s to about 15% in 2000. This coincides with the period of decline of the population.
- Causes for the decline of thorny skate in 3LNOPs are unclear. The area of greatest decline, on the Northern Grand Banks, is where little or no fishing occurred but where bottom temperatures reached a minimum. The period of decline coincided with the decline of many other demersal species. On the other hand, there was a significant inverse relationship between relative exploitation and relative biomass/abundance.

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Table 1. Number of thorny skates measured for total length in commercial catches, 1994-2002. Data are from Canadian Fishery Observers.

| Year | Gear | Males | Females | Unsexed | Total |
|--------------|-------------|--------------|----------------|----------------|--------------|
| 1994 | Otter trawl | 820 | 298 | | 1118 |
| 1995 | Longline | 147 | 376 | | 523 |
| 1996 | Otter trawl | 270 | 260 | | 530 |
| 1998 | Otter trawl | 237 | 332 | | 569 |
| | Gillnet | 111 | 218 | | 329 |
| 1999 | Otter trawl | 548 | 280 | | 828 |
| | Gillnet | | 381 | | 381 |
| | All | 548 | 661 | | 1209 |
| 2000 | Gillnet | 2307 | 5475 | | 7782 |
| | Longline | 336 | 194 | | 530 |
| | All | 2643 | 5669 | | 8312 |
| 2001 | Otter trawl | 1529 | 1331 | | 2860 |
| | Gillnet | 1794 | 2275 | 393 | 4462 |
| | All | 3323 | 3606 | 393 | 7322 |
| 2002 | Otter trawl | 92 | 96 | | 148 |
| | Gillnet | 1781 | 3983 | | 5764 |
| | All | 1873 | 4079 | | 5952 |
| Total | | 9972 | 15499 | 393 | 25864 |

Table 2a. Biomass, abundance, and mean weight of thorny skate from spring research surveys, 1971-2002. Surveys were conducted with an Engels trawl during 1971-spring 1995, and Campelen trawl during fall 1995-2002.

Biomass (tonnes)

| Year | Div. 3L | Div. 3N | Div. 3O | Div. 3Ps | All Divisions |
|------|---------|---------|---------|----------|---------------|
| 1971 | 35,100 | 11,308 | | | 46,408 |
| 1972 | 23,391 | 36,085 | | 16,422 | 75,898 |
| 1973 | 17,993 | 27,241 | 23,288 | 13,417 | 81,939 |
| 1974 | 40,252 | 21,823 | | 22,428 | 84,503 |
| 1975 | 31,191 | 21,579 | 25,328 | 5,719 | 83,817 |
| 1976 | 40,242 | 39,416 | 80,235 | 29,506 | 189,399 |
| 1977 | 63,602 | 44,092 | 19,632 | 12,326 | 139,652 |
| 1978 | 37,944 | 16,394 | 17,803 | 7,574 | 79,715 |
| 1979 | 44,377 | 23,877 | 19,820 | 10,094 | 98,168 |
| 1980 | 41,247 | 26,141 | 21,488 | 21,149 | 110,025 |
| 1981 | 55,274 | 17,293 | 12,311 | 11,450 | 96,329 |
| 1982 | 37,768 | 30,161 | 22,868 | 7,363 | 98,161 |
| 1983 | | 13,704 | | 13,704 | 13,704 |
| 1984 | 6,799 | 22,724 | 24,026 | 7,999 | 61,548 |
| 1985 | 40,296 | 34,031 | 43,434 | 14,549 | 132,309 |
| 1986 | 27,506 | 43,435 | 18,360 | 18,790 | 108,091 |
| 1987 | 32,298 | 23,833 | 20,081 | 16,022 | 92,234 |
| 1988 | 27,616 | 19,561 | 34,400 | 11,808 | 93,385 |
| 1989 | 28,855 | 19,347 | 15,816 | 17,430 | 81,448 |
| 1990 | 17,839 | 18,693 | 24,388 | 9,553 | 70,473 |
| 1991 | 8,739 | 11,388 | 38,978 | 24,226 | 83,331 |
| 1992 | 4,623 | 9,074 | 22,807 | 15,234 | 51,738 |
| 1993 | 3,365 | 7,303 | 13,824 | 5,476 | 29,968 |
| 1994 | 1,543 | 4,013 | 11,368 | 6,512 | 23,436 |
| 1995 | 1,102 | 1,112 | 12,726 | 9,812 | 24,752 |
| | | | | | |
| 1996 | 4,992 | 11,010 | 35,529 | 21,851 | 73,382 |
| 1997 | 3,969 | 9,703 | 28,293 | 20,705 | 62,670 |
| 1998 | 5,807 | 13,186 | 42,351 | 28,629 | 89,973 |
| 1999 | 7,278 | 26,254 | 54,045 | 32,062 | 119,639 |
| 2000 | 14,011 | 27,861 | 40,917 | 22,528 | 105,317 |
| 2001 | 10,383 | 29,197 | 59,078 | 24,566 | 123,224 |
| 2002 | 8,580 | 13,987 | 38,025 | 22,127 | 82,719 |

Abundance (thousands)

| Year | Div. 3L | Div. 3N | Div. 3O | Div. 3Ps | All Divisions |
|------|---------|---------|---------|----------|---------------|
| 1971 | 11,533 | 3,921 | | | 15,454 |
| 1972 | 11,037 | 15,634 | | 5,615 | 32,286 |
| 1973 | 12,114 | 11,033 | 12,830 | 6,822 | 42,799 |
| 1974 | 26,621 | 11,627 | | 11,136 | 49,384 |
| 1975 | 24,762 | 8,273 | 12,183 | 1,654 | 46,872 |
| 1976 | 28,294 | 21,420 | 28,595 | 19,118 | 97,427 |
| 1977 | 25,240 | 16,375 | 7,518 | 8,840 | 57,973 |
| 1978 | 21,879 | 10,117 | 7,578 | 11,270 | 50,844 |
| 1979 | 23,370 | 13,859 | 7,496 | 8,310 | 53,034 |
| 1980 | 19,206 | 15,847 | 16,788 | 12,200 | 64,041 |
| 1981 | 33,223 | 9,694 | 5,912 | 12,195 | 61,024 |
| 1982 | 21,391 | 23,623 | 11,055 | 3,562 | 59,632 |
| 1983 | | | | 12,249 | 12,249 |
| 1984 | 3,130 | 10,424 | 10,171 | 3,891 | 27,616 |
| 1985 | 26,067 | 18,710 | 20,712 | 22,816 | 88,305 |
| 1986 | 21,170 | 22,064 | 8,733 | 14,939 | 66,906 |
| 1987 | 16,178 | 13,859 | 14,066 | 11,617 | 55,720 |
| 1988 | 14,475 | 10,940 | 17,765 | 7,869 | 51,049 |
| 1989 | 16,673 | 12,409 | 7,305 | 10,687 | 47,074 |
| 1990 | 18,156 | 29,610 | 16,578 | 8,820 | 73,164 |
| 1991 | 14,372 | 18,409 | 14,543 | 20,766 | 68,090 |
| 1992 | 15,242 | 8,531 | 14,697 | 8,889 | 47,359 |
| 1993 | 11,473 | 7,053 | 6,209 | 6,612 | 31,347 |
| 1994 | 6,611 | 7,258 | 7,895 | 7,943 | 29,707 |
| 1995 | 3,851 | 2,900 | 11,067 | 8,055 | 25,873 |
| | | | | | |
| 1996 | 10,416 | 10,636 | 22,731 | 25,591 | 69,374 |
| 1997 | 6,804 | 13,554 | 25,635 | 18,379 | 64,372 |
| 1998 | 7,764 | 10,141 | 34,130 | 22,781 | 74,816 |
| 1999 | 8,273 | 15,967 | 36,042 | 20,212 | 80,494 |
| 2000 | 12,512 | 16,027 | 28,525 | 18,574 | 75,638 |
| 2001 | 8,521 | 16,276 | 33,321 | 17,606 | 75,724 |
| 2002 | 5,920 | 8,469 | 32,902 | 17,560 | 64,851 |

Mean weight (kg)

| Year | Div. 3L | Div. 3N | Div. 3O | Div. 3Ps | All Divisions |
|------|---------|---------|---------|----------|---------------|
| 1971 | 3.04 | 2.88 | | | 3.00 |
| 1972 | 2.12 | 2.31 | | 2.92 | 2.35 |
| 1973 | 1.49 | 2.47 | 1.82 | 1.97 | 1.91 |
| 1974 | 1.51 | 1.88 | | 2.01 | 1.71 |
| 1975 | 1.26 | 2.61 | 2.08 | 3.46 | 1.79 |
| 1976 | 1.42 | 1.84 | 2.81 | 1.54 | 1.94 |
| 1977 | 2.52 | 2.69 | 2.61 | 1.39 | 2.41 |
| 1978 | 1.73 | 1.62 | 2.35 | 0.67 | 1.57 |
| 1979 | 1.90 | 1.72 | 2.64 | 1.21 | 1.85 |
| 1980 | 2.15 | 1.65 | 1.28 | 1.73 | 1.72 |
| 1981 | 1.66 | 1.78 | 2.08 | 0.94 | 1.58 |
| 1982 | 1.77 | 1.28 | 2.07 | 2.07 | 1.65 |
| 1983 | | | | 1.12 | 1.12 |
| 1984 | 2.17 | 2.18 | 2.36 | 2.06 | 2.23 |
| 1985 | 1.55 | 1.82 | 2.10 | 0.64 | 1.50 |
| 1986 | 1.30 | 1.97 | 2.10 | 1.26 | 1.62 |
| 1987 | 2.00 | 1.72 | 1.43 | 1.38 | 1.66 |
| 1988 | 1.91 | 1.79 | 1.94 | 1.50 | 1.83 |
| 1989 | 1.73 | 1.56 | 2.17 | 1.63 | 1.73 |
| 1990 | 0.98 | 0.63 | 1.47 | 1.08 | 0.96 |
| 1991 | 0.61 | 0.62 | 2.68 | 1.17 | 1.22 |
| 1992 | 0.30 | 1.06 | 1.55 | 1.71 | 1.09 |
| 1993 | 0.29 | 1.04 | 2.23 | 0.83 | 0.96 |
| 1994 | 0.23 | 0.55 | 1.44 | 0.82 | 0.79 |
| 1995 | 0.29 | 0.38 | 1.15 | 1.22 | 0.96 |
| | | | | | |
| 1996 | 0.48 | 1.04 | 1.56 | 0.85 | 1.06 |
| 1997 | 0.58 | 0.72 | 1.10 | 1.13 | 0.97 |
| 1998 | 0.75 | 1.30 | 1.24 | 1.26 | 1.20 |
| 1999 | 0.88 | 1.64 | 1.50 | 1.59 | 1.49 |
| 2000 | 1.12 | 1.74 | 1.43 | 1.21 | 1.39 |
| 2001 | 1.22 | 1.79 | 1.77 | 1.40 | 1.63 |
| 2002 | 1.45 | 1.65 | 1.16 | 1.26 | 1.28 |

Table 2b. Biomass, abundance, and mean weight of thorny skate from fall research surveys, 1981-2002. Surveys were conducted with an Engels trawl during 1981-spring 1995, and Campelen trawl during fall 1995-2002.

Biomass (tonnes)

| Year | Div. 3L | Div. 3N | Div. 3O | All Divisions |
|------|---------|---------|---------|---------------|
| 1971 | | | | |
| 1972 | | | | |
| 1973 | | | | |
| 1974 | | | | |
| 1975 | | | | |
| 1976 | | | | |
| 1977 | | | | |
| 1978 | | | | |
| 1979 | | | | |
| 1980 | | | | |
| 1981 | 36,467 | | | |
| 1982 | 65,293 | | | |
| 1983 | 65,157 | | | |
| 1984 | 58,685 | | | |
| 1985 | 55,533 | | | |
| 1986 | | | | |
| 1987 | 34,584 | | | |
| 1988 | 42,484 | | | |
| 1989 | 26,723 | | | |
| 1990 | 37,632 | 26,559 | 38,384 | 102,575 |
| 1991 | 20,730 | 40,929 | 29,735 | 91,394 |
| 1992 | 15,862 | 20,858 | 16,686 | 53,406 |
| 1993 | 9,487 | 13,987 | 25,313 | 48,787 |
| 1994 | 6,379 | 20,059 | 12,570 | 39,008 |
| | | | | |
| 1995 | 11,306 | 40,775 | 44,653 | 96,734 |
| 1996 | 14,459 | 28,629 | 36,969 | 80,057 |
| 1997 | 7,534 | 43,075 | 58,160 | 108,769 |
| 1998 | 9,205 | 34,279 | 39,280 | 82,764 |
| 1999 | 13,614 | 32,609 | 42,609 | 88,832 |
| 2000 | 17,722 | 61,202 | 40,861 | 119,785 |
| 2001 | 16,420 | 34,311 | 62,156 | 112,887 |
| 2002 | 11,068 | 52,856 | 40,593 | 104,517 |

Abundance (thousands)

| Year | Div. 3L | Div. 3N | Div. 3O | All Divisions |
|------|---------|---------|---------|---------------|
| 1971 | | | | |
| 1972 | | | | |
| 1973 | | | | |
| 1974 | | | | |
| 1975 | | | | |
| 1976 | | | | |
| 1977 | | | | |
| 1978 | | | | |
| 1979 | | | | |
| 1980 | | | | |
| 1981 | 33,523 | | | |
| 1982 | 36,223 | | | |
| 1983 | 42,687 | | | |
| 1984 | 29,330 | | | |
| 1985 | 35,566 | | | |
| 1986 | | | | |
| 1987 | 33,421 | | | |
| 1988 | 35,799 | | | |
| 1989 | 31,733 | | | |
| 1990 | 48,247 | 18,122 | 21,980 | 88,349 |
| 1991 | 30,403 | 25,260 | 12,264 | 67,927 |
| 1992 | 38,867 | 13,989 | 10,196 | 63,053 |
| 1993 | 25,414 | 12,840 | 17,100 | 55,354 |
| 1994 | 18,263 | 20,720 | 12,706 | 51,689 |
| | | | | |
| 1995 | 23,284 | 37,322 | 30,582 | 91,188 |
| 1996 | 23,483 | 22,694 | 45,145 | 91,322 |
| 1997 | 13,448 | 30,540 | 50,047 | 94,035 |
| 1998 | 8,917 | 21,132 | 29,785 | 59,834 |
| 1999 | 10,448 | 25,117 | 31,847 | 67,412 |
| 2000 | 12,536 | 31,419 | 39,918 | 83,873 |
| 2001 | 12,655 | 21,353 | 42,095 | 76,103 |
| 2002 | 7,541 | 30,925 | 24,488 | 62,954 |

Mean Weight (kg)

| Year | Div. 3L | Div. 3N | Div. 3O | All Divisions |
|------|---------|---------|---------|---------------|
| 1971 | | | | |
| 1972 | | | | |
| 1973 | | | | |
| 1974 | | | | |
| 1975 | | | | |
| 1976 | | | | |
| 1977 | | | | |
| 1978 | | | | |
| 1979 | | | | |
| 1980 | | | | |
| 1981 | 1.09 | | | |
| 1982 | 1.80 | | | |
| 1983 | 1.53 | | | |
| 1984 | 2.00 | | | |
| 1985 | 1.56 | | | |
| 1986 | | | | |
| 1987 | 1.03 | | | |
| 1988 | 1.19 | | | |
| 1989 | 0.84 | | | |
| 1990 | 0.78 | 1.47 | 1.75 | 1.16 |
| 1991 | 0.68 | 1.62 | 2.42 | 1.35 |
| 1992 | 0.41 | 1.49 | 1.64 | 0.85 |
| 1993 | 0.37 | 1.09 | 1.48 | 0.88 |
| 1994 | 0.35 | 0.97 | 0.99 | 0.75 |
| | | | | |
| 1995 | 0.49 | 1.09 | 1.46 | 1.06 |
| 1996 | 0.62 | 1.26 | 0.82 | 0.88 |
| 1997 | 0.56 | 1.41 | 1.16 | 1.16 |
| 1998 | 1.03 | 1.62 | 1.32 | 1.38 |
| 1999 | 1.30 | 1.30 | 1.34 | 1.32 |
| 2000 | 1.41 | 1.95 | 1.02 | 1.43 |
| 2001 | 1.30 | 1.61 | 1.48 | 1.48 |
| 2002 | 1.47 | 1.71 | 1.66 | 1.66 |

Table 3. Percent difference between spring and fall estimates of biomass, abundance, and mean size, by NAFO Division and year. Research surveys are not conducted in NAFO Subdiv. 3Ps in the fall. Fall surveys in Div. 3L commenced in 1981, and in 1990 in Div. 3NO.

| Biomass (tonnes) | | | | | Abundance (thousands) | | | | | Mean weight (kg) | | | | |
|---------------------------------|---------|---------|---------|---------------|---------------------------------|---------|---------|---------|---------------|---------------------------------|----------|---------|---------|---------------|
| Year | Div. 3L | Div. 3N | Div. 3O | All Divisions | Year | Div. 3L | Div. 3N | Div. 3O | All Divisions | Year | Div. 3L | Div. 3N | Div. 3O | All Divisions |
| 1981 | -51.57% | | | -132.75% | 1981 | 0.89% | | | -45.66% | 1981 | -52.94% | | | |
| 1982 | 42.16% | | | -39.06% | 1982 | 40.95% | | | -54.79% | 1982 | 2.05% | | | |
| 1983 | | | | | 1983 | | | | | 1983 | | | | |
| 1984 | 88.41% | | | 8.75% | 1984 | 89.33% | | | 19.11% | 1984 | -8.57% | | | |
| 1985 | 27.44% | | | -112.06% | 1985 | 26.71% | | | -84.13% | 1985 | 0.99% | | | |
| 1986 | | | | | 1986 | | | | | 1986 | | | | |
| 1987 | 6.61% | | | -120.37% | 1987 | 51.59% | | | -31.96% | 1987 | -92.93% | | | |
| 1988 | 35.00% | | | -92.02% | 1988 | 59.57% | | | -20.62% | 1988 | -60.76% | | | |
| 1989 | -7.98% | | | -139.56% | 1989 | 47.46% | | | -14.67% | 1989 | -105.51% | | | |
| 1990 | 52.60% | 29.62% | 36.46% | 40.61% | 1990 | 62.37% | -63.39% | 24.58% | 27.17% | 1990 | -25.97% | 56.92% | 15.76% | 18.45% |
| 1991 | 57.84% | 72.18% | -31.09% | 35.33% | 1991 | 52.73% | 27.12% | -18.58% | 30.33% | 1991 | 10.82% | 61.82% | -10.55% | 7.17% |
| 1992 | 70.85% | 56.50% | -36.68% | 31.65% | 1992 | 60.78% | 39.02% | -44.14% | 38.99% | 1992 | 25.68% | 28.66% | 5.17% | -12.03% |
| 1993 | 64.53% | 47.79% | 45.39% | 49.80% | 1993 | 54.86% | 45.07% | 63.69% | 55.31% | 1993 | 21.43% | 4.95% | -50.41% | -12.35% |
| 1994 | 75.81% | 79.99% | 9.56% | 56.61% | 1994 | 63.80% | 64.97% | 37.86% | 57.89% | 1994 | 33.18% | 42.89% | -45.55% | -3.04% |
| 1995 | 90.25% | 97.27% | 71.50% | 84.56% | 1995 | 83.46% | 92.23% | 63.81% | 80.46% | 1995 | 41.07% | 64.90% | 21.25% | 20.96% |
| 1996 | 65.47% | 61.54% | 3.90% | 35.63% | 1996 | 55.64% | 53.13% | 49.65% | 52.06% | 1996 | 22.16% | 17.94% | -90.87% | -34.26% |
| 1997 | 47.32% | 77.47% | 51.35% | 61.42% | 1997 | 49.41% | 55.62% | 48.78% | 51.09% | 1997 | -4.12% | 49.24% | 5.03% | 21.12% |
| 1998 | 36.91% | 61.53% | -7.82% | 25.88% | 1998 | 12.93% | 52.01% | -14.59% | 13.03% | 1998 | 27.55% | 19.84% | 5.91% | 14.77% |
| 1999 | 46.54% | 19.49% | -26.84% | 1.41% | 1999 | 20.82% | 36.43% | -13.17% | 10.58% | 1999 | 32.49% | -26.65% | -12.08% | -10.25% |
| 2000 | 20.94% | 54.48% | -0.14% | 30.89% | 2000 | 0.19% | 48.99% | 28.54% | 31.96% | 2000 | 20.79% | 10.76% | -40.13% | -1.59% |
| 2001 | 36.77% | 14.90% | 4.95% | 12.60% | 2001 | 32.67% | 23.78% | 20.84% | 23.63% | 2001 | 6.09% | -11.64% | -20.08% | -14.44% |
| 2002 | 22.48% | 73.54% | 6.33% | 42.03% | 2002 | 21.50% | 72.61% | -34.36% | 24.88% | 2002 | 1.25% | 3.37% | 30.28% | 22.83% |
| Average: | 41.42% | 57.41% | 9.76% | -5.93% | Average: | 44.38% | 42.12% | 16.38% | 13.23% | Average: | -5.26% | 24.85% | -14.33% | 1.33% |
| 1996-2002: (Campelen) | 39.49% | 51.85% | 4.53% | 29.98% | 1996-2002: (Campelen) | 27.59% | 48.94% | 12.24% | 29.60% | 1996-2002: (Campelen) | 15.17% | 8.98% | -17.42% | -0.26% |

Table 4. Skate catch history for non-Canadian fleets, 1970-2002 (from NAFO STATLANT-21A). Catch statistics are preliminary for 2002; 2000-2001 are incomplete. Additional catches in 2002 include: Lithuania (18 tons; first report for this country); EU (6 040 tons in 3NO, countries/areas undifferentiated); EU (11 184 tons in 3L, countries undifferentiated); and Estonia (328 tons in 3LMNO).

| Year | Cuba | Estonia | Faroes | F.R.G. | France (main) | France (SPM) | G.D.R. | Japan | Norway | Poland | Portugal | Spain | South Korea | Russia | U.S.S.R. | U.K. | All |
|------|------|---------|--------|--------|---------------|--------------|--------|-------|--------|--------|----------|--------|-------------|--------|----------|------|--------|
| 1970 | 0 | 0 | 0 | 0 | 0 | 341 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 341 | 0 | 682 |
| 1971 | 0 | 0 | 0 | 0 | 0 | 272 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1 | 0 | 273 |
| 1972 | 0 | 0 | 0 | 5 | 0 | 226 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 235 | 14 | 480 |
| 1973 | 0 | 0 | 0 | 3 | 0 | 153 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | | 264 | 34 | 457 |
| 1974 | 0 | 0 | 0 | 0 | 71 | 150 | 0 | 0 | 239 | 0 | 0 | 0 | 0 | | 1,562 | 87 | 2,109 |
| 1975 | 0 | 0 | 0 | 0 | 326 | 153 | 0 | 0 | 46 | 0 | 472 | 0 | 0 | | 1,443 | 0 | 2,440 |
| 1976 | 0 | 0 | 0 | 0 | 219 | 72 | 0 | 0 | 80 | 0 | 401 | 0 | 0 | | 255 | 0 | 1,027 |
| 1977 | 0 | 0 | 0 | 0 | 384 | 82 | 0 | 0 | 0 | 0 | 240 | 57 | 0 | | 587 | 0 | 1,350 |
| 1978 | 0 | 0 | 0 | 1 | 159 | 135 | 2 | 0 | 6 | 0 | 0 | 4 | 0 | | 764 | 31 | 1,102 |
| 1979 | 0 | 0 | 0 | 0 | 79 | 58 | 0 | 0 | 0 | 2 | 10 | 23 | 0 | | 69 | 0 | 241 |
| 1980 | 0 | 0 | 14 | 0 | 403 | 278 | 0 | 0 | 0 | 0 | 55 | 19 | 0 | | 605 | 0 | 1,374 |
| 1981 | 0 | 0 | 0 | 0 | 197 | 330 | 0 | 18 | 0 | 0 | 13 | 222 | 0 | | 1,032 | 0 | 1,812 |
| 1982 | 0 | 0 | 0 | 0 | 0 | 413 | 0 | 29 | 0 | 0 | 1 | 44 | 108 | | 189 | 0 | 784 |
| 1983 | 6 | 0 | 0 | 0 | 45 | 538 | 0 | 0 | 0 | 0 | 0 | 611 | 65 | | 407 | 0 | 1,672 |
| 1984 | 0 | 0 | 0 | 0 | 543 | 133 | 0 | 0 | 0 | 2 | 6 | 1,056 | 0 | | 296 | 0 | 2,036 |
| 1985 | 26 | 0 | 0 | 44 | 774 | 170 | 0 | 0 | 0 | 0 | 0 | 8,108 | 0 | | 1,816 | 0 | 10,938 |
| 1986 | 0 | 0 | 0 | 0 | 641 | 939 | 0 | 0 | 0 | 0 | 742 | 10,646 | 147 | | 2,400 | 0 | 15,515 |
| 1987 | 0 | 0 | 0 | 0 | 643 | 152 | 0 | 0 | 0 | 0 | 3,079 | 12,428 | 888 | | 1,444 | 0 | 18,634 |
| 1988 | 0 | 0 | 0 | 3 | 128 | 653 | 0 | 0 | 0 | 0 | 1,026 | 9,367 | 1,659 | | 6,526 | 0 | 19,362 |
| 1989 | 0 | 0 | 0 | 0 | 0 | 1,687 | 0 | 0 | 0 | 0 | 441 | 12,762 | 490 | | 271 | 0 | 15,651 |
| 1990 | 0 | 0 | 2 | 0 | 0 | 571 | 0 | 0 | 0 | 0 | 10,468 | 3,347 | 744 | | 8 | 0 | 15,140 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 639 | 0 | 0 | 0 | 0 | 21,018 | 6,462 | 762 | | 28 | 1 | 28,910 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 0 | 0 | 0 | 3,459 | 128 | 1,044 | 62 | | 3 | 4,742 |
| 1993 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 3,799 | 1,994 | 5 | 6 | | 0 | 5,815 |
| 1994 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1,294 | 5,203 | 0 | 0 | | 0 | 6,500 |
| 1995 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 609 | 4,281 | 0 | 5 | | 0 | 4,899 |
| 1996 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 722 | 4,060 | 0 | 0 | | 0 | 4,784 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 682 | 9,047 | 0 | 0 | | 0 | 9,732 |
| 1998 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 940 | 7,503 | 0 | 2 | | 0 | 8,454 |
| 1999 | 0 | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 1,583 | 8,727 | 0 | 155 | | 0 | 10,471 |
| 2000 | 0 | 240 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | 0 | 554 | 13,367 | 0 | 3,567 | | 0 | 17,749 |
| 2001 | 0 | 1,015 | 0 | 0 | 0 | 38 | 0 | 0 | 0 | 2 | 734 | 4,472 | 0 | 2,570 | | 0 | 8,831 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 3,154 | | 0 | 3,187 |

Table 5. Canadian landings of thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps by gear type and month, 1985-2002.

| Gear | Year | Jan. | Feb. | March | April | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Not recorded |
|---------|------|------|------|-------|-------|------|------|------|------|------|------|------|------|--------------|
| Gillnet | 1985 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| | 1986 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 1987 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 95 |
| | 1988 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 |
| | 1989 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| | 1992 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| | 1993 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 11 |
| | 1994 | 0 | 0 | 0 | 0 | 1 | 9 | 6 | 0 | 24 | 0 | 23 | 33 | 492 |
| | 1995 | 2 | 7 | 101 | 108 | 335 | 15 | 36 | 61 | 12 | 7 | 0 | 8 | 585 |
| | 1996 | 0 | 1 | 14 | 760 | 67 | 80 | 1 | 9 | 7 | 1 | 2 | 4 | 188 |
| | 1997 | 7 | 1 | 15 | 114 | 659 | 563 | 88 | 4 | 0 | 1 | 0 | 0 | 154 |
| | 1998 | 5 | 4 | 14 | 43 | 530 | 181 | 104 | 38 | 24 | 6 | 3 | 0 | 0 |
| | 1999 | 7 | 7 | 15 | 43 | 249 | 344 | 89 | 107 | 89 | 2 | 4 | 0 | 0 |
| 2000 | 9 | 7 | 1 | 0 | 38 | 171 | 232 | 182 | 28 | 1 | 4 | 0 | 0 | |
| 2001 | 8 | 3 | 1 | 0 | 33 | 171 | 244 | 97 | 28 | 5 | 5 | 7 | 7 | |
| 2002 | 13 | 9 | 15 | 3 | 18 | 333 | 341 | 318 | 58 | 7 | 0 | 0 | 4 | |
| Lines | 1985 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| | 1987 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 |
| | 1988 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1990 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1991 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1992 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 18 | 9 | 1 | 0 | 0 | 17 |
| | 1993 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 9 |
| | 1994 | 0 | 0 | 0 | 6 | 0 | 0 | 6 | 10 | 0 | 0 | 0 | 0 | 3 |
| | 1995 | 0 | 0 | 2 | 33 | 5 | 32 | 248 | 214 | 2 | 0 | 0 | 39 | 0 |
| | 1996 | 13 | 0 | 8 | 341 | 0 | 0 | 1 | 68 | 5 | 3 | 29 | 91 | 0 |
| | 1997 | 0 | 48 | 131 | 84 | 8 | 1 | 0 | 0 | 8 | 97 | 121 | 99 | 33 |
| | 1998 | 0 | 7 | 35 | 99 | 66 | 1 | 6 | 22 | 47 | 37 | 29 | 0 | 0 |
| | 1999 | 8 | 78 | 133 | 33 | 80 | 4 | 17 | 9 | 44 | 8 | 30 | 42 | 1 |
| | 2000 | 2 | 0 | 72 | 94 | 62 | 30 | 7 | 1 | 43 | 23 | 21 | 38 | 0 |
| 2001 | 1 | 0 | 7 | 150 | 92 | 31 | 51 | 62 | 31 | 18 | 17 | 6 | 3 | |
| 2002 | 0 | 8 | 50 | 60 | 126 | 53 | 97 | 89 | 31 | 17 | 0 | 0 | 0 | |
| Trawl | 1986 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72 |
| | 1987 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 |
| | 1988 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1989 | 0 | 2 | 1 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1990 | 15 | 12 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1991 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | 1992 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1993 | 0 | 0 | 0 | 0 | 2 | 20 | 0 | 6 | 0 | 0 | 1 | 1 | 0 |
| | 1994 | 0 | 0 | 0 | 34 | 23 | 43 | 4 | 93 | 88 | 420 | 240 | 43 | 936 |
| | 1995 | 0 | 0 | 504 | 2120 | 0 | 0 | 0 | 0 | 21 | 7 | 0 | 0 | 22 |
| | 1996 | 0 | 0 | 0 | 801 | 508 | 70 | 0 | 17 | 22 | 2 | 4 | 2 | 0 |
| | 1997 | 0 | 1 | 0 | 875 | 1499 | 105 | 178 | 60 | 18 | 1 | 7 | 0 | 0 |
| | 1998 | 0 | 0 | 5 | 800 | 112 | 6 | 3 | 1 | 9 | 5 | 5 | 0 | 0 |
| | 1999 | 0 | 0 | 0 | 527 | 59 | 75 | 8 | 4 | 14 | 16 | 21 | 0 | 0 |
| 2000 | 0 | 0 | 1 | 1 | 277 | 57 | 5 | 4 | 1 | 2 | 3 | 3 | 0 | |
| 2001 | 0 | 2 | 153 | 299 | 571 | 8 | 3 | 1 | 2 | 4 | 3 | 0 | 0 | |
| 2002 | 0 | 0 | 18 | 584 | 107 | 2 | 6 | 93 | 22 | 2 | 0 | 0 | 0 | |

Table 6. Fishery regulations and quota allocations for thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps in 2002 and 2003.

| Gear Type | Vessel Size | Sector | Season | Gear Restrictions | Adjustments /reason | TAC |
|------------------|--------------------|---------------|--|---|--|---|
| Fixed Gear | <35' | Inshore | 3LNO Apr.1/02 – Apr.30/02 May 15/02-Sep.30/02 | 3LNO – Gillnets (200 nets, min mesh size 12".) OR hook and line. 3Ps – Gillnets only <12miles from shore: 40 nets, min mesh size 10½") >12miles from shore: 200 nets, min mesh size 12") | 3LNO April 30 closure due to by-catch. | 3L-100 3Ps-250 |
| Fixed Gear | 35-64' | Inshore | 3Ps <12miles from shore July 8/02-Feb.28/03 (vessels <35' only) >12miles from shore June 3/02-July 18/02 (vessels 35'-65') | | | 3LN-150 3O-575 3Ps-250 |
| Fixed Gear | 65'-100' | Inshore | Apr.1/ 02 – Mar.31/03 | GN min mesh size 12" | | 3LN-50 3O-150 3Ps-100 |
| Mobile Gear | <65' | Inshore | 3LNO Apr 8/02-Dec.31.02 3Ps Apr 8/02-May 7/02 | Min mesh size 300mm for codend 254 for rest of trawl | | For all mobile gear 3LN-150 3O-775 3Ps-450 |
| Mobile Gear | 65'-100' | Inshore | Jan.1/02 – Dec.31/02 | Min mesh size 300mm for codend 250 for rest of trawl | | |
| Mobile Gear | >100' | Offshore | Jan.1/02 – Dec.31/02 | Min mesh size 300mm for codend 250 for rest of trawl | | |

Table 7. Size of thorny skate, proportion mature in the commercial trawl catches in NAFO Div. 3NO and size of codend mesh used.

| Country | Area | Year | Size Range (cm) | Percent mature | Codend Mesh Size |
|----------|------|-----------|-----------------|----------------|------------------|
| Canada | 3O | 1995-2002 | 27-99 | 20 | 300 |
| Portugal | 3NO | 2002 | 18-61 | 1 | |
| Spain | 3NO | 1997 | 13-91 | 34 | |
| | | 1999 | 28-91 | 42 | |
| | | 2000 | 25-91 | 46 | 220 |
| | | 2001 | 25-91 | 49 | 220 |
| | | 2002 | 30-96 | 53 | 280 |
| Russia | 3NO | 2000 | 20-72 | 4 | |
| | | 2001 | 27-90 | 50 | 280 |
| | | 2002 | 30-102 | | 280 |

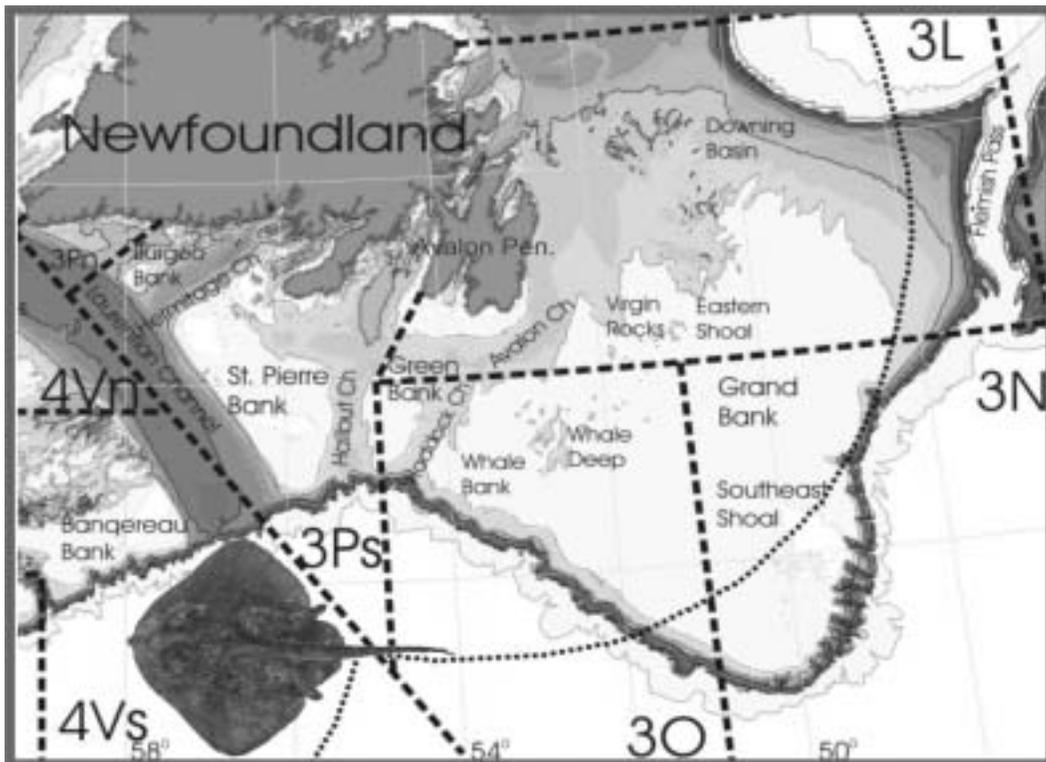


Fig. 1. The Grand Banks, showing locations referenced in the text, bathymetry, Canada's 200-mile-limit, and NAFO Div. 3L, 3N, 3O, and Subdiv. 3Ps (image of thorny skate on lower left).

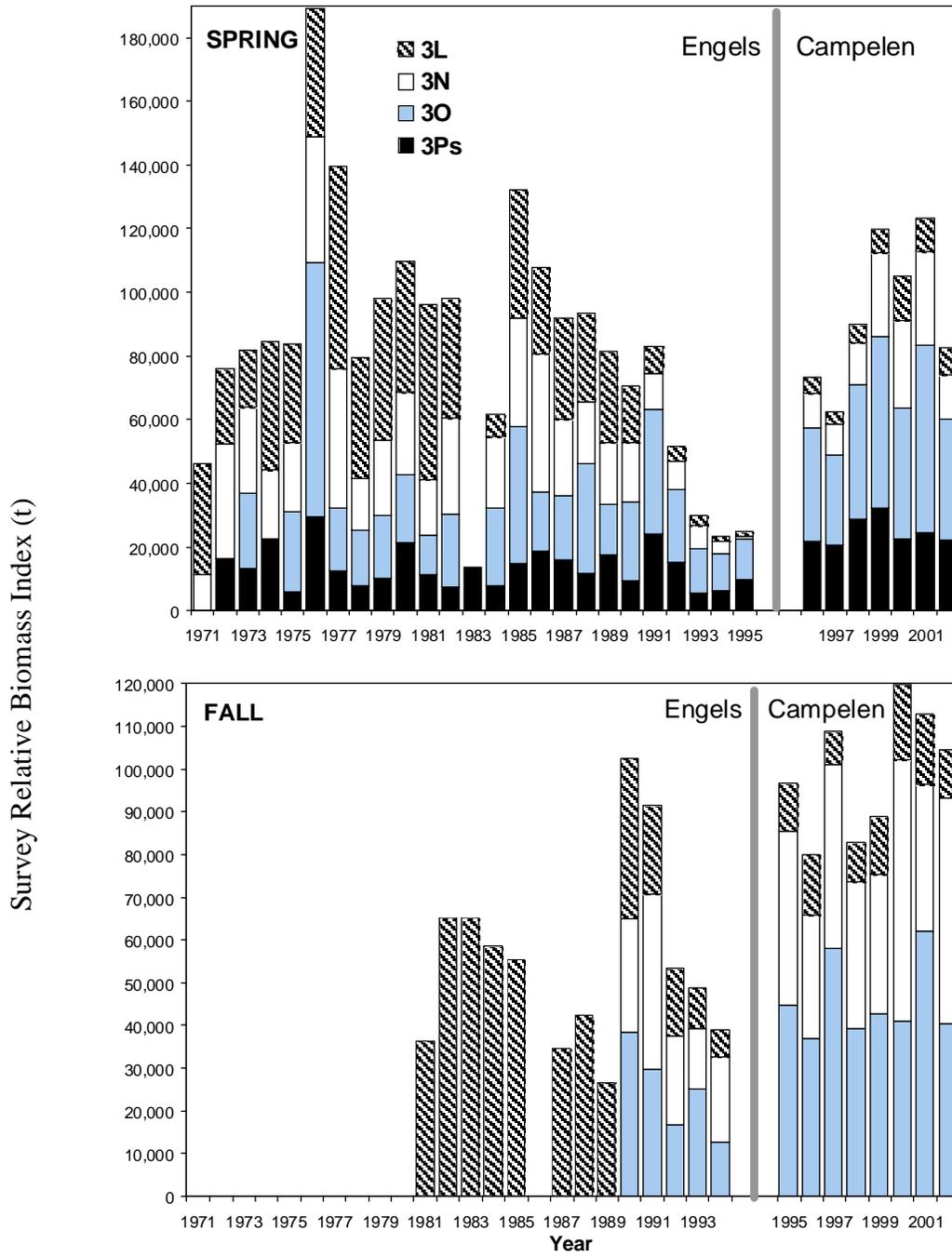


Fig. 2. Spring and fall research survey relative biomass indices for thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps, 1971-2002.

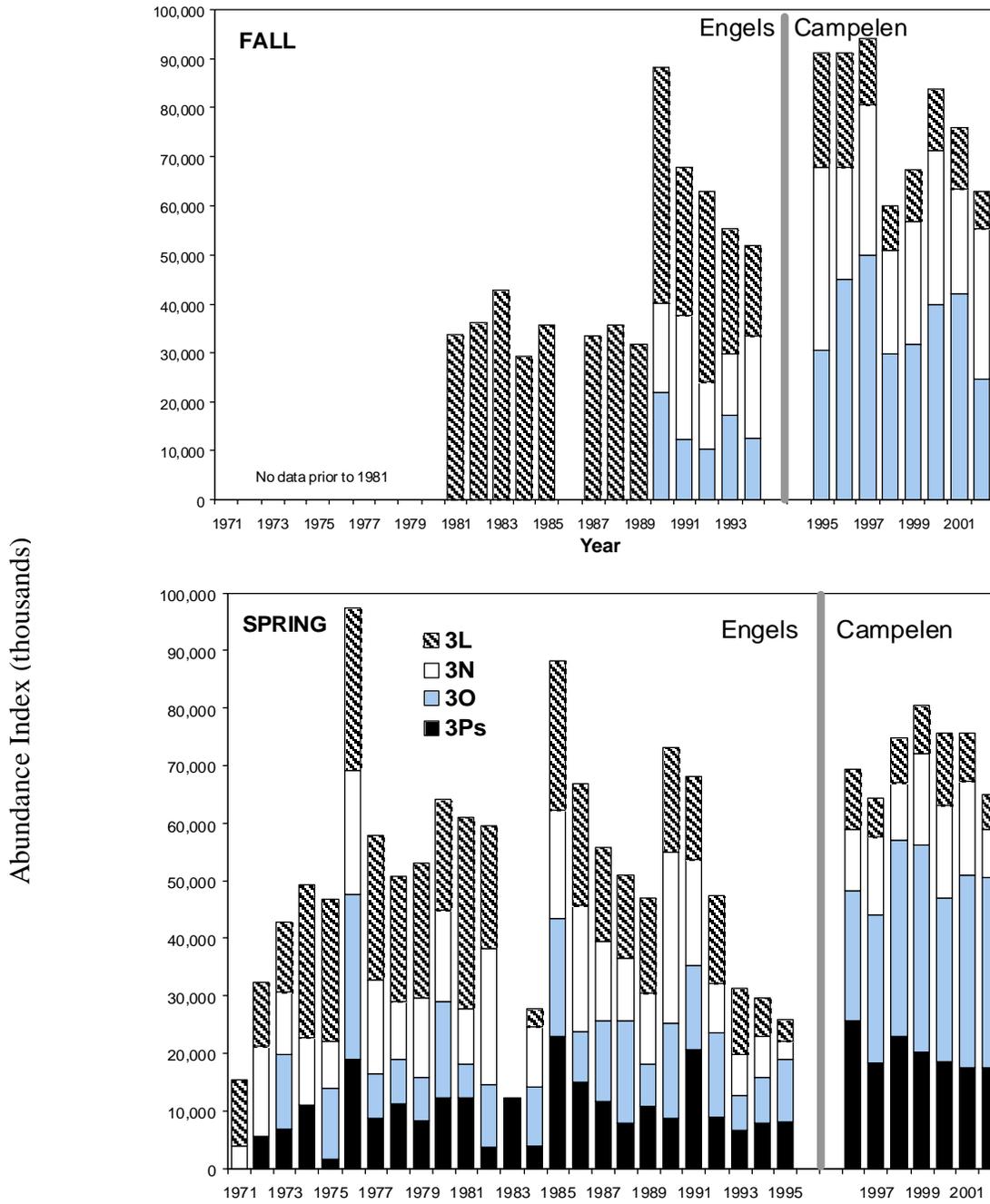


Fig. 3. Spring and fall survey abundance indices for thorny skate in NAFO Div. 3L, 3N, 3O, and Subdiv. 3Ps, 1971-2002.

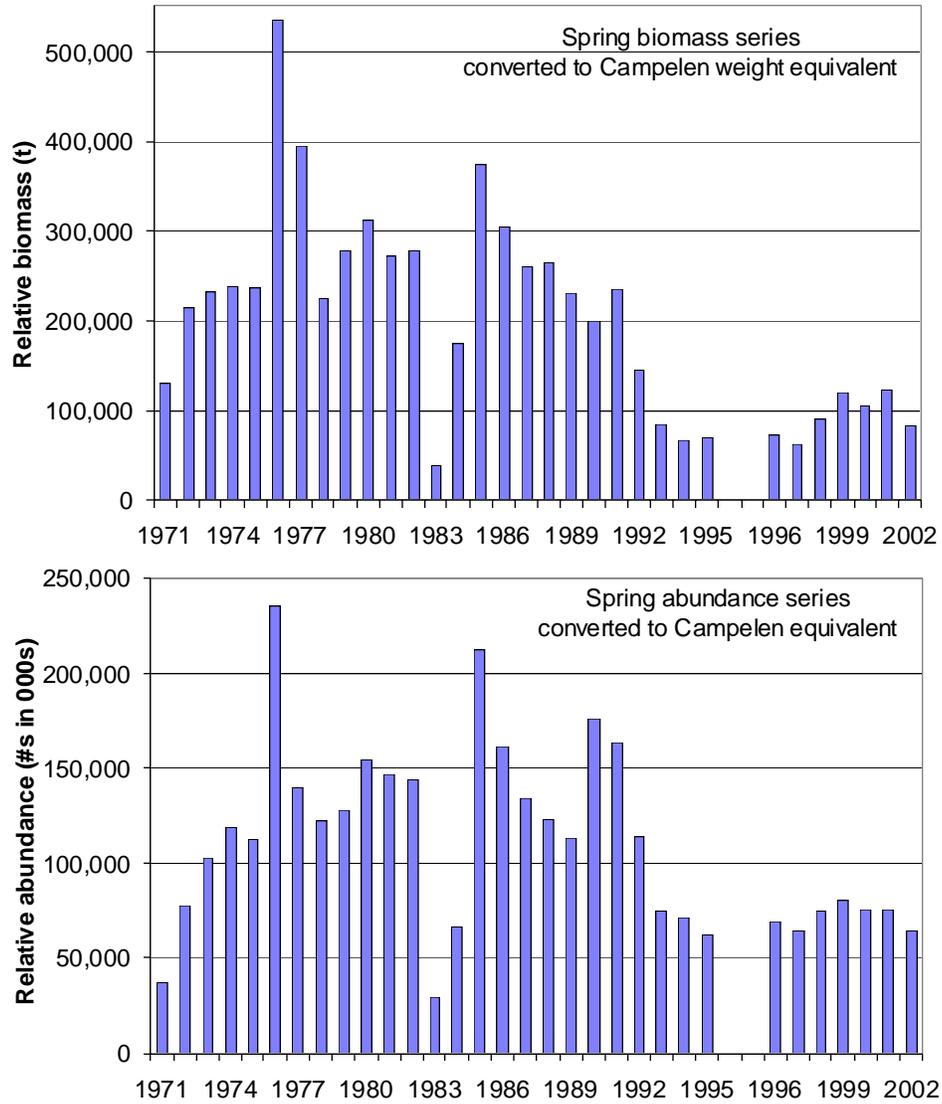


Fig. 4. Relative biomass of thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps, with Engles estimates converted to Campelen equivalents. Some Divisions were not sampled in 1971, 1972, 1974, and 1983.

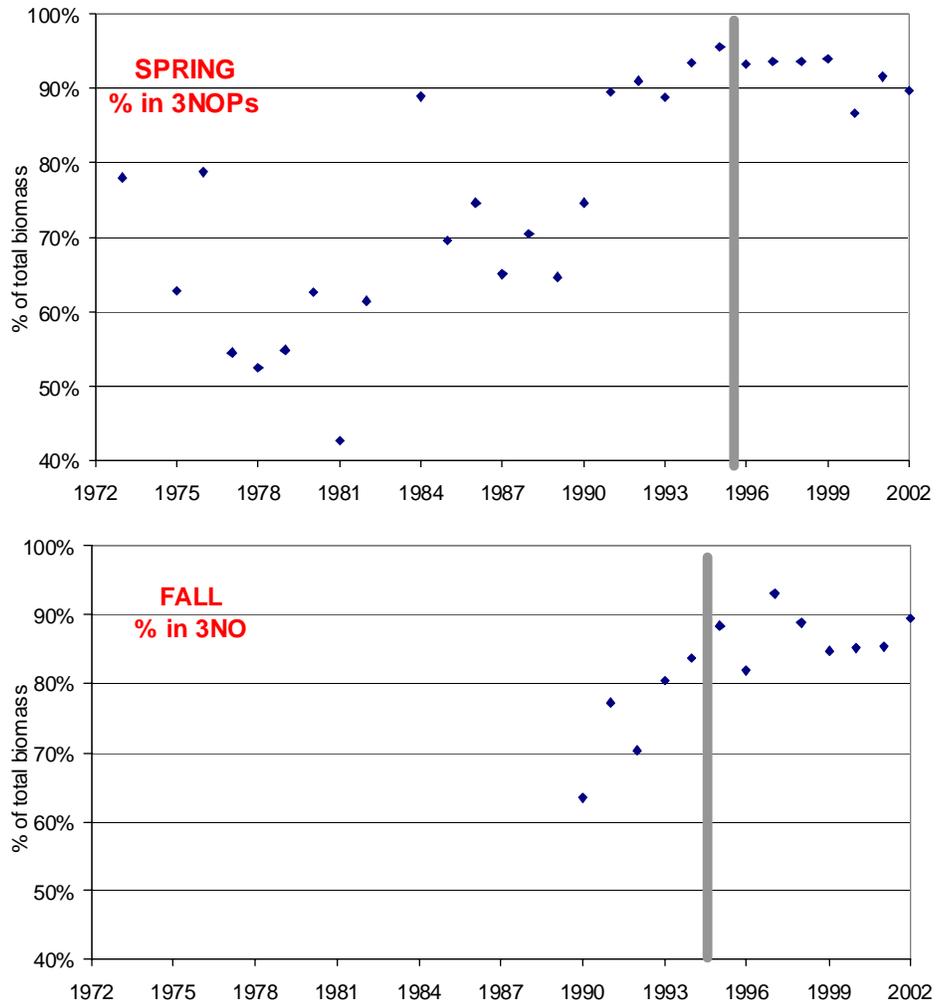


Fig. 5. Upper Panel: Proportion of thorny skate that occurred in NAFO Div. 3NO and Subdiv. 3Ps in relation to the entire stock area (3LNOPs) in the spring. Lower Panel: Proportion of thorny skate that occurred in NAFO Div. 3NO in relation to the entire stock area (3LNO) in the fall.

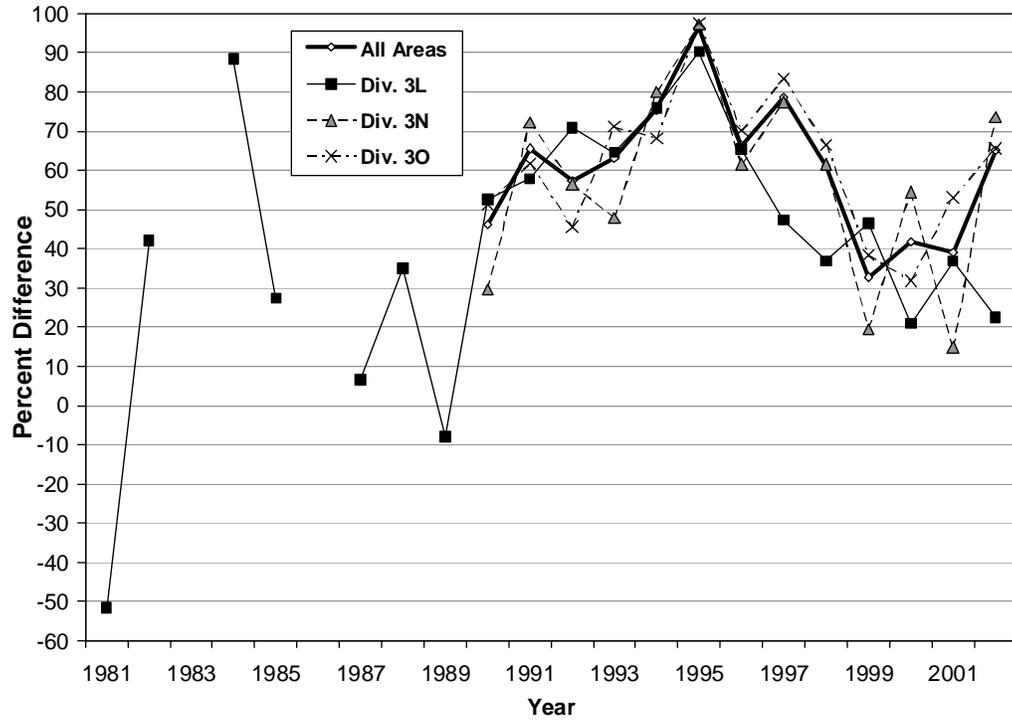


Fig. 6. Percent difference between spring and fall survey biomass estimates for thorny skate in NAFO Div. 3LNO, 1981-2002.

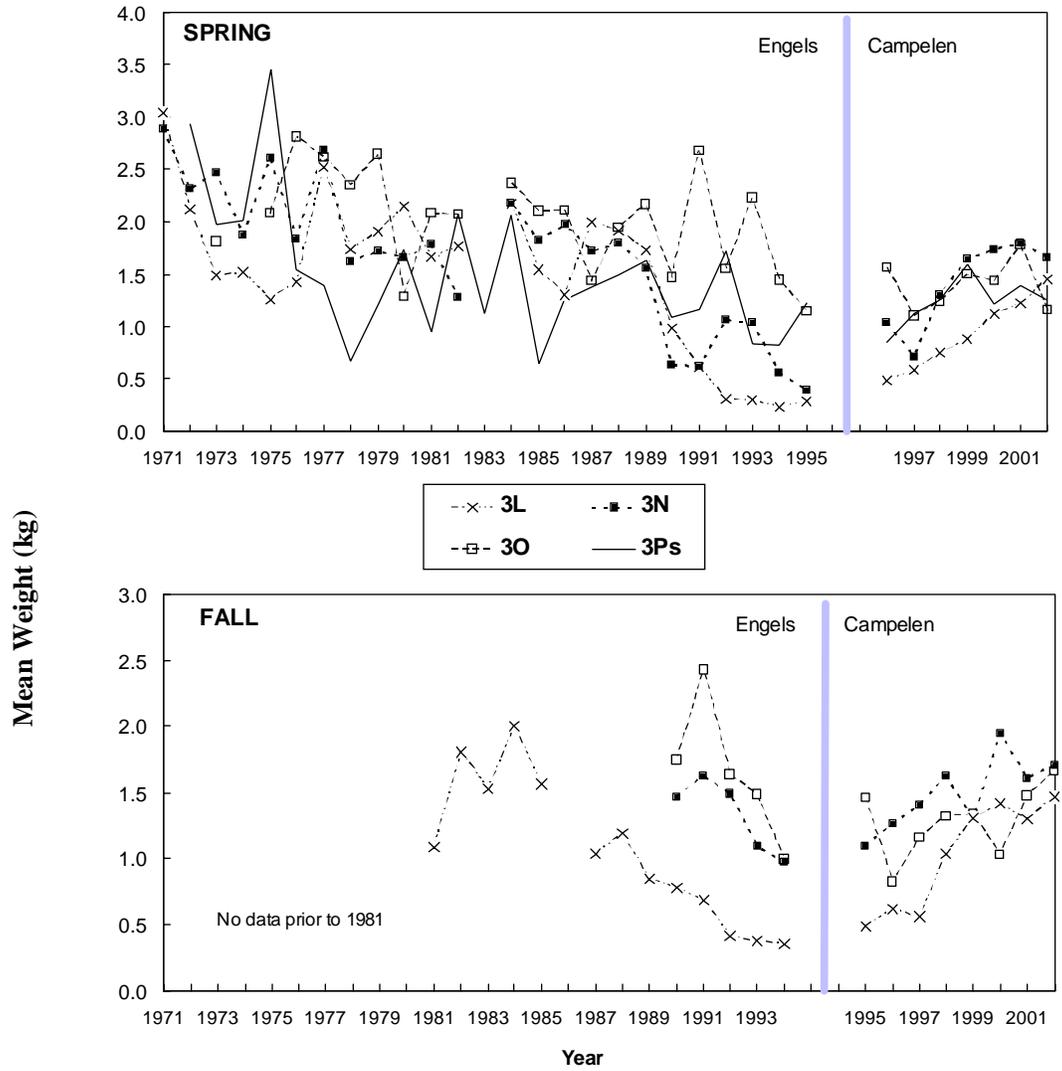


Fig. 7. Mean weight of thorny skate in spring (1971-2002) and fall (1981-2002) surveys in NAFO Div. 3LNO and Subdiv. 3Ps.,

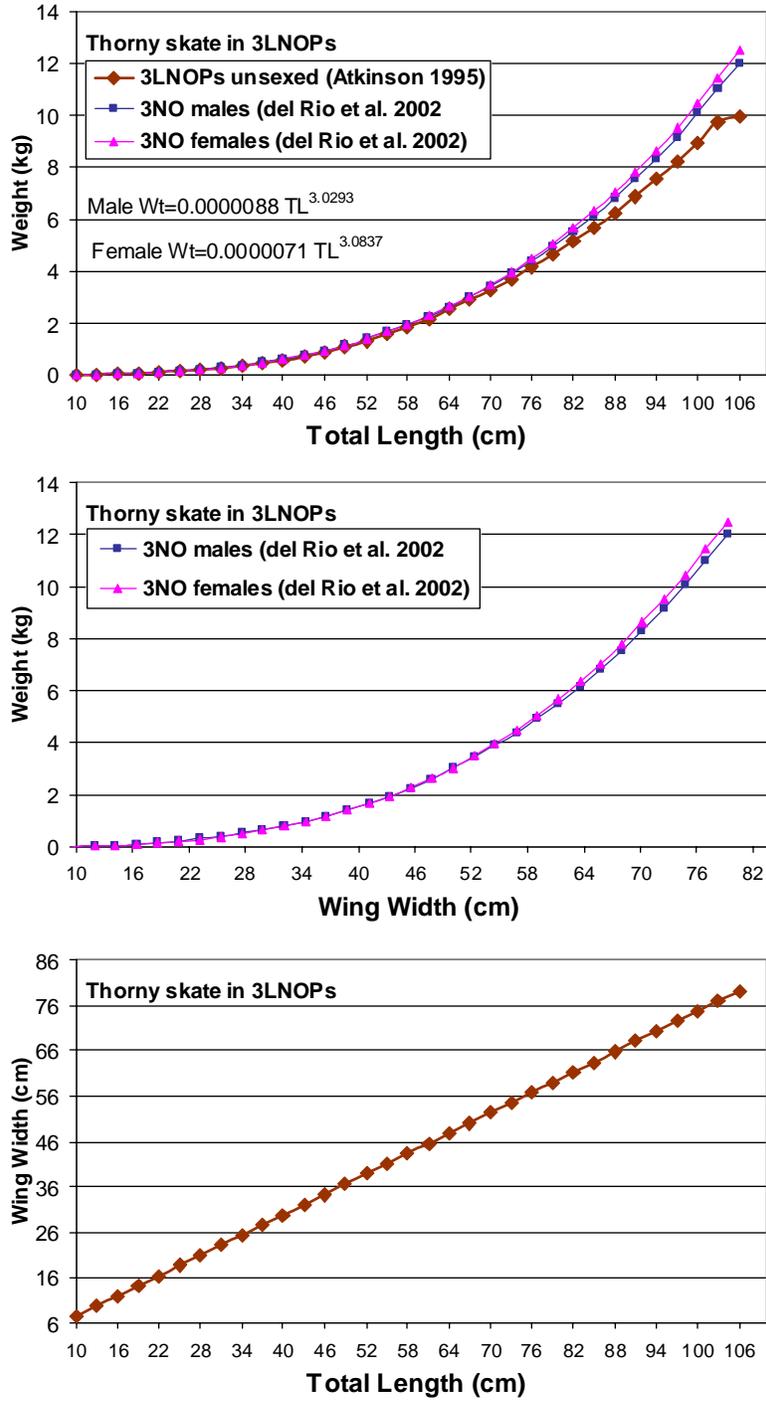


Fig. 8. Total length, average weight, and wing width relationships for thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps (after Atkinson 1995, and del Río *et al.* 2002).

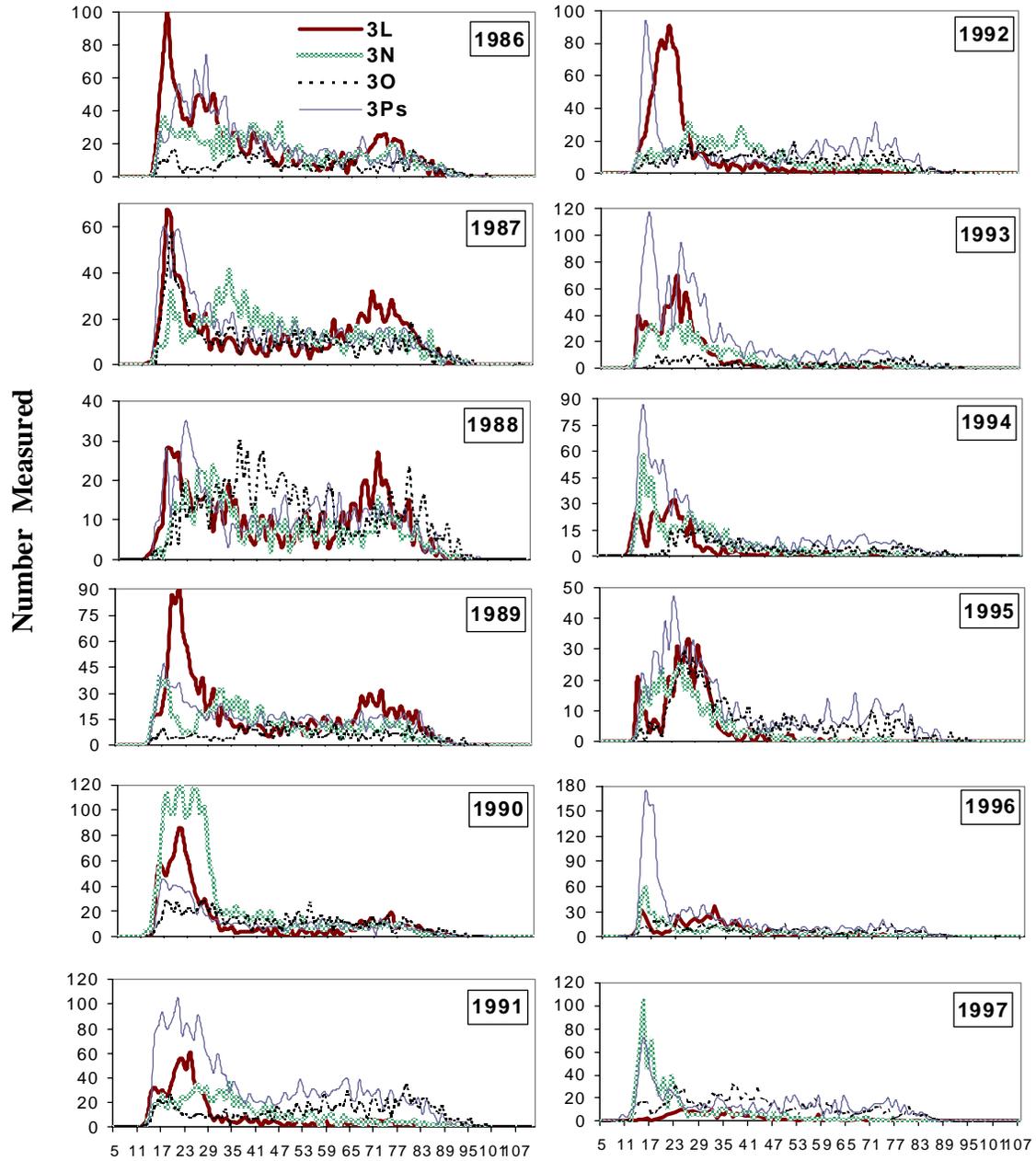


Fig. 9a. Length frequencies of thorny skate caught by spring research vessel surveys in NAFO Div. 3LNOPs, 1986-2002. X-axis represents the lengths of skate in centimeters.

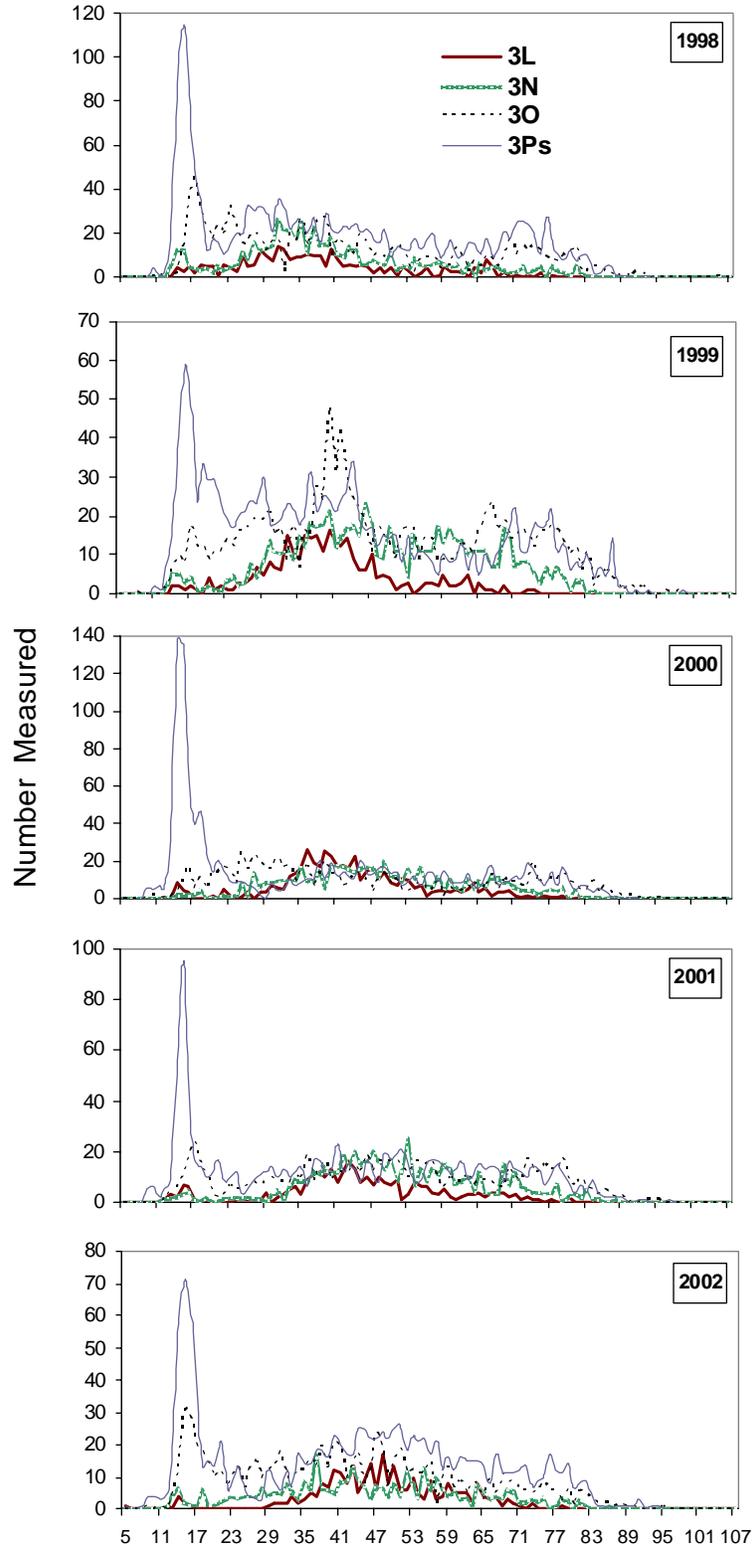


Fig. 9a – continued (1998-2002).

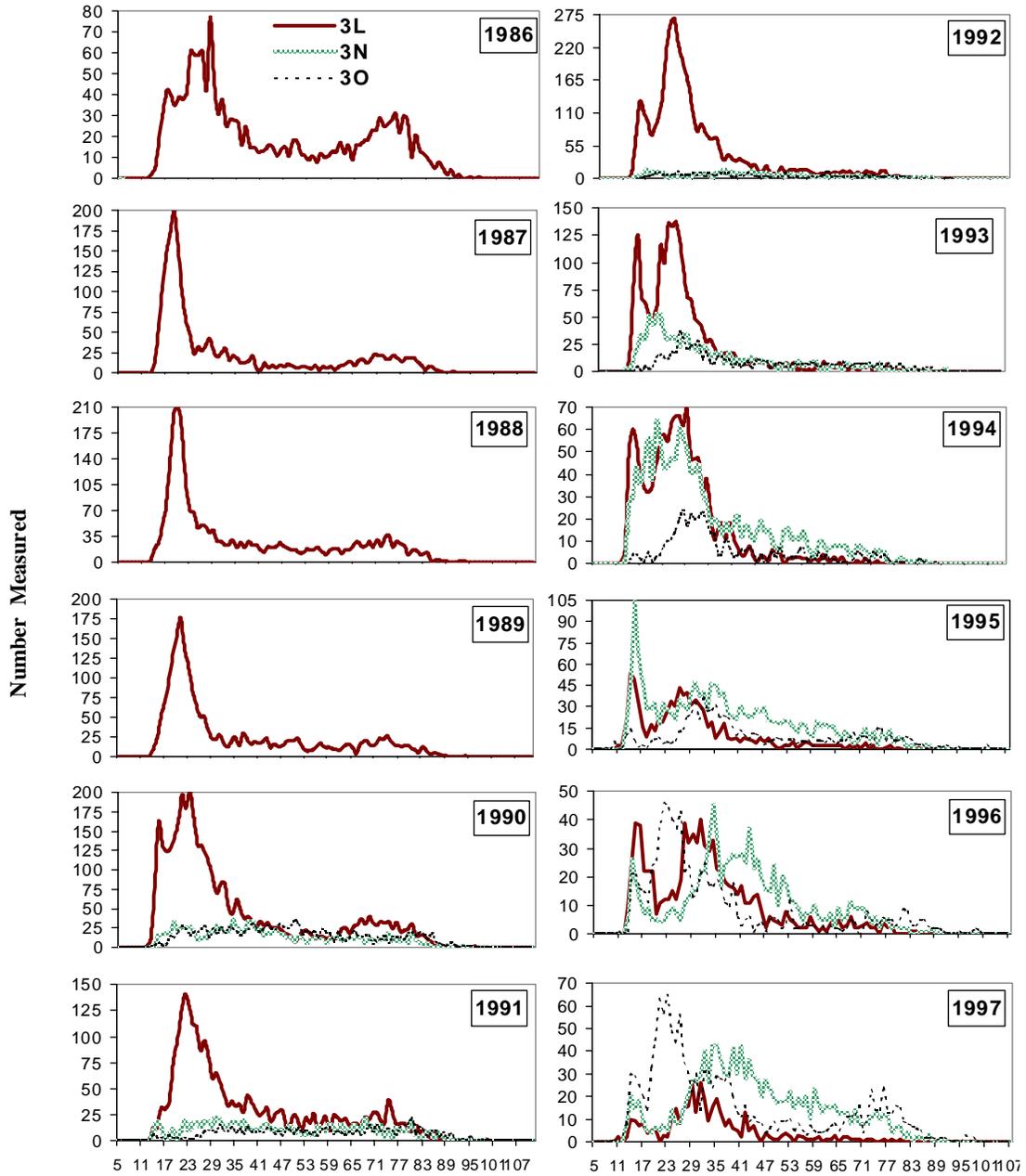


Fig. 9b. Length frequencies of thorny skate caught by fall research vessel surveys in NAFO Divisions 3LNOPs, 1986-2002. X-axis represents the lengths of skate in centimeters.

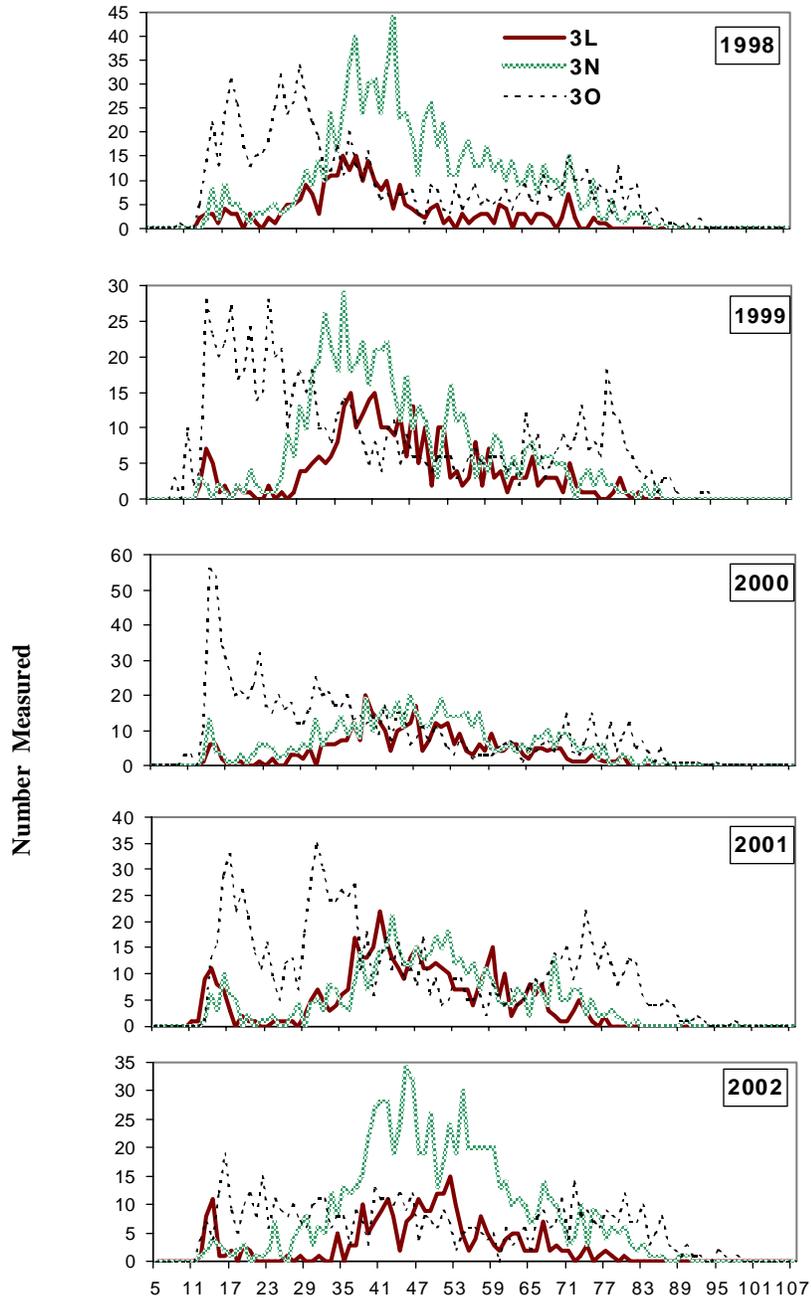


Fig. 9b – continued (1998-2002).

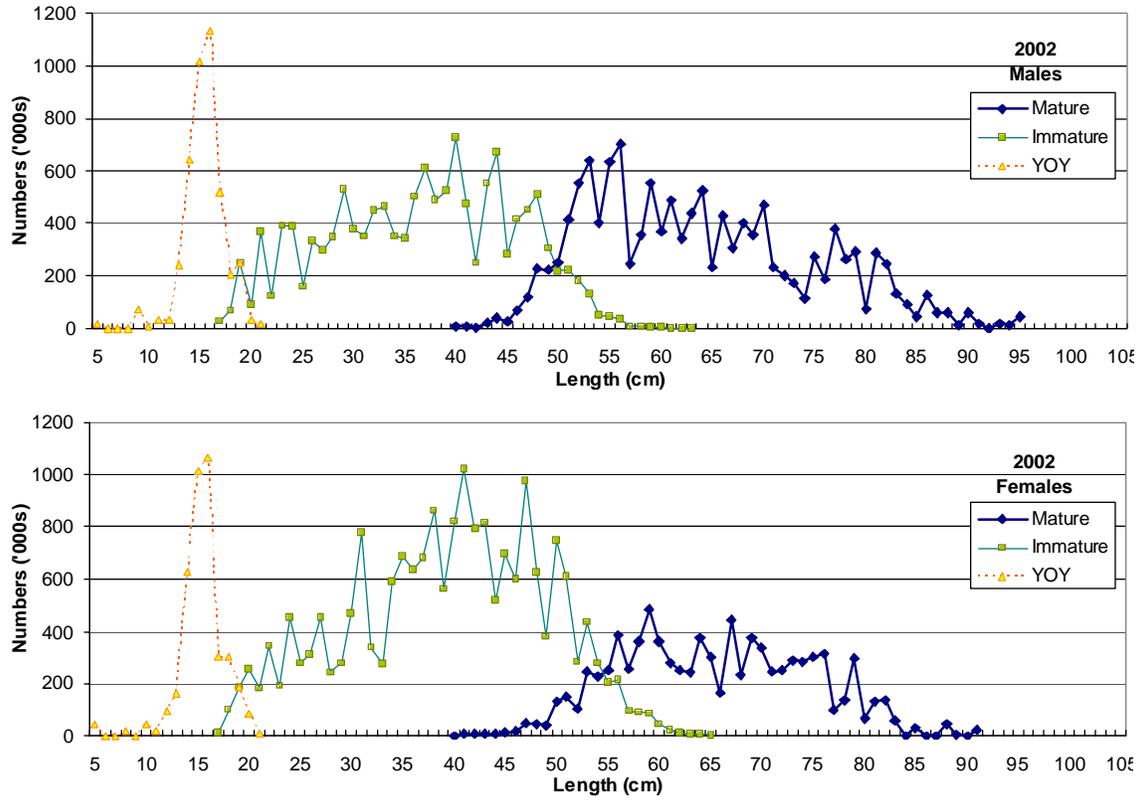


Fig. 10. Example of research survey sexed size frequency partitioned into Young of the Year (YOY), Immature, and Mature in 2002 (based on del Río 2002 ogives).

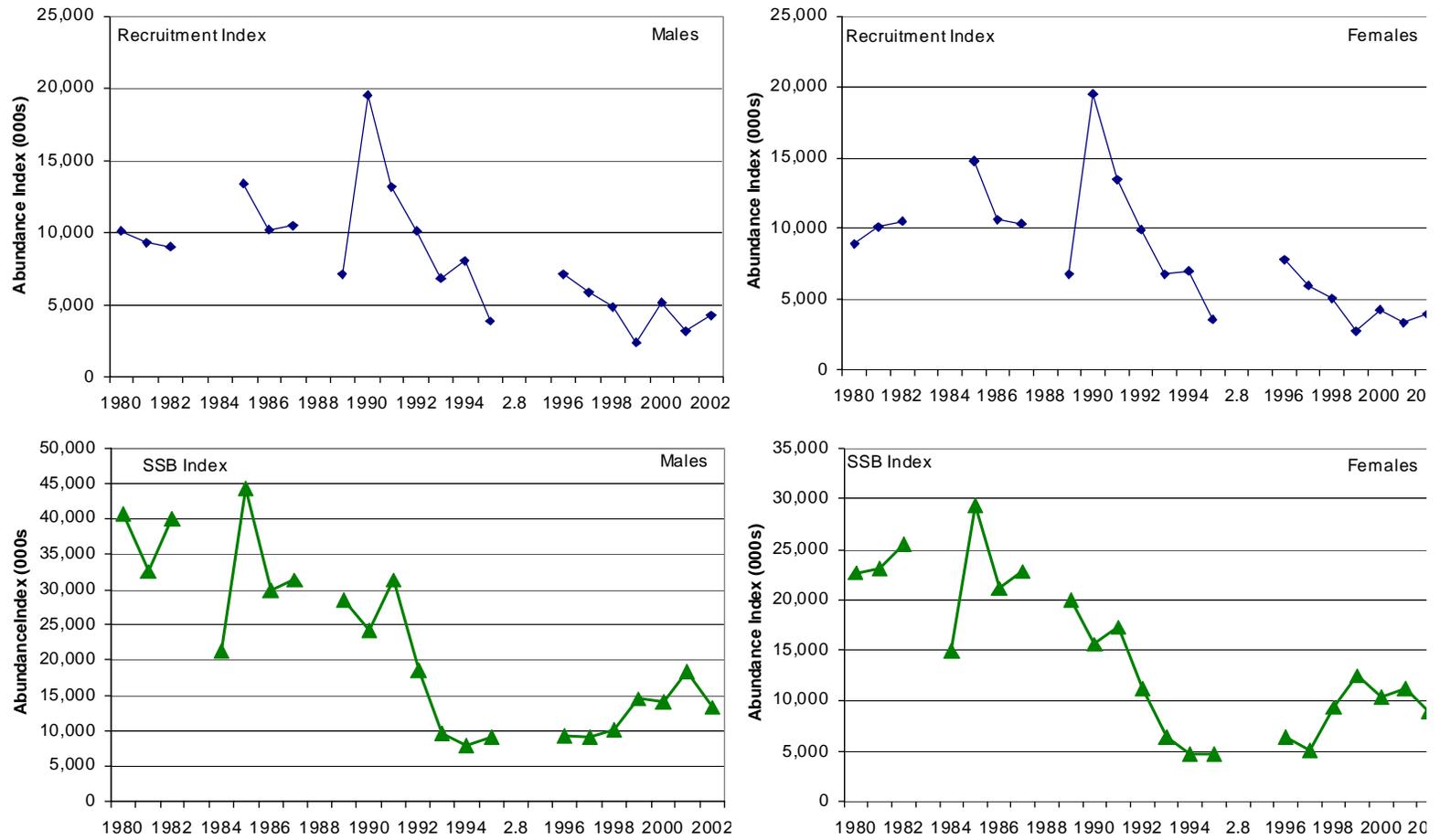


Fig. 11. Relative Recruitment Index and Spawning Stock Biomass (SSB) Index for male and female thorny skates, 1980-2002.

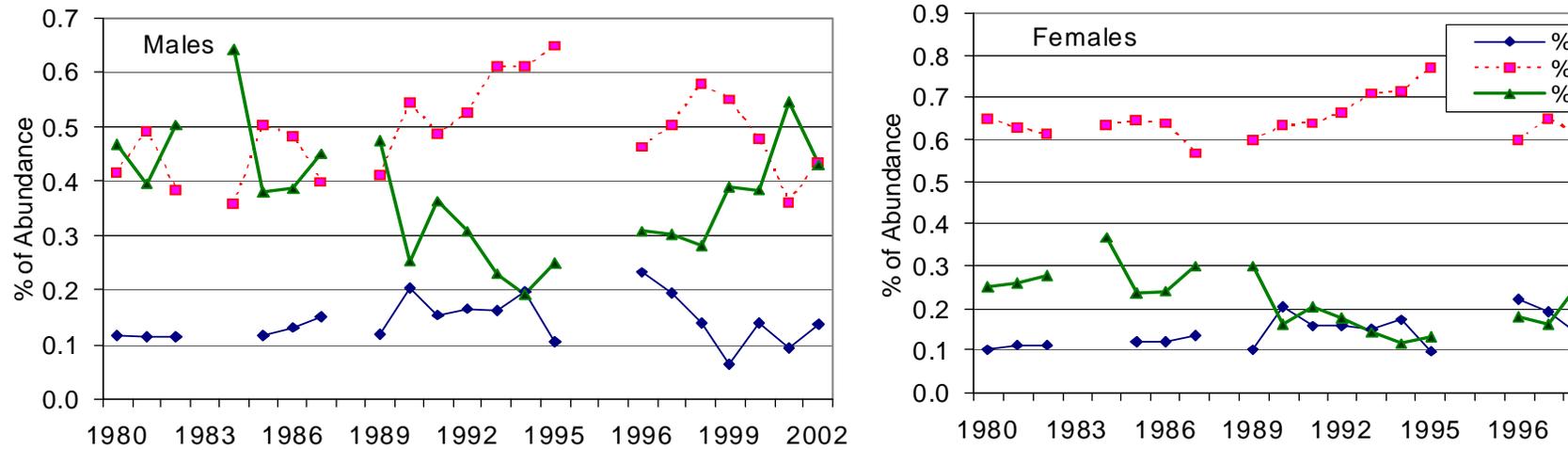


Fig. 12. Percent of total abundance that is young of the year (YOY), immature, and mature, depicted separately by sex, 1980-2002.

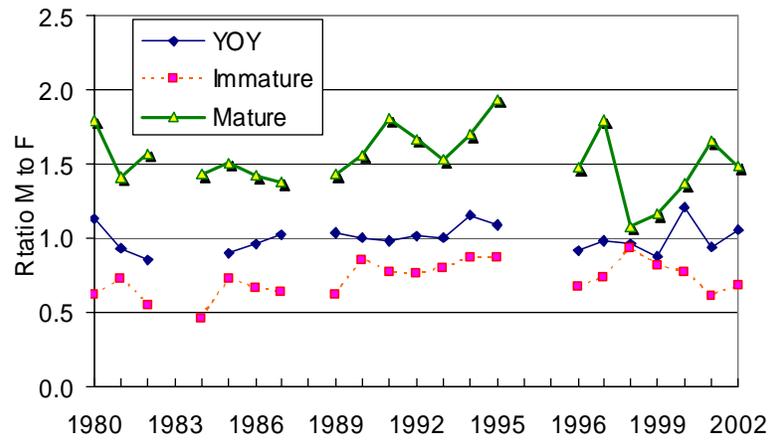


Fig. 13. Ratio of males to females for YOY (young of the year), immature, and mature thorny skates, 1980-2002.

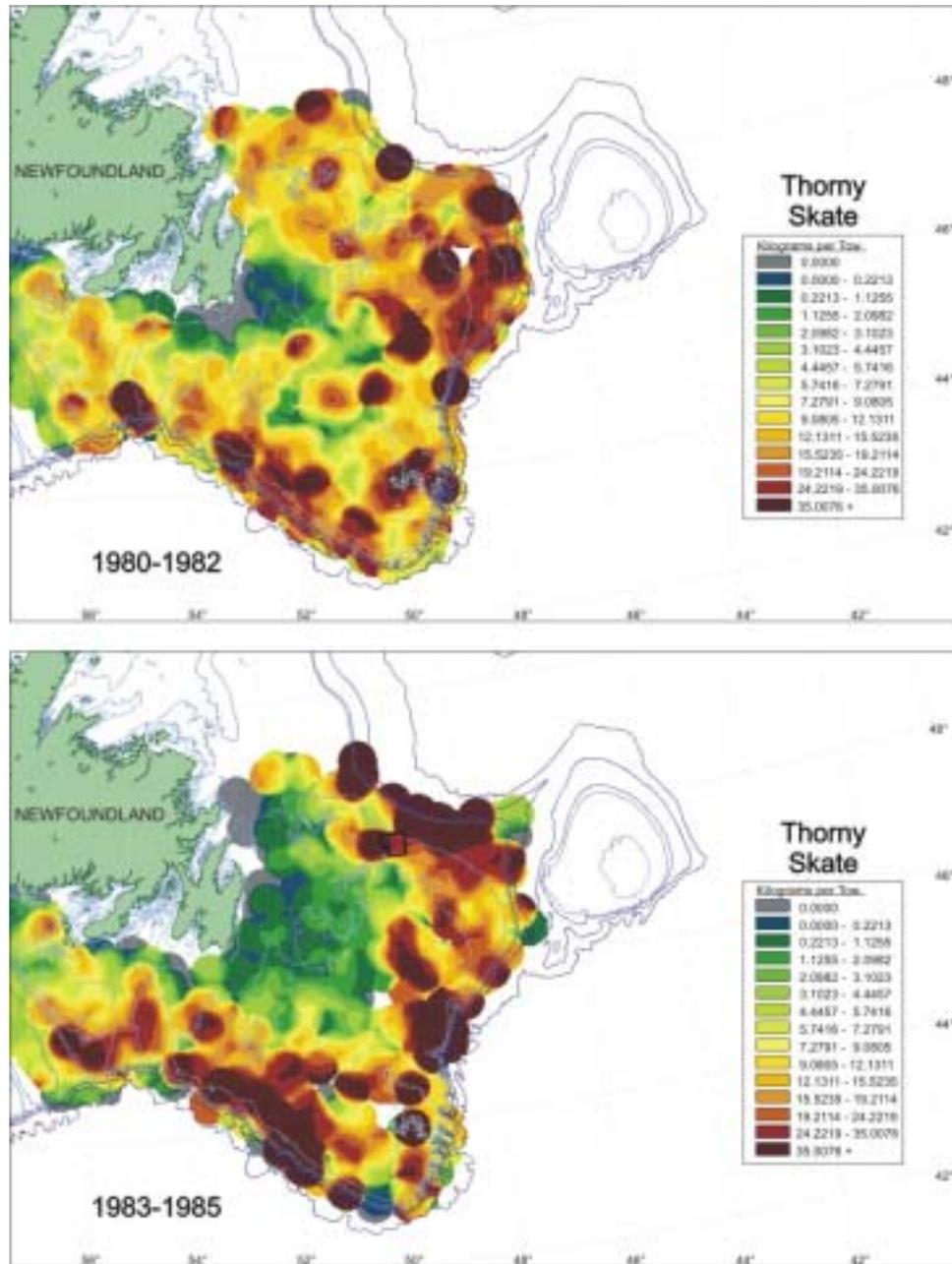


Fig. 14a. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on spring surveys in 1980-1982 and 1983-1985 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

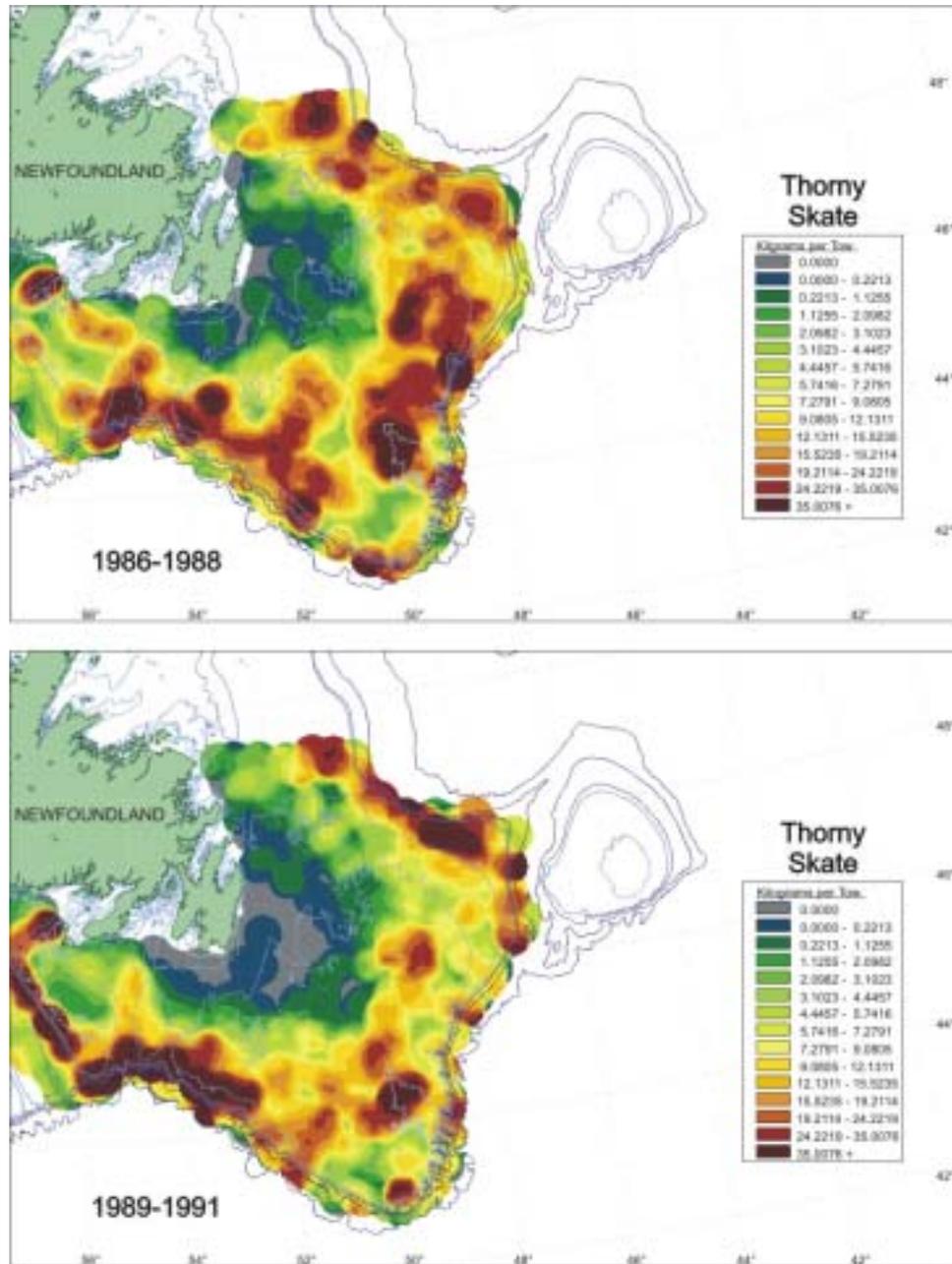


Fig. 14b. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on spring surveys in 1986-1988 and 1989-1991 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

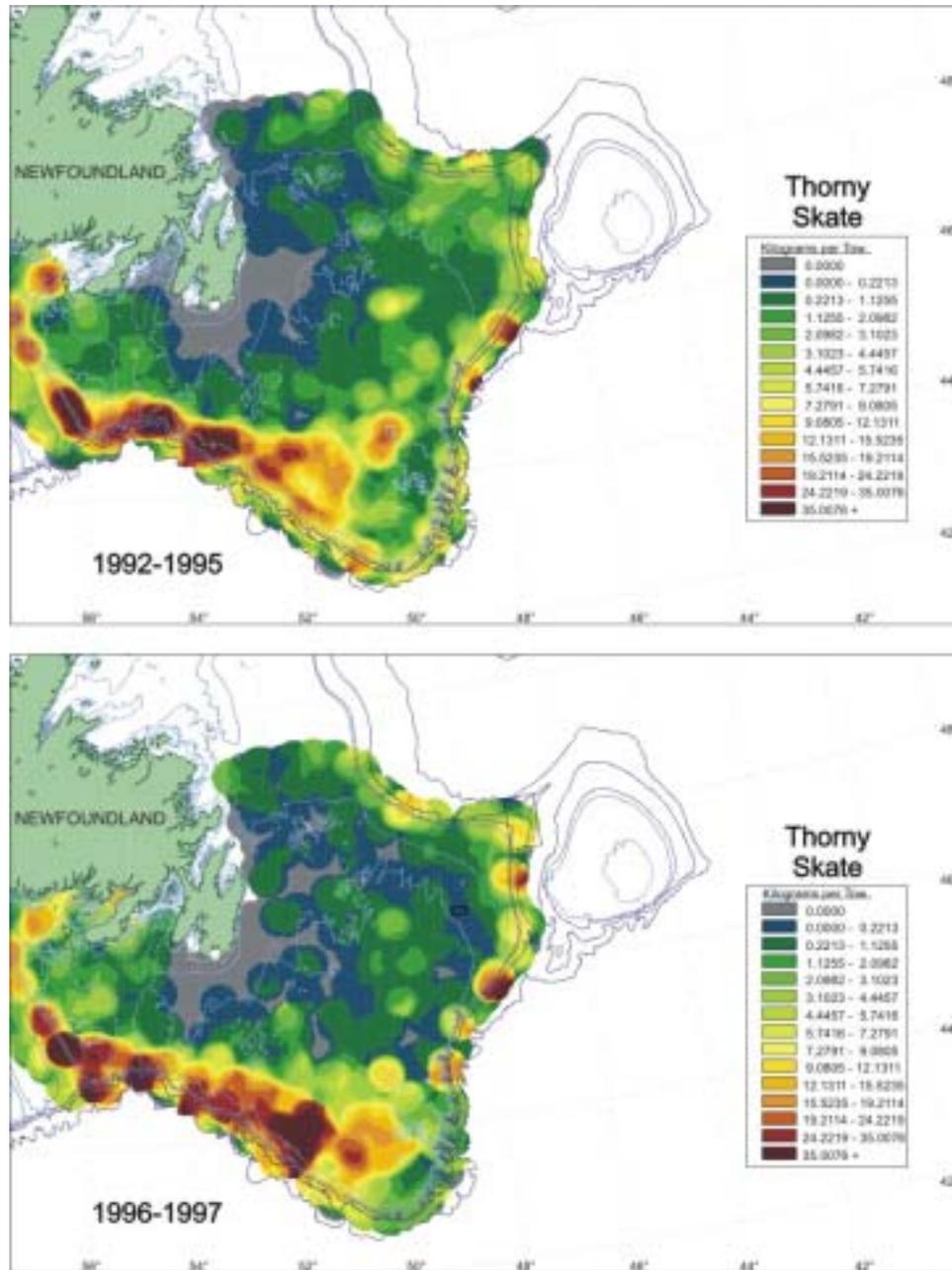


Fig. 14c. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on spring surveys in 1992-1995 and 1996-1997 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

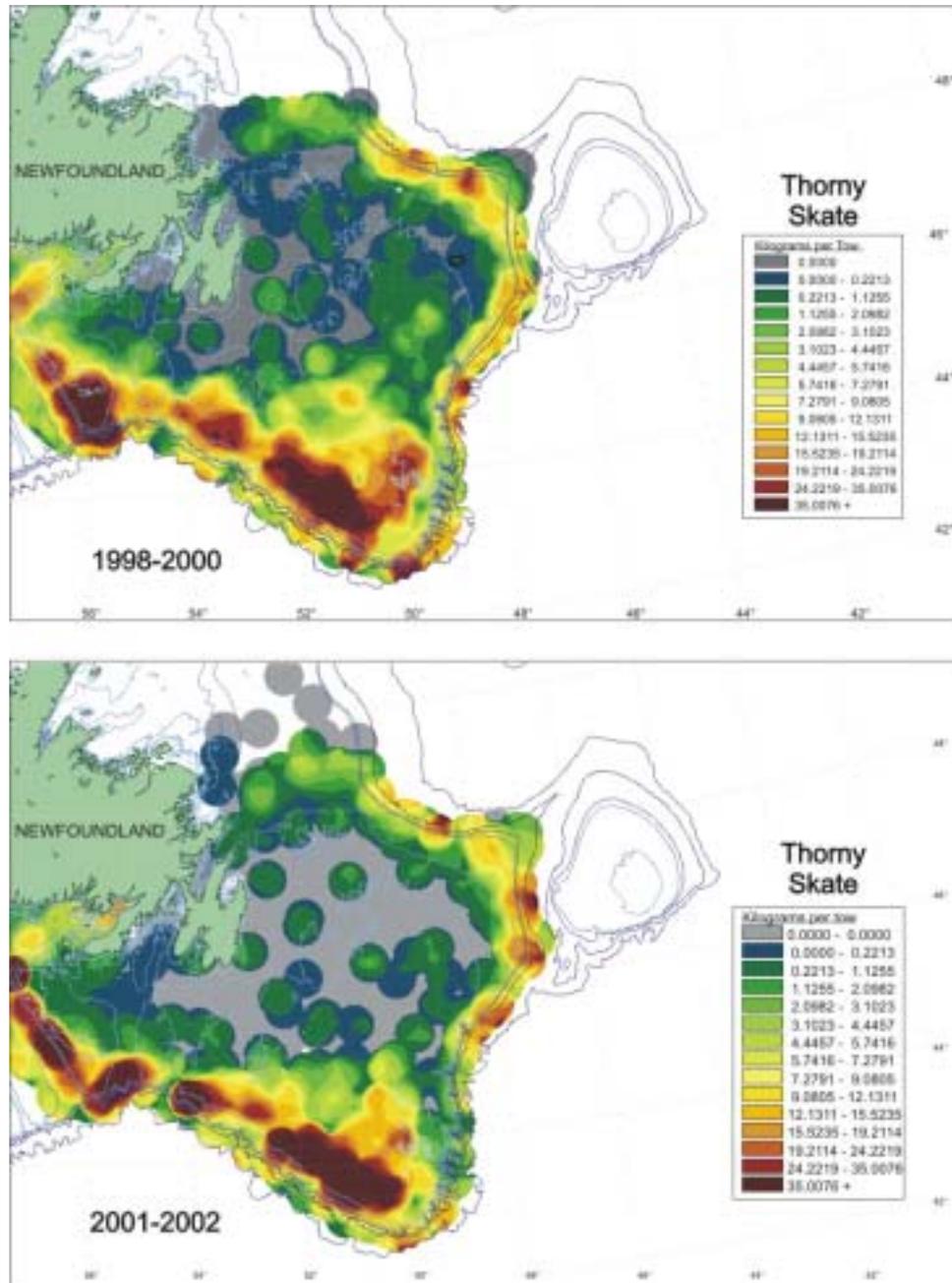


Fig. 14d. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on spring surveys in 1998-2000 and 2001-2002 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

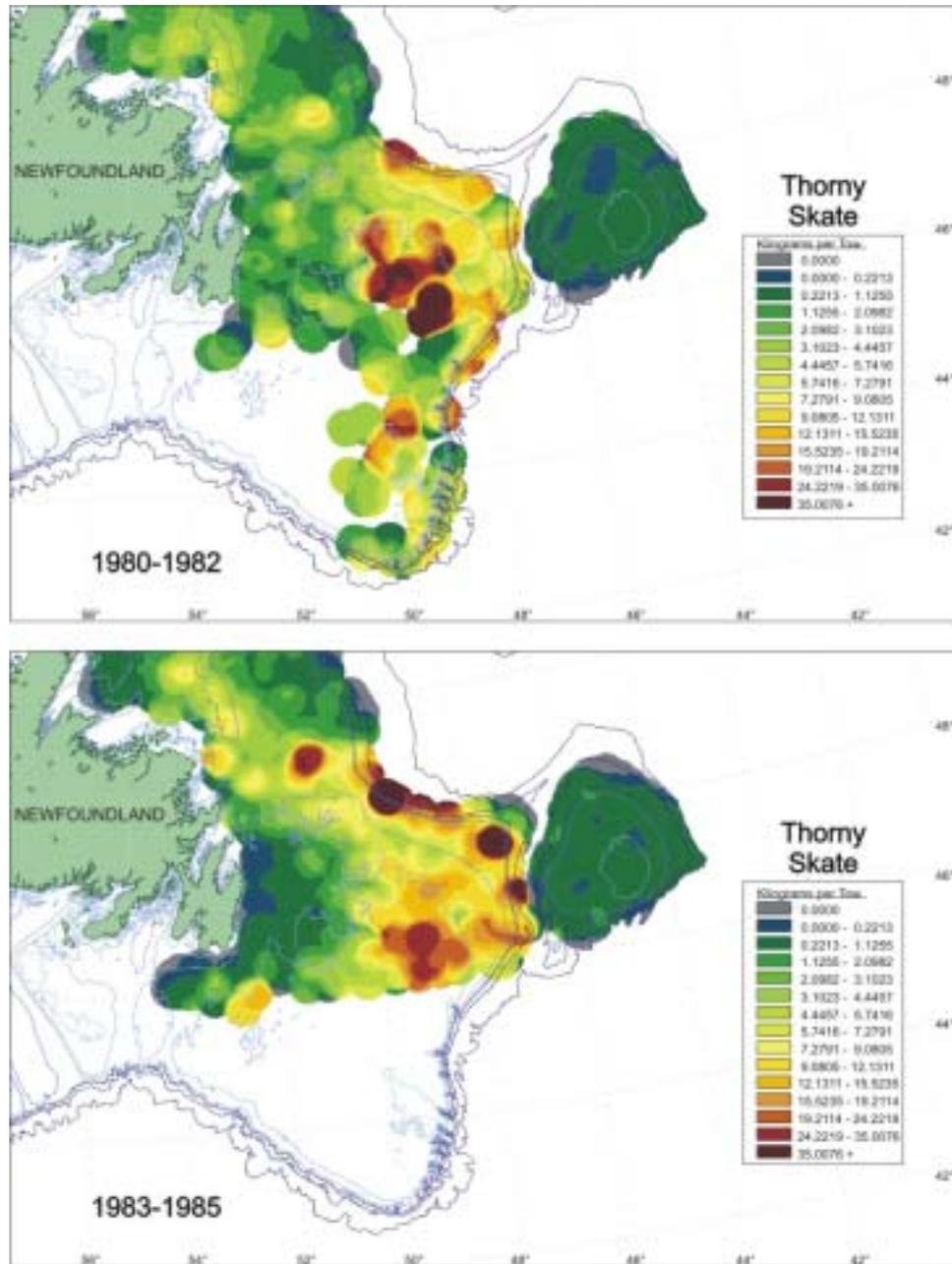


Fig. 15a. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on fall surveys in 1981-1982 and 1983-1985 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

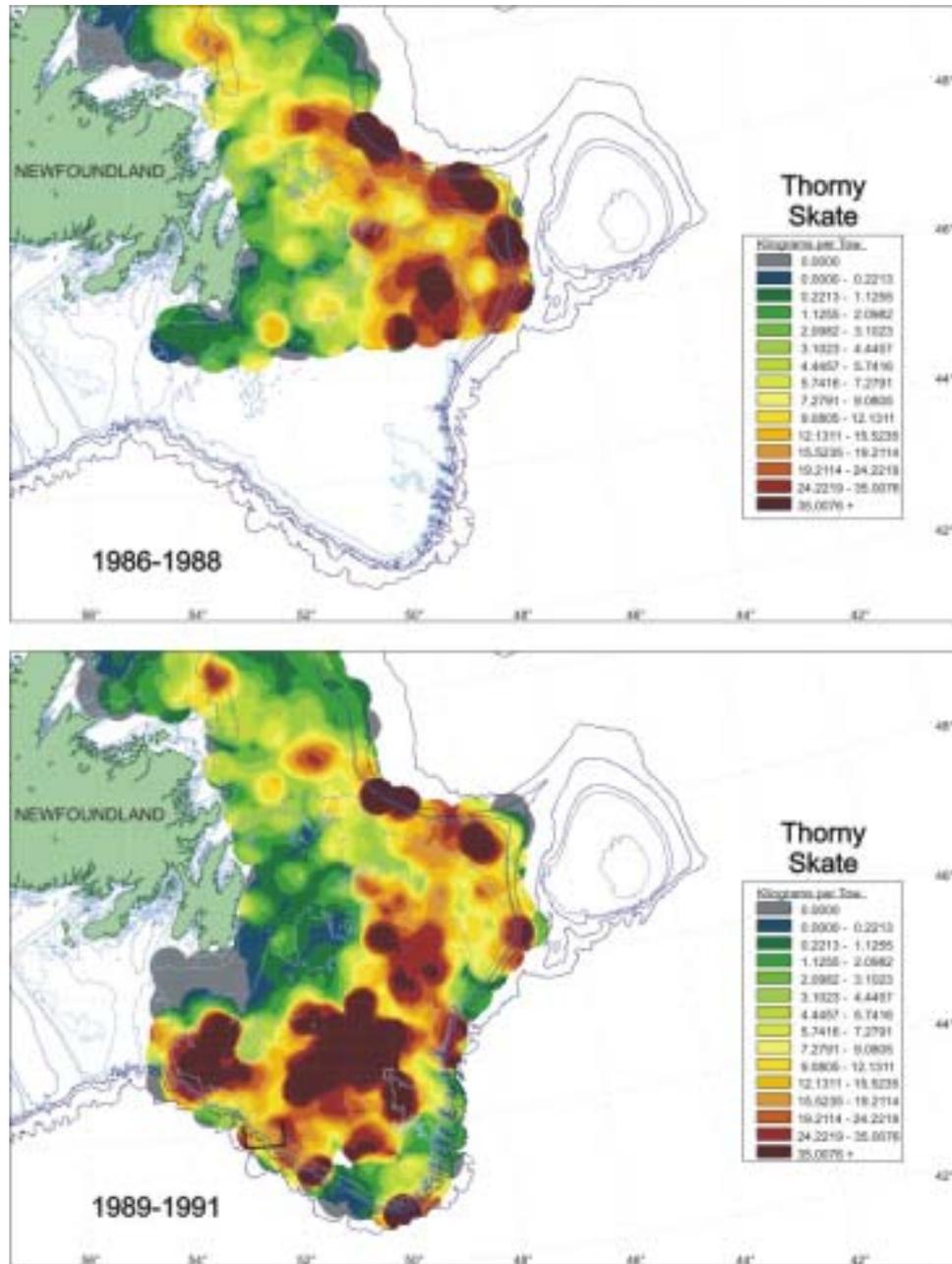


Fig. 15b. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on fall surveys in 1986-1988 and 1989-1991 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

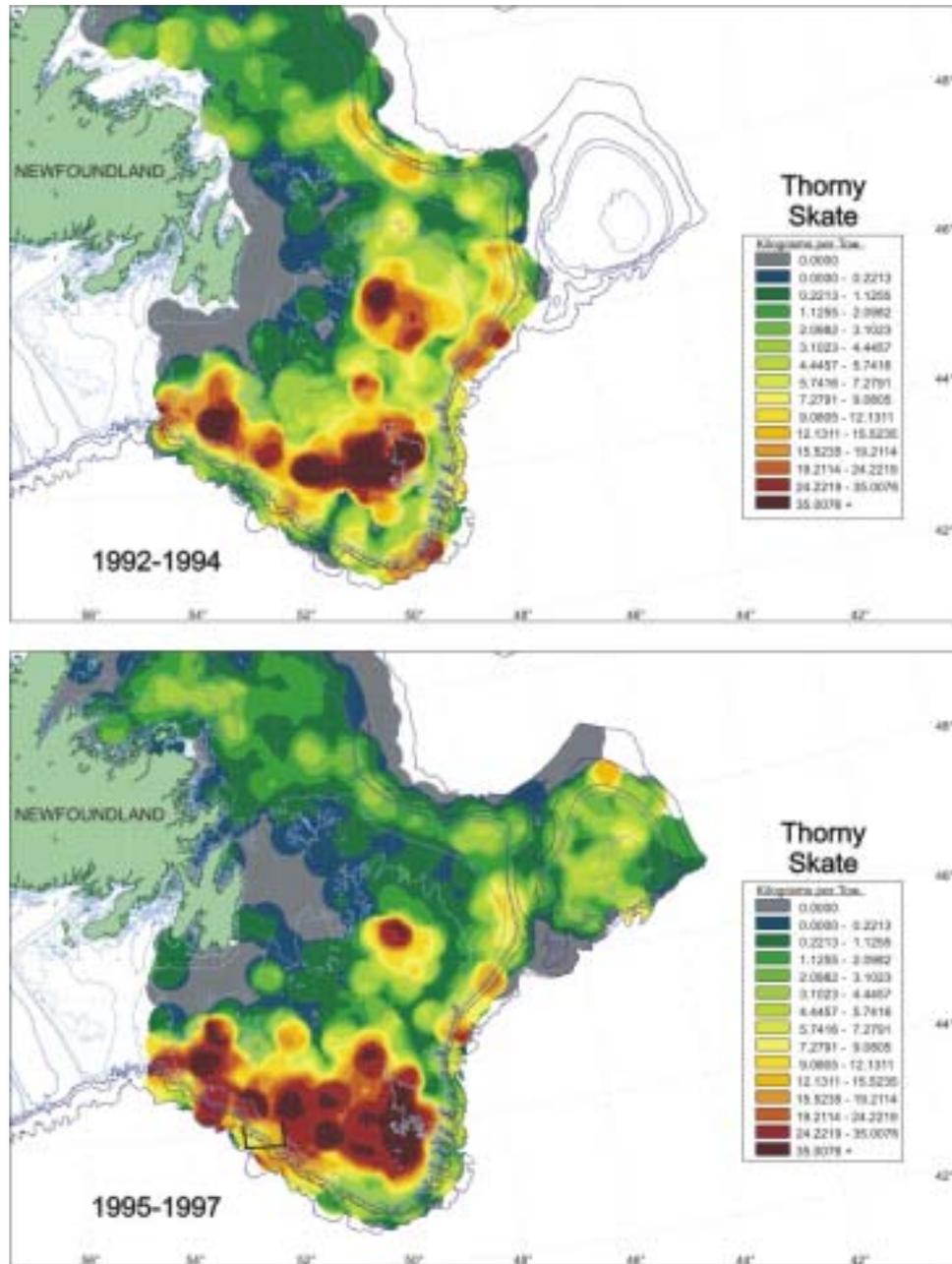


Fig. 15c. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on fall surveys in 1992-1994 and 1995-1997 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

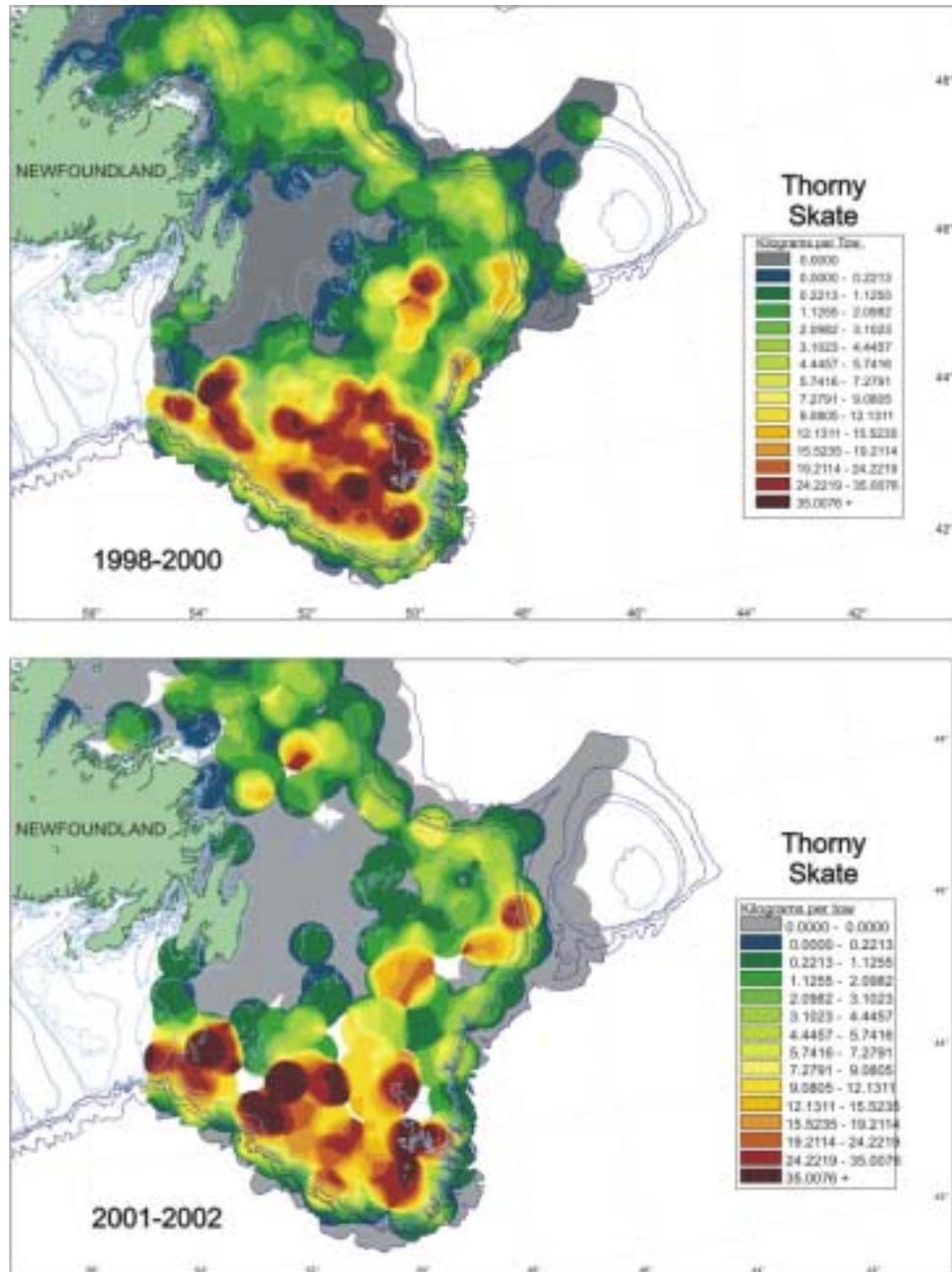


Fig. 15d. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on fall surveys in 1998-2000 and 2001-2002 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

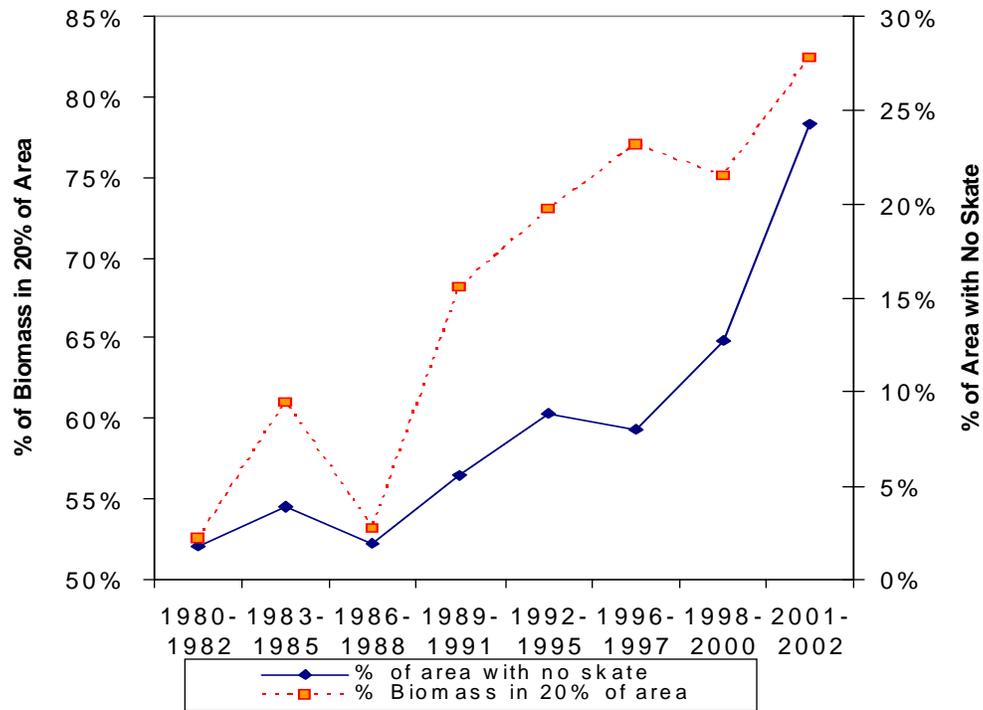


Fig. 16. Changes in area of occupancy, based on spring research surveys in 1980-2002: percent of the stock area (3LNOPs) without thorny skate (solid line), and percent of biomass contained within 20% of the total stock area (dotted line).

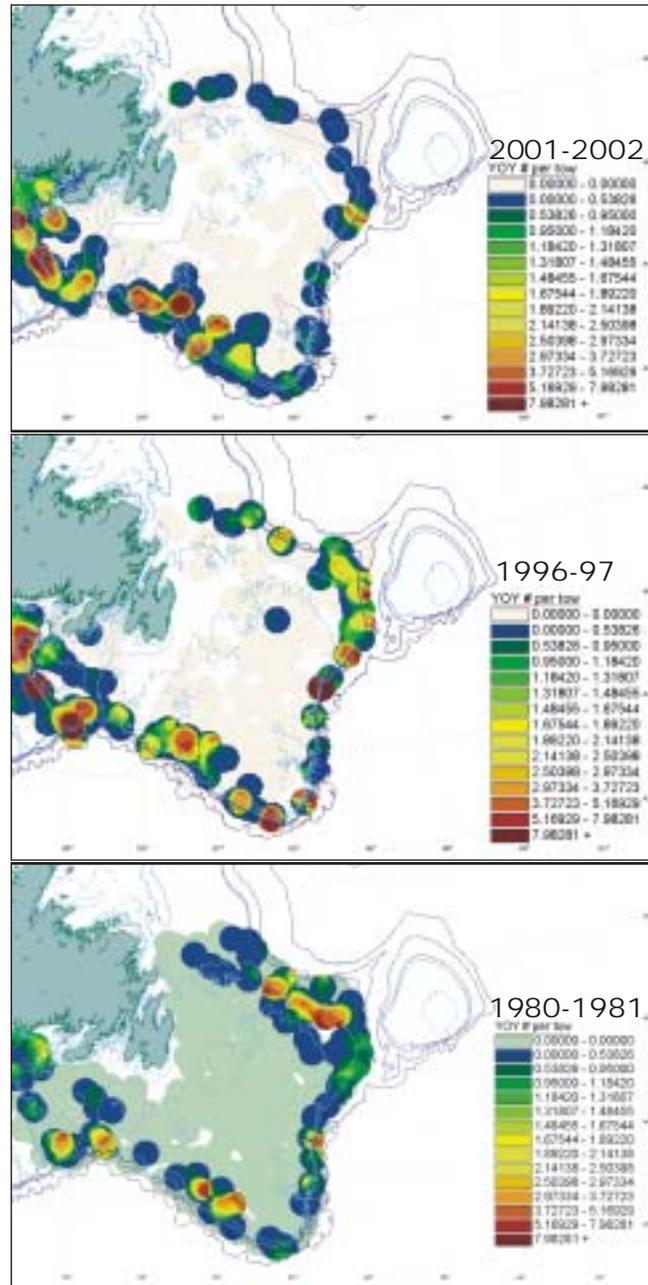


Fig. 17a. Distribution of thorny skate young of the year (YOY) during spring research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

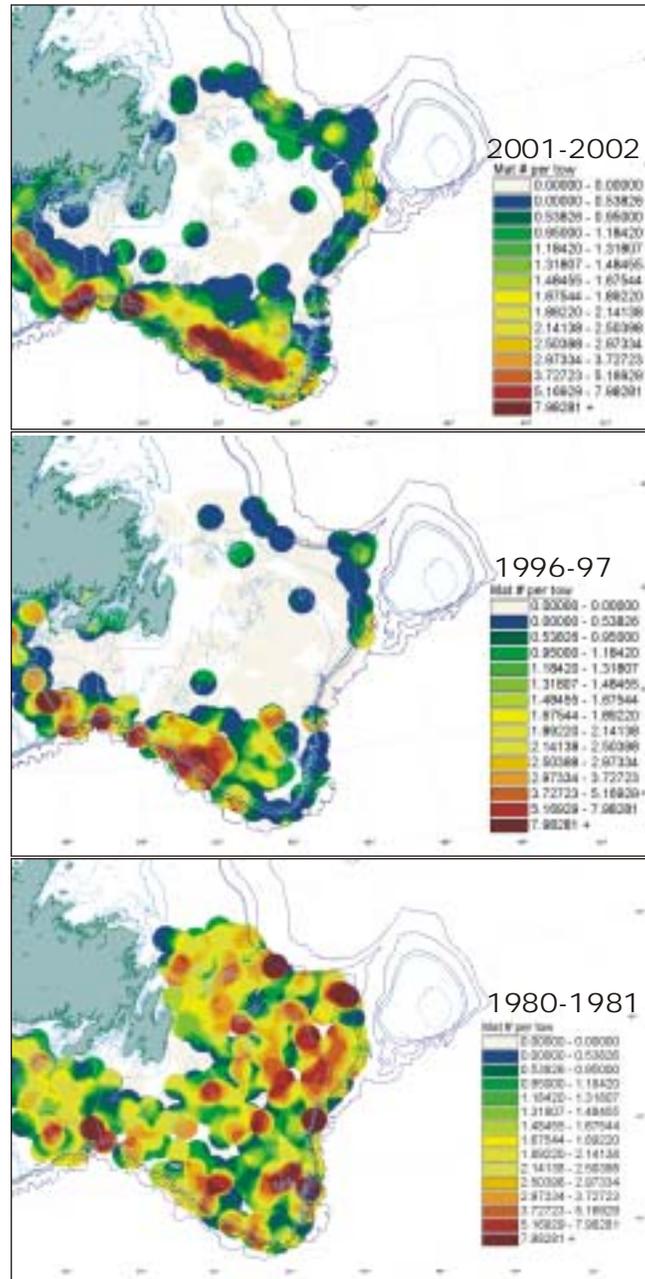


Fig. 17b. Distribution of mature male and female thorny skates during spring research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

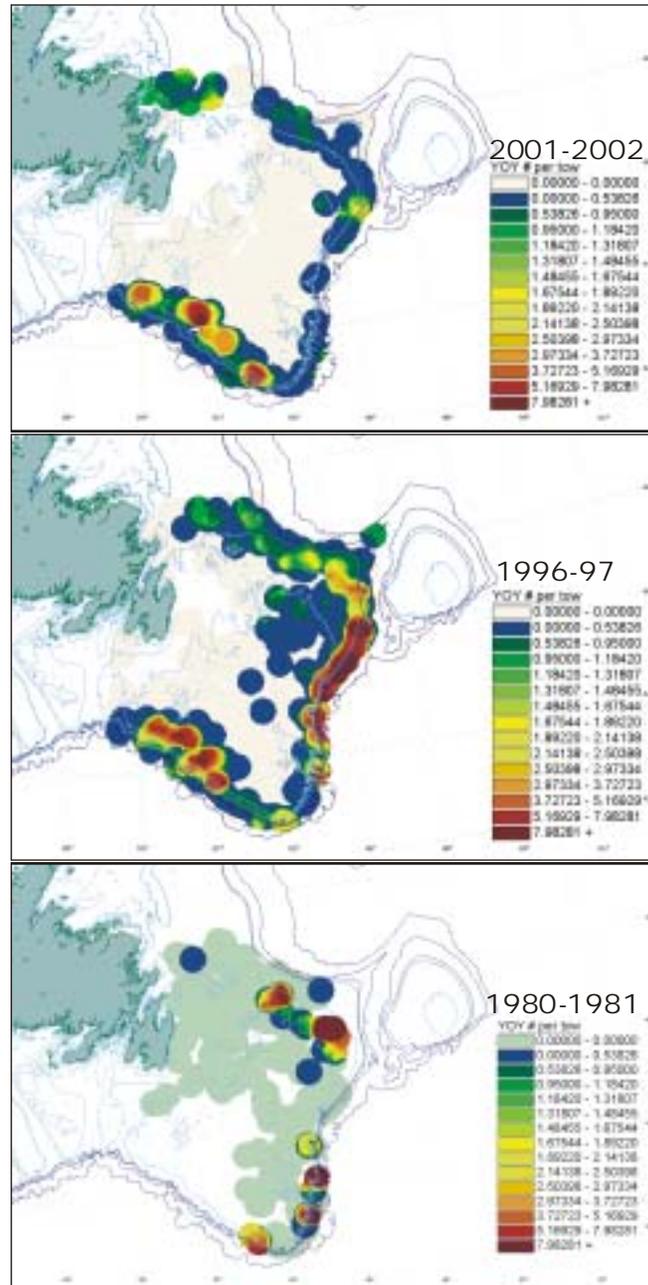


Fig. 17c. Distribution of thorny skate young of the year (YOY) during fall research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

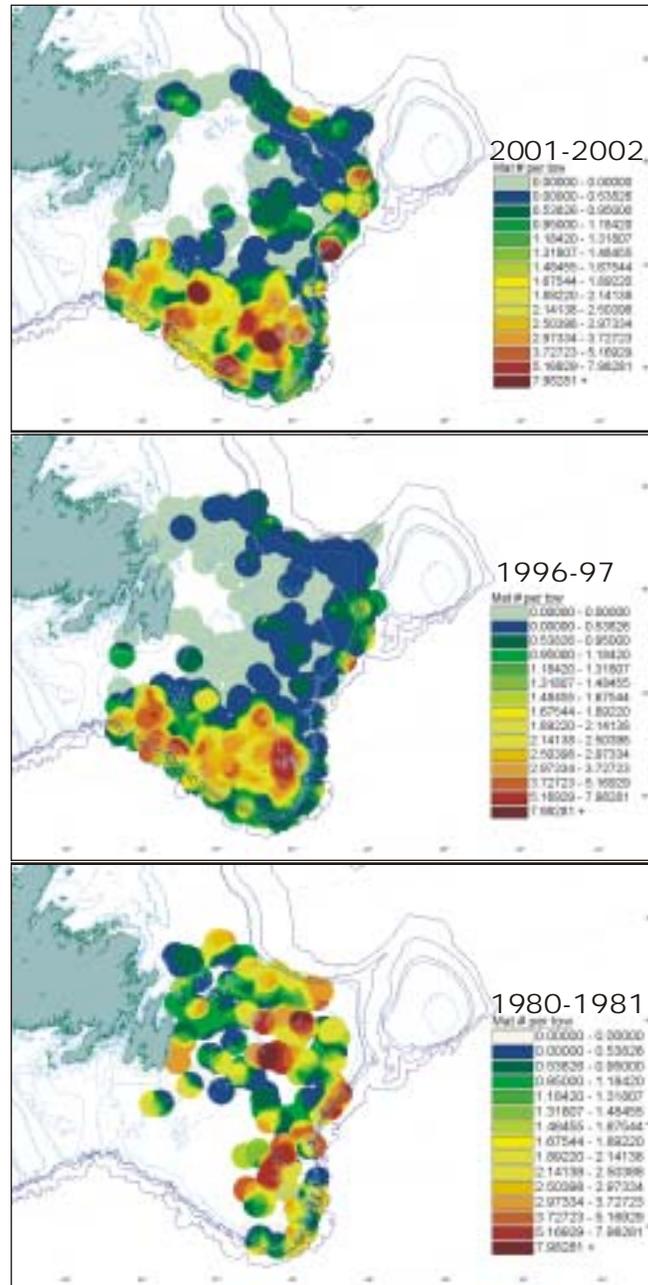


Fig. 17d. Distribution of mature male and female thorny skates during fall research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

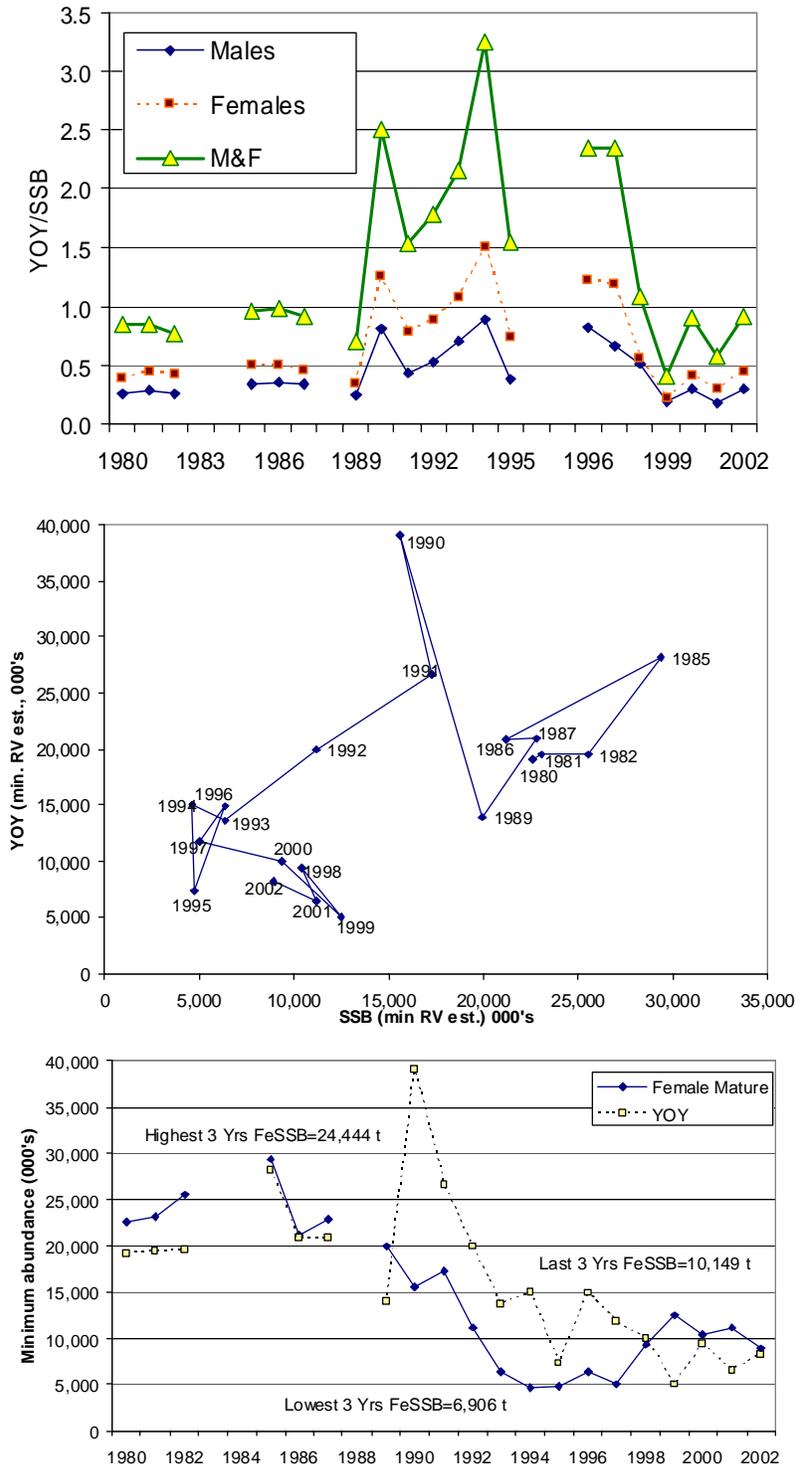


Fig. 18. Relationship between male and female thorny skate young of the year (YOY) and female spawning stock biomass (SSB). Upper panel: Ratio of YOY (young of the year) to SSB (spawning stock biomass; consisting of mature females), 1980-2002. Middle panel: relationship between YOY and SSB derived from spring research surveys. Lower panel: the trends in YOY and SSB over 1980-2002.

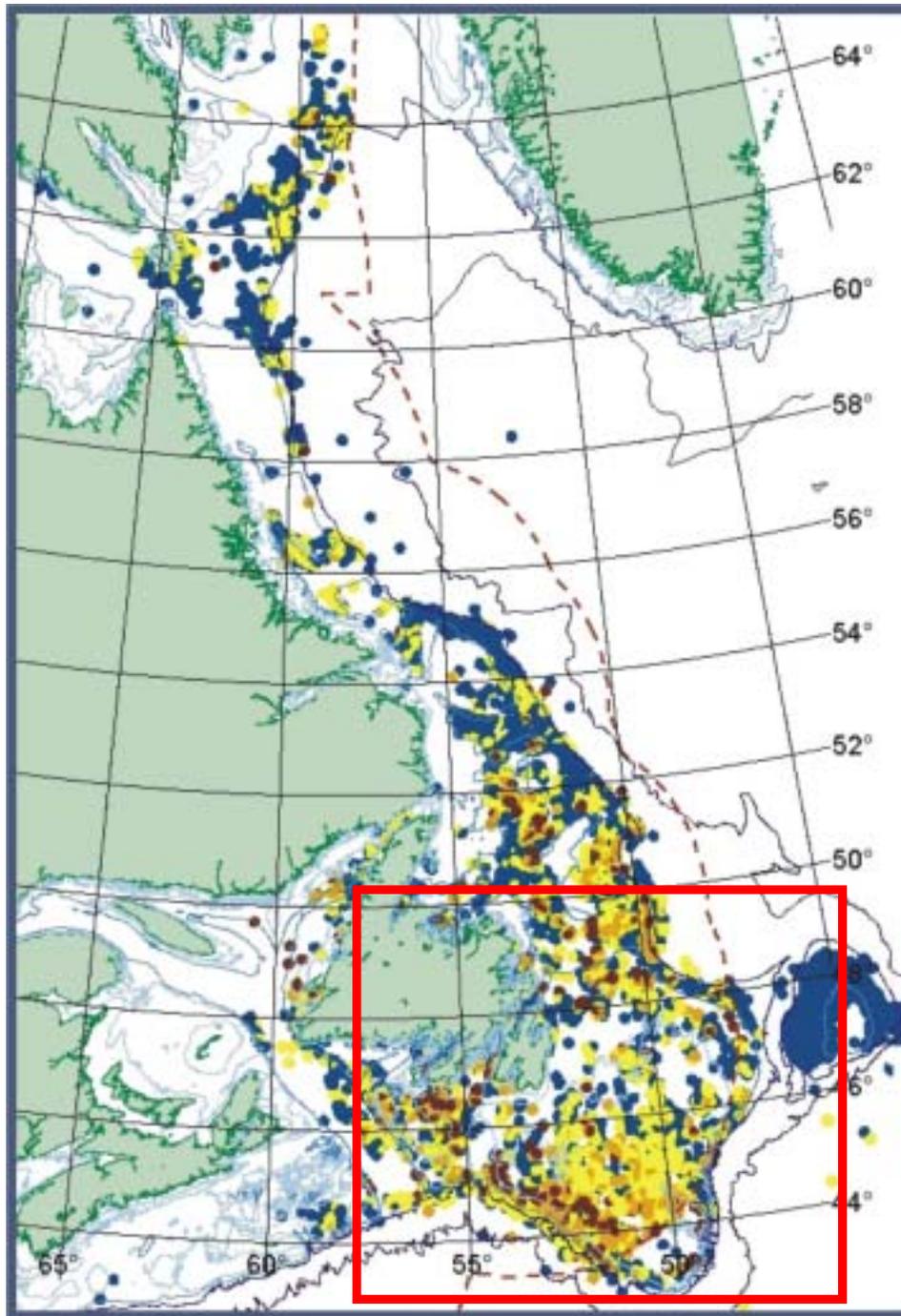


Fig. 19. Distribution of thorny skate catches in all commercial fisheries north of the Laurentian Channel, 1992-2002. Data are from Canadian Fishery Observers.

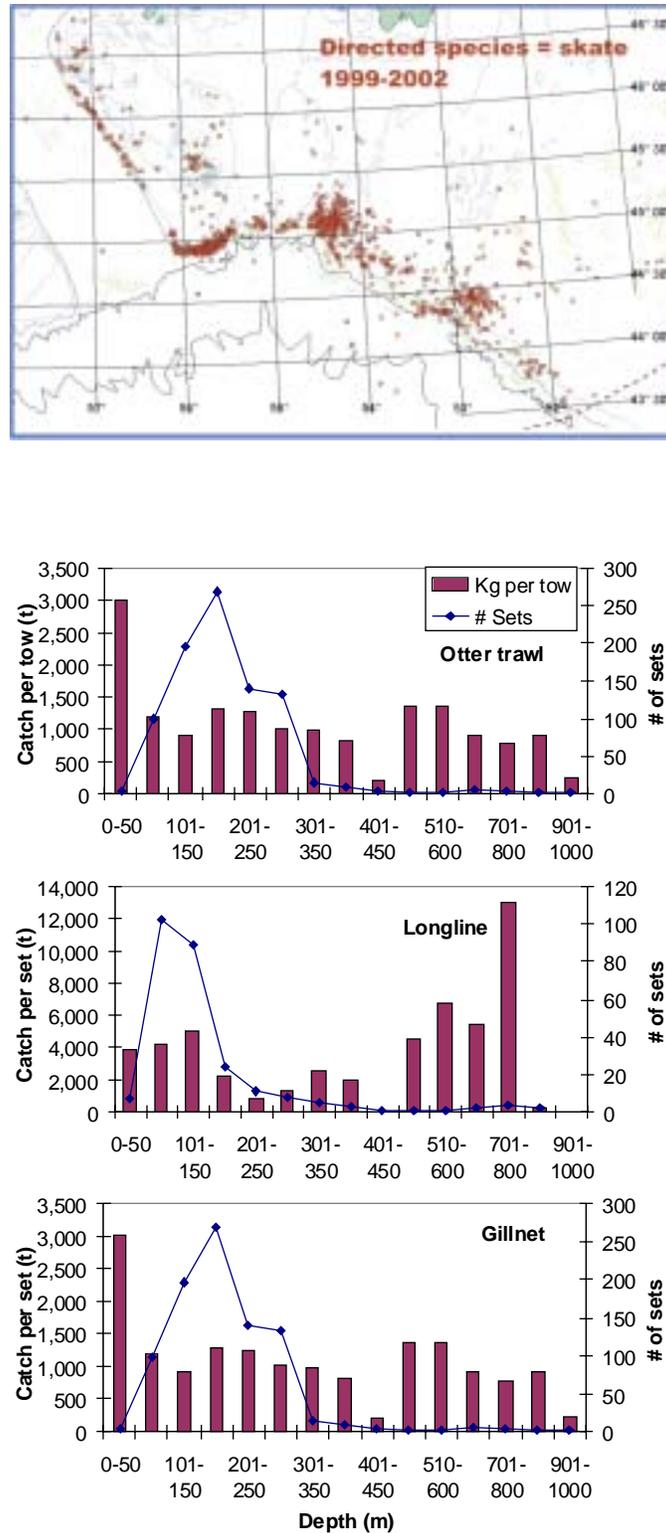


Fig. 20. Distribution of Canadian skate-directed sets for all gear types, 1999-2002. Upper Panel: location depicted as open squares (small dots are sets for other directed species). Lower Panels: fishing effort (number of sets) and skate catch per set by depth for each gear type, 1999-2002.

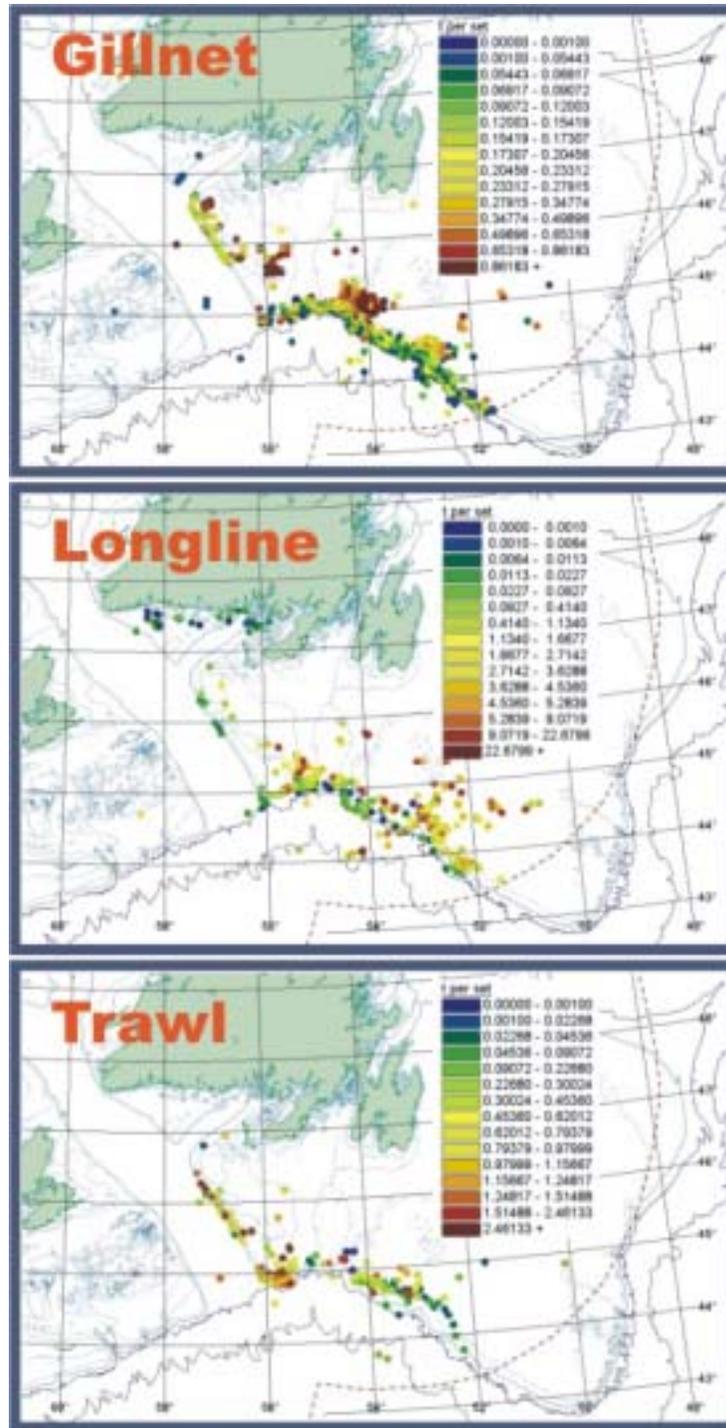


Fig. 21. Distribution of thorny skate catches by gear type in the skate/monkfish/white hake/Atlantic halibut mixed fishery on the Grand Banks, 1999-2002. Red areas denote locations with higher catch rates. Data are from Canadian fishing logs.

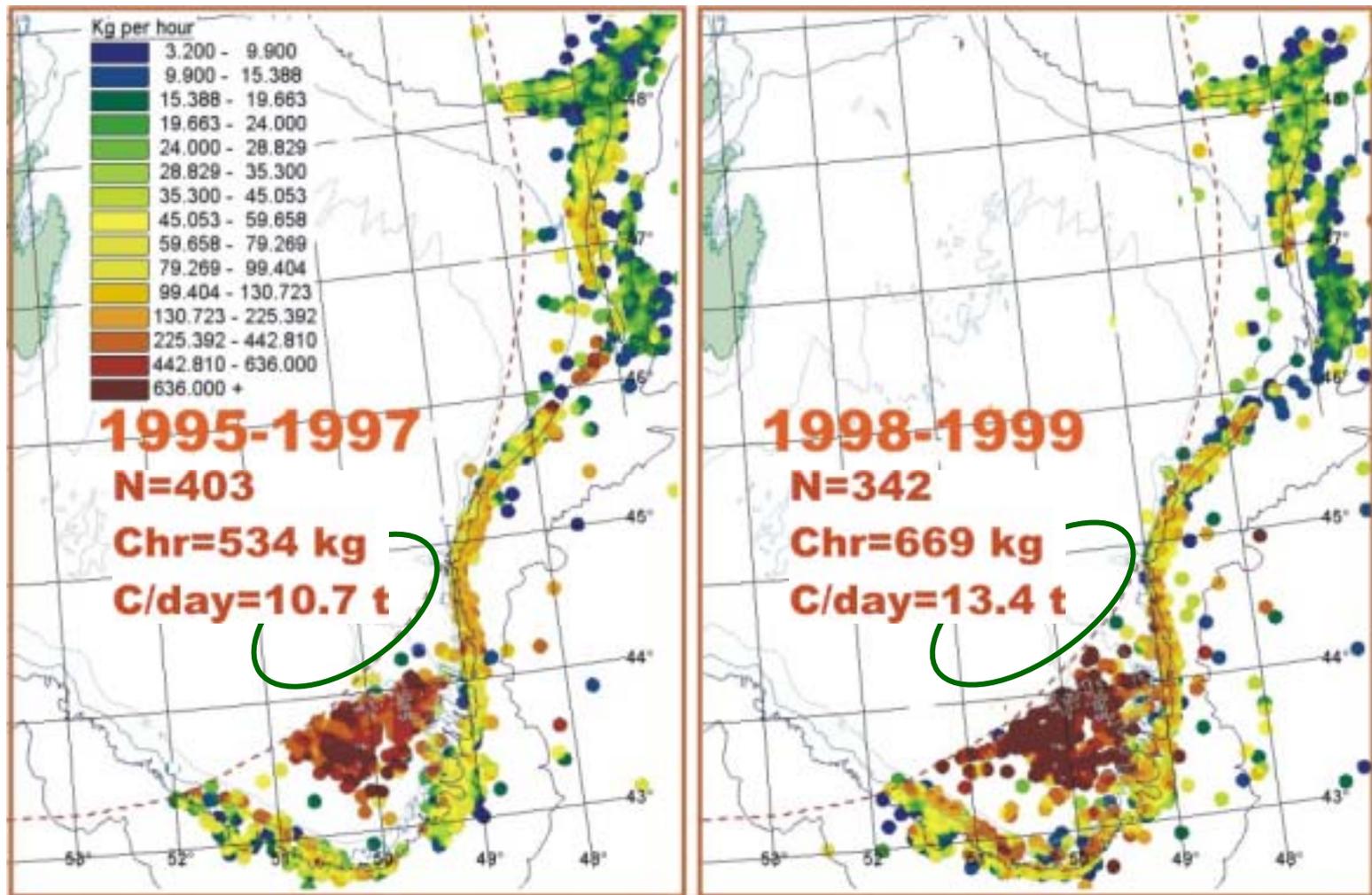


Fig. 22a. Skate catch rates for the non-Canadian otter trawl fishery outside Canada's 200-mile-limit, 1995-1999: directed (encircled) and by-catch (shelf edge; primarily Greenland halibut-directed). Data were derived from fishing logbooks during Canadian commercial vessel inspections at sea (DFO Canada – Conservation & Protection Division). Statistics below the date refer only to sets within the circled area: N= number of sets; Chr= catch rate per hour; C/day= skate catch per day.

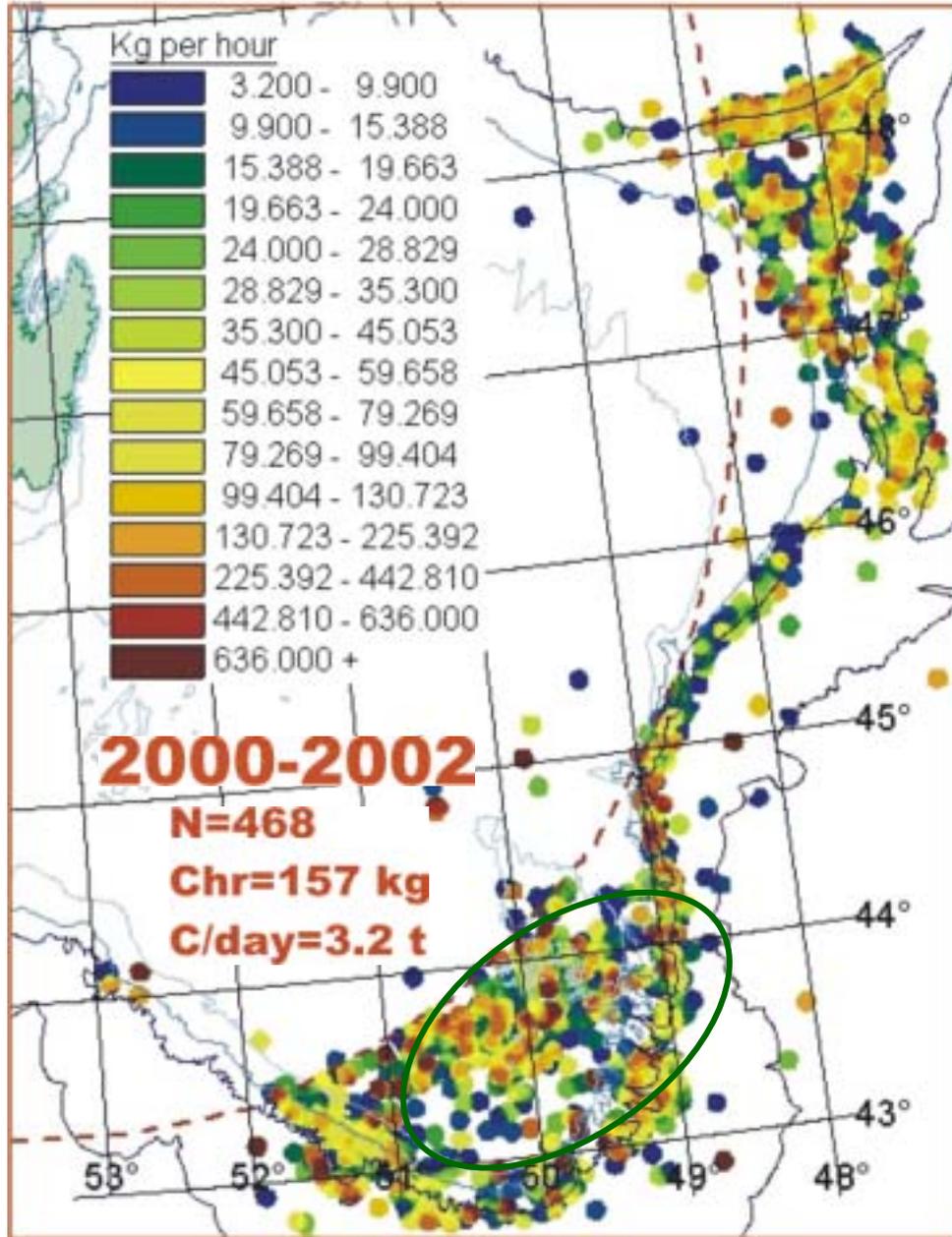


Fig. 22b. Skate catch rates for the non-Canadian otter trawl fishery outside Canada's 200-mile-limit, 2000-2002: directed (encircled) and by-catch (shelf edge; primarily Greenland halibut-directed). Data were derived from fishing logbooks during Canadian commercial vessel inspections at sea (DFO Canada – Conservation & Protection Division). Statistics below the date refer only to sets within the circled area: N= number of sets; Chr= catch rate per hour; C/day= skate catch per day.

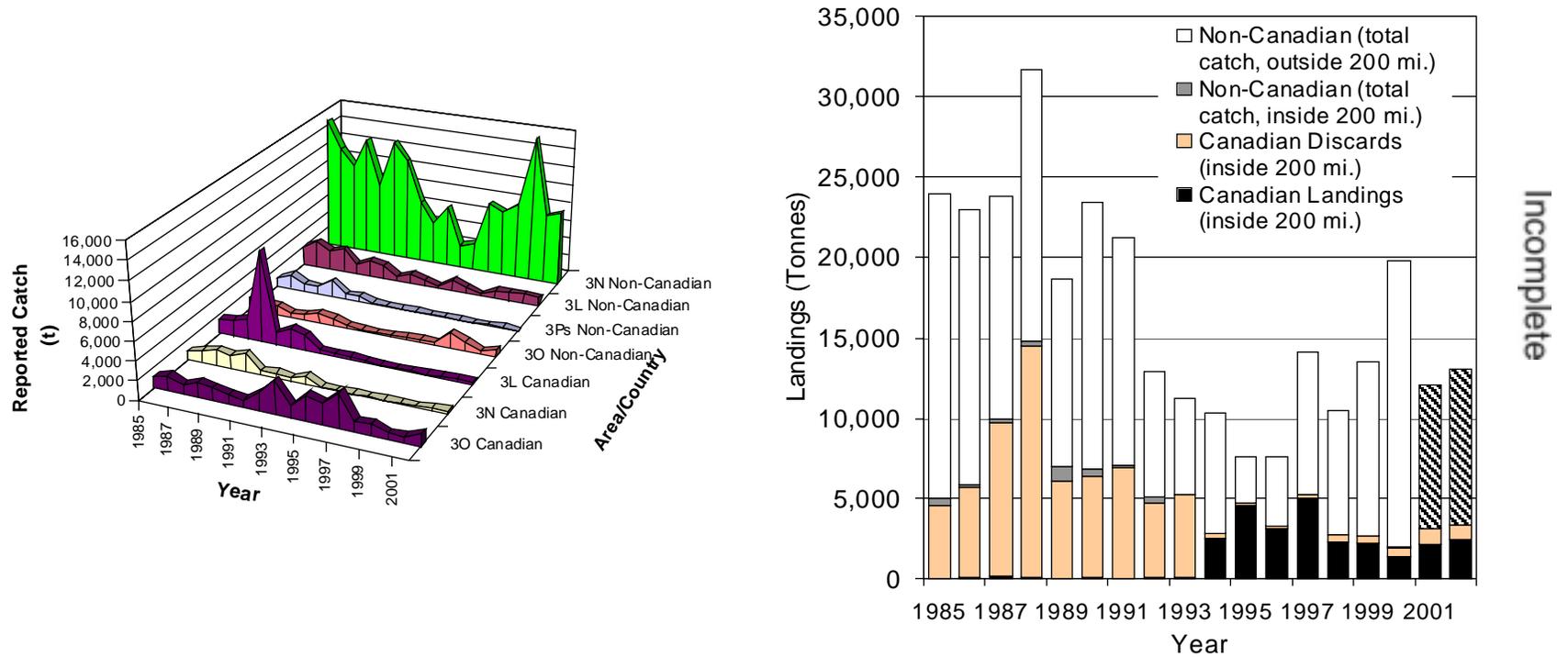


Fig. 23. Reported catches of skate in NAFO Divisions 3LNOPs by all countries, 1985-2002. Non-Canadian data for 2001 and 2002 (striped portion of vertical bars) are preliminary. Non-Canadian total catches (outside Canada's 200-mile-limit) in 2002 are those agreed upon by the NAFO Scientific Council in 2003. Skate data were not speciated; although Canadian Fishery Observer data indicated that thorny skates comprise 90% of skate catches on the Grand Banks.

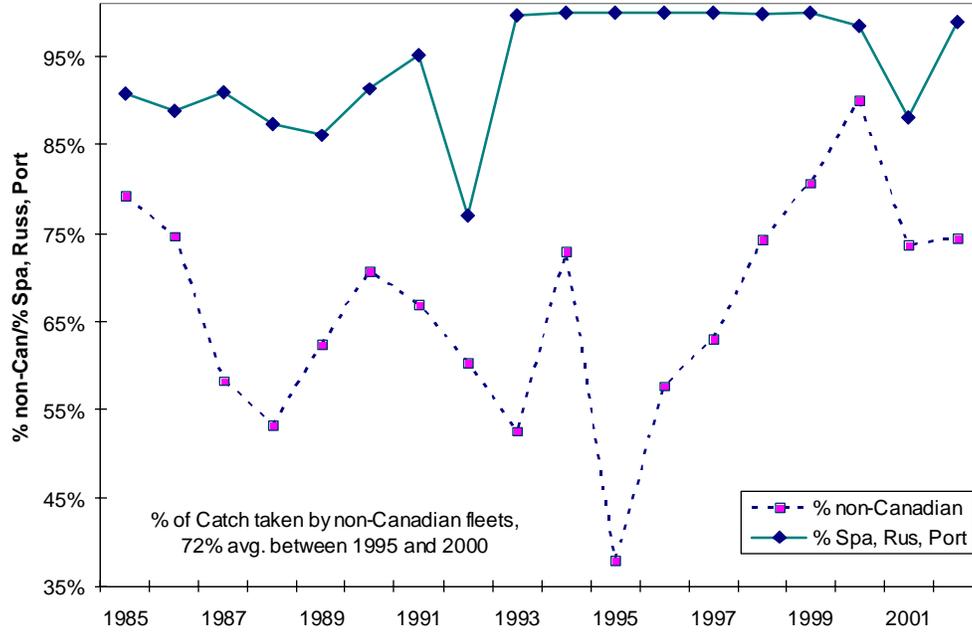
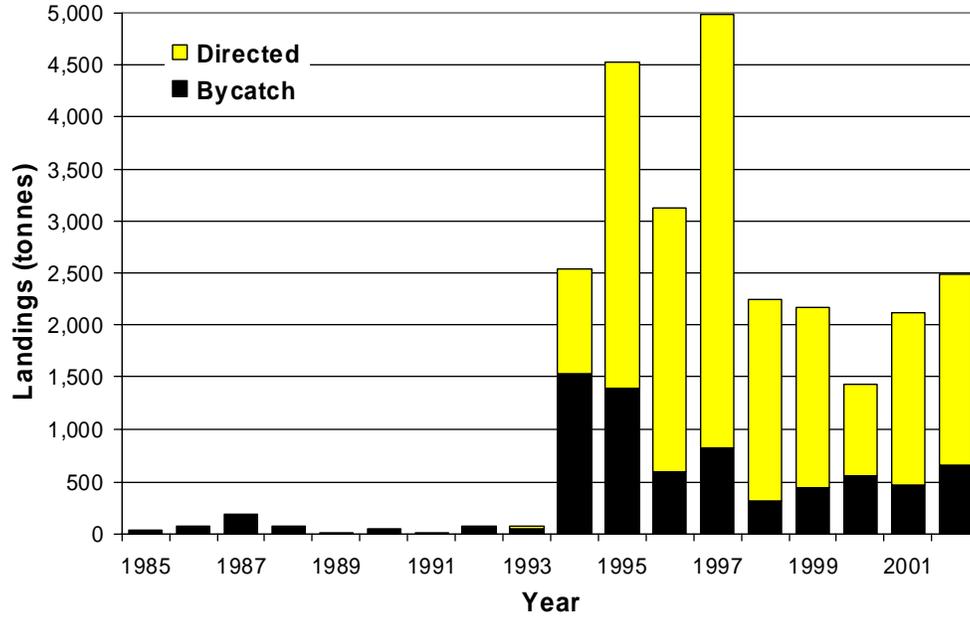
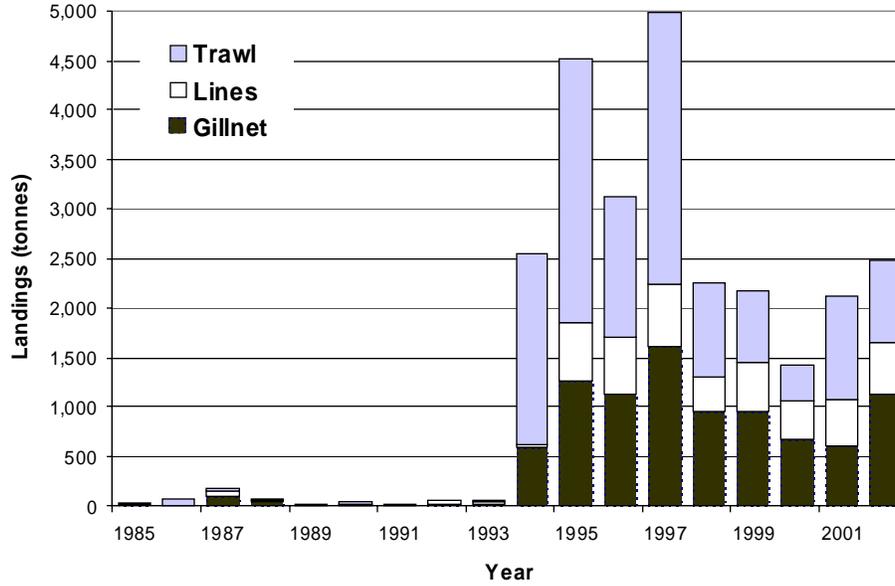


Fig. 24. Percent of total skate catches taken by non-Canadian fleets (from DFO C&P commercial vessel inspections), and percent of non-Canadian catches taken by Spain, Portugal, and Russia, 1985-2002 (from NAFO STATLANT-21A). Catches from twelve other countries comprised the remainder. Non-Canadian data for 2001 and 2002 are preliminary.



| Year | 3L | | 3N | | 3O | | 3Ps | | All Divisions | | |
|------|---------|----------|---------|----------|---------|----------|---------|----------|---------------|---------|----------|
| | Bycatch | Directed | Bycatch | Directed | Bycatch | Directed | Bycatch | Directed | Total | Bycatch | Directed |
| 1985 | 7 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 21 | 21 | 0 |
| 1986 | 70 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 73 | 73 | 0 |
| 1987 | 148 | 0 | 0 | 0 | 0 | 0 | 36 | 0 | 184 | 184 | 0 |
| 1988 | 57 | 0 | 2 | 0 | 8 | 0 | 1 | 0 | 68 | 68 | 0 |
| 1989 | 9 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 14 | 10 | 4 |
| 1990 | 34 | 0 | 1 | 0 | 1 | 4 | 4 | 0 | 44 | 40 | 4 |
| 1991 | 4 | 0 | 6 | 0 | 5 | 0 | 0 | 0 | 15 | 15 | 0 |
| 1992 | 16 | 0 | 41 | 0 | 4 | 0 | 3 | 0 | 63 | 63 | 0 |
| 1993 | 8 | 0 | 5 | 0 | 14 | 21 | 15 | 0 | 62 | 42 | 21 |
| 1994 | 165 | 0 | 3 | 2 | 1,018 | 178 | 348 | 825 | 2,540 | 1,535 | 1,005 |
| 1995 | 157 | 15 | 0 | 1 | 459 | 1,965 | 780 | 1,153 | 4,530 | 1,396 | 3,135 |
| 1996 | 54 | 1 | 3 | 4 | 274 | 1,850 | 256 | 681 | 3,123 | 588 | 2,536 |
| 1997 | 26 | 0 | 3 | 145 | 524 | 2,981 | 272 | 1,032 | 4,983 | 824 | 4,158 |
| 1998 | 11 | 12 | 5 | 0 | 95 | 868 | 199 | 1,059 | 2,250 | 311 | 1,939 |
| 1999 | 7 | 15 | 2 | 9 | 83 | 951 | 357 | 744 | 2,168 | 450 | 1,719 |
| 2000 | 25 | 2 | 4 | 0 | 149 | 317 | 369 | 566 | 1,432 | 547 | 885 |
| 2001 | 13 | 4 | 0 | 0 | 95 | 242 | 368 | 1,399 | 2,121 | 476 | 1,645 |
| 2002 | 9 | 8 | 3 | 16 | 291 | 767 | 355 | 1,037 | 2,486 | 658 | 1,829 |

Fig. 25. Directed and non-directed Canadian skate landings in NAFO Div. 3LNOPs, 1985-2002. Data do not include discards at sea.



| Year | Gillnet | | Lines | | Trawl | | Other | | Total | Bycatch and Directed | | |
|------|---------|----------|---------|----------|---------|----------|---------|----------|-------|----------------------|-------|-------|
| | Bycatch | Directed | Bycatch | Directed | Bycatch | Directed | Bycatch | Directed | | Gillnet | Lines | Trawl |
| 1985 | 12 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 21 | 12 | 9 | 0 |
| 1986 | 1 | 0 | 0 | 0 | 72 | 0 | 0 | 0 | 73 | 1 | 0 | 72 |
| 1987 | 95 | 0 | 46 | 0 | 40 | 0 | 2 | 0 | 182 | 95 | 46 | 40 |
| 1988 | 43 | 0 | 11 | 0 | 14 | 0 | 0 | 0 | 68 | 43 | 11 | 14 |
| 1989 | 1 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 14 | 1 | 0 | 13 |
| 1990 | 5 | 0 | 1 | 0 | 33 | 0 | 1 | 4 | 39 | 5 | 1 | 33 |
| 1991 | 0 | 0 | 9 | 0 | 6 | 0 | 0 | 0 | 15 | 0 | 9 | 6 |
| 1992 | 11 | 0 | 45 | 0 | 7 | 0 | 1 | 0 | 62 | 11 | 45 | 7 |
| 1993 | 16 | 0 | 16 | 0 | 10 | 21 | 0 | 0 | 62 | 16 | 16 | 31 |
| 1994 | 565 | 24 | 24 | 0 | 943 | 982 | 2 | 0 | 2,538 | 589 | 24 | 1,925 |
| 1995 | 820 | 450 | 489 | 86 | 76 | 2,598 | 11 | 0 | 4,519 | 1,270 | 575 | 2,674 |
| 1996 | 444 | 689 | 120 | 442 | 22 | 1,405 | 0 | 0 | 3,121 | 1,133 | 561 | 1,427 |
| 1997 | 258 | 1,349 | 183 | 447 | 382 | 2,362 | 0 | 0 | 4,982 | 1,607 | 630 | 2,745 |
| 1998 | 116 | 835 | 156 | 195 | 38 | 910 | 0 | 0 | 2,249 | 951 | 351 | 948 |
| 1999 | 177 | 778 | 203 | 284 | 69 | 656 | 0 | 0 | 2,168 | 956 | 487 | 724 |
| 2000 | 184 | 488 | 345 | 48 | 18 | 336 | 0 | 0 | 1,419 | 672 | 393 | 354 |
| 2001 | 254 | 354 | 198 | 269 | 23 | 1,022 | 0 | 0 | 2,120 | 608 | 467 | 1,044 |
| 2002 | 487 | 632 | 135 | 397 | 34 | 799 | 0 | 0 | 2,484 | 1,119 | 532 | 834 |

Fig. 26. Canadian skate landings in NAFO Div. 3LNOPs by gear type and mode (directed or by-catch), 1985-2002. Data do not include discards at sea.

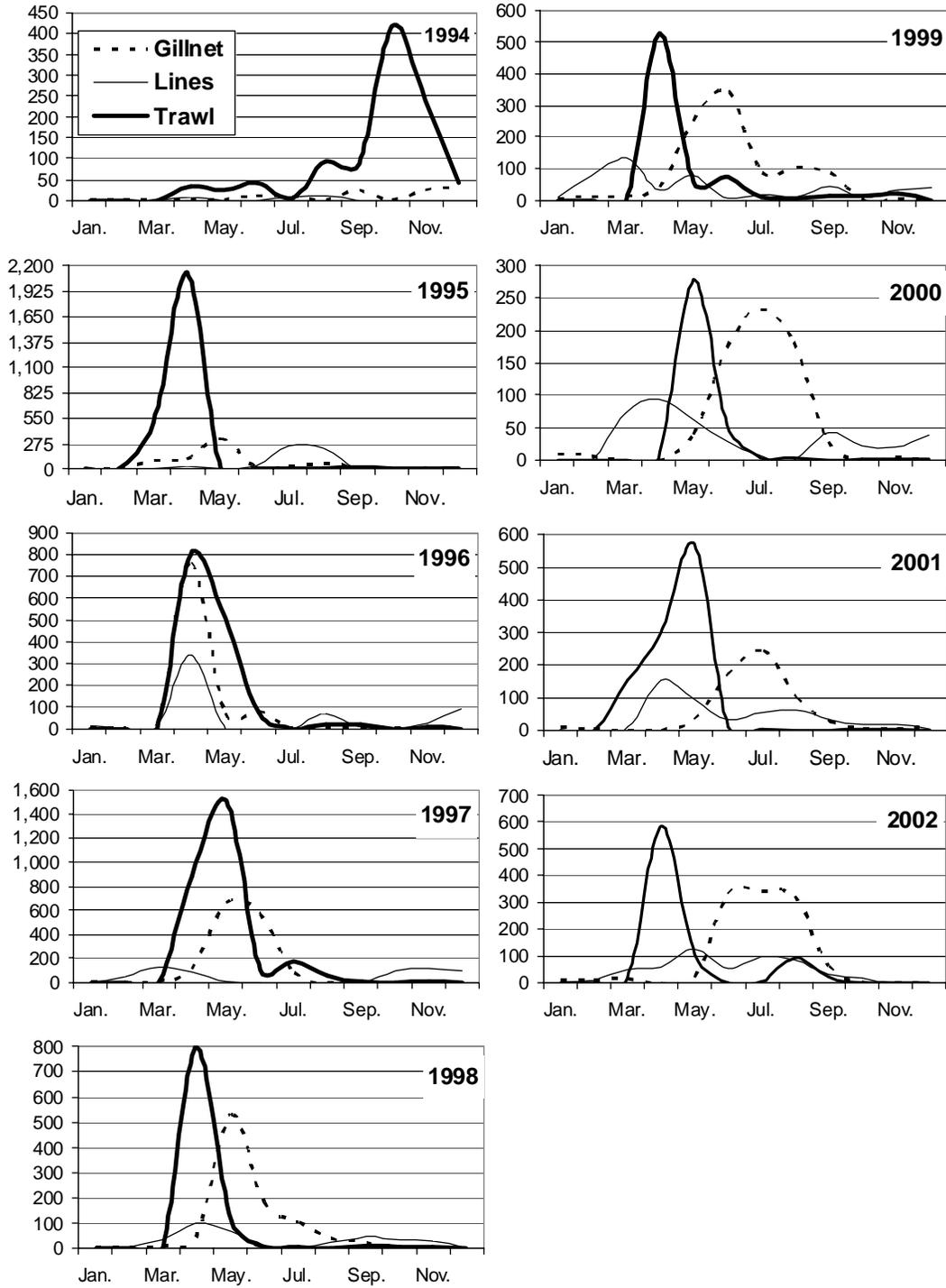


Fig. 27. Monthly Canadian landings of skate in NAFO Div. 3LNOPs, 1994-2002. Landing records for which no month was recorded are excluded.

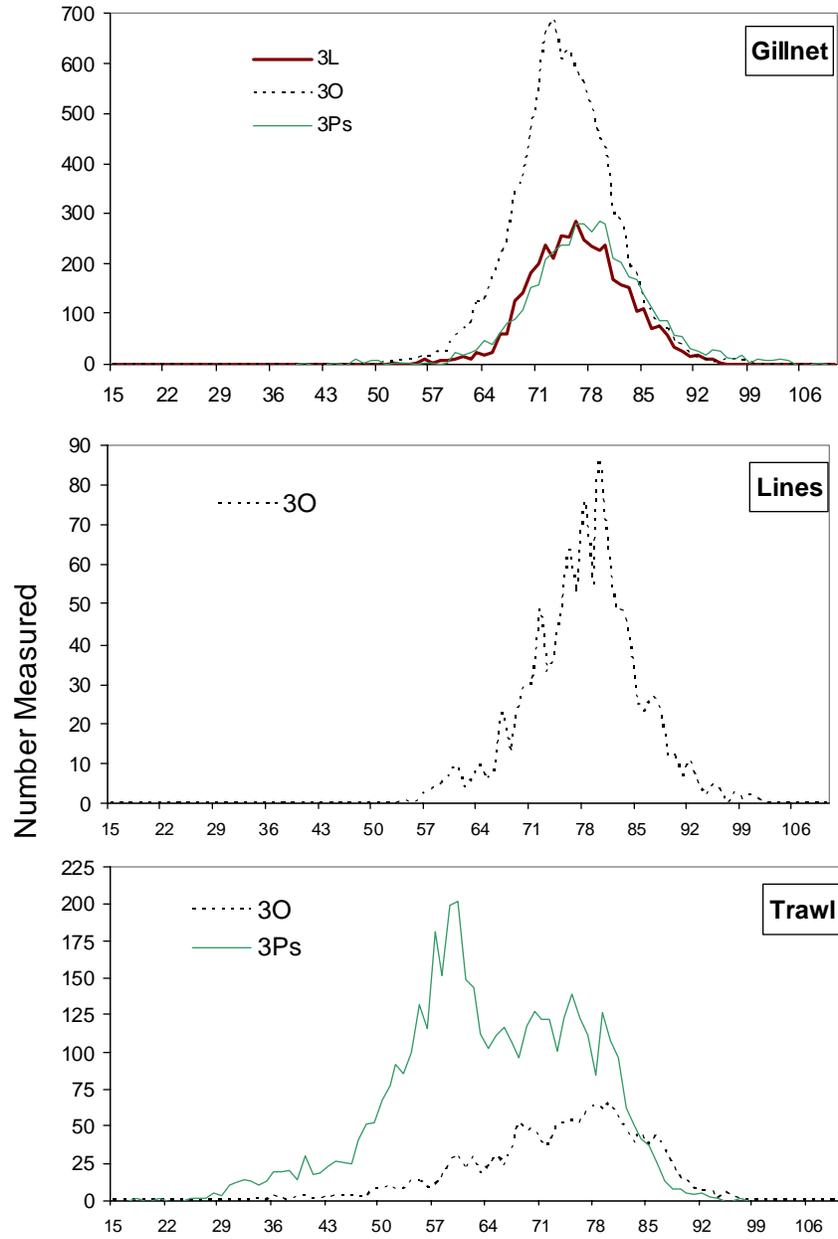


Fig. 28. Length frequencies of Canadian commercial skate catches in NAFO Div. 3LOPs. Data are from Canadian Fishery Observers, 1994-2002.

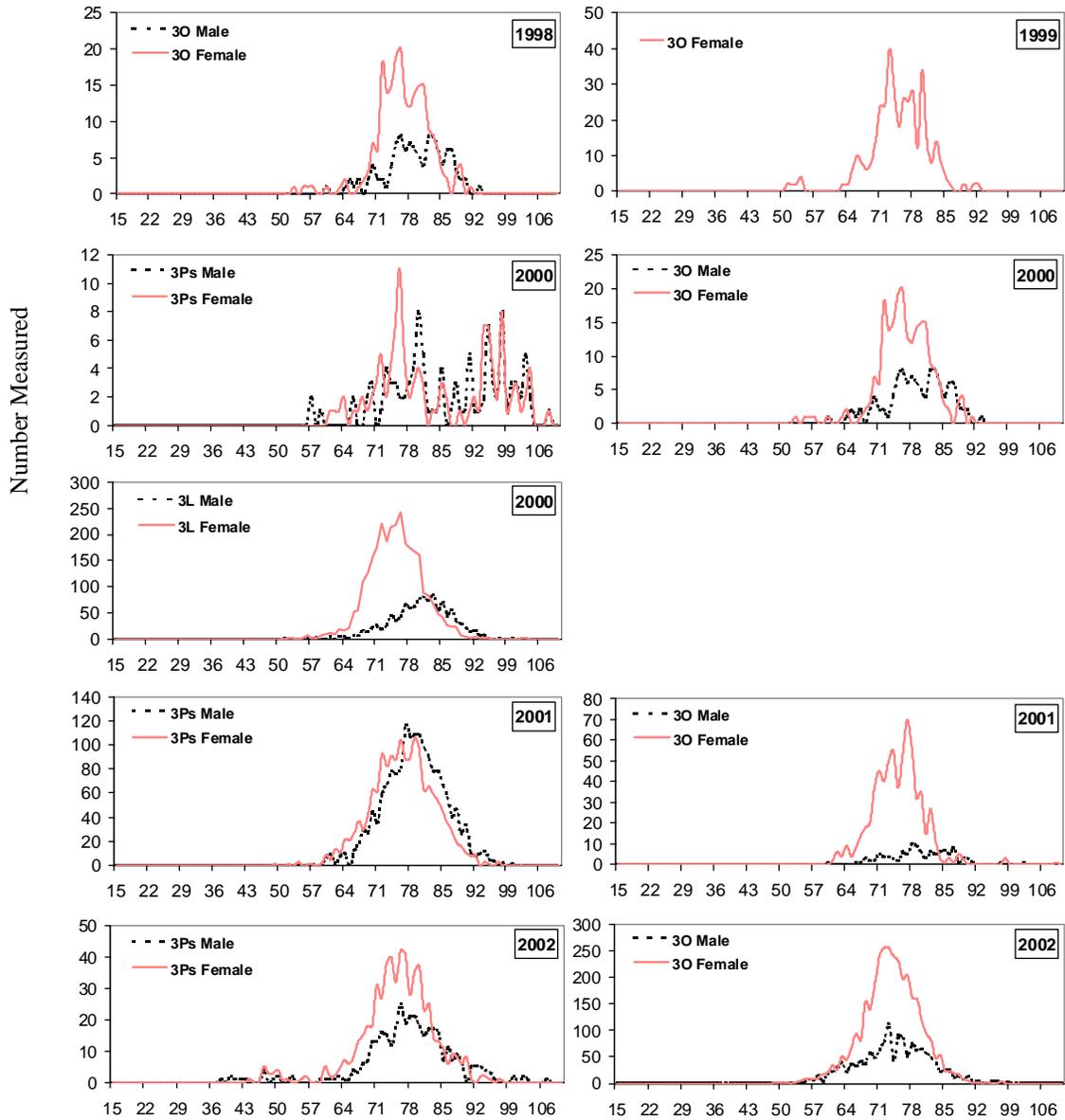


Fig. 29a. Length frequencies of Canadian commercial skate catches for gillnets in NAFO Div. 3LOPs, 1998-2002. X-axis represents lengths of skate in centimeters. Data are from Canadian Fishery Observers.

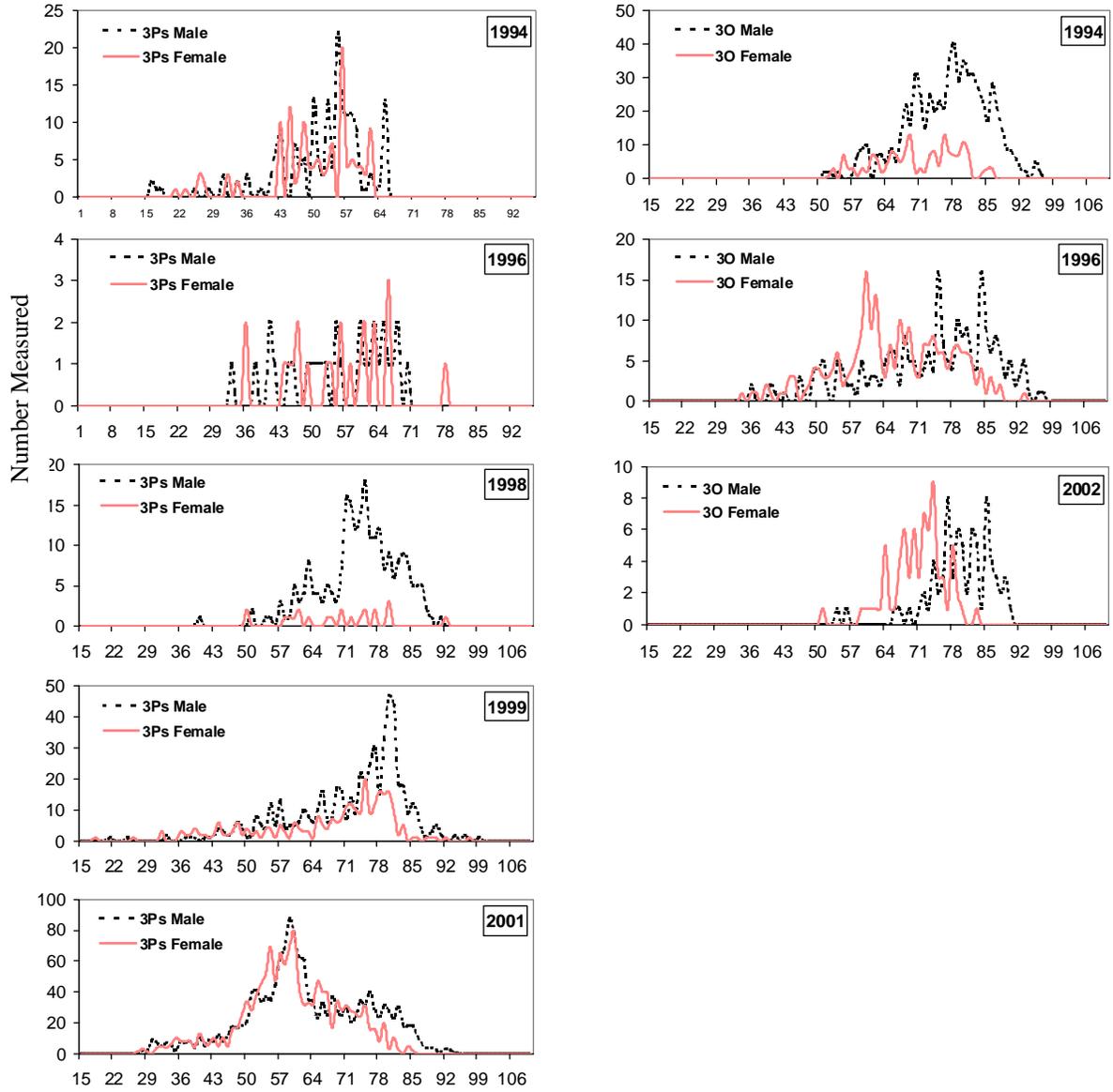


Fig. 29b. Length frequencies of Canadian commercial skate catches for trawls in NAFO Div. 3OPs, 1994-2002. X-axis represents lengths of skate in centimeters. Data are from Canadian Fishery Observers.

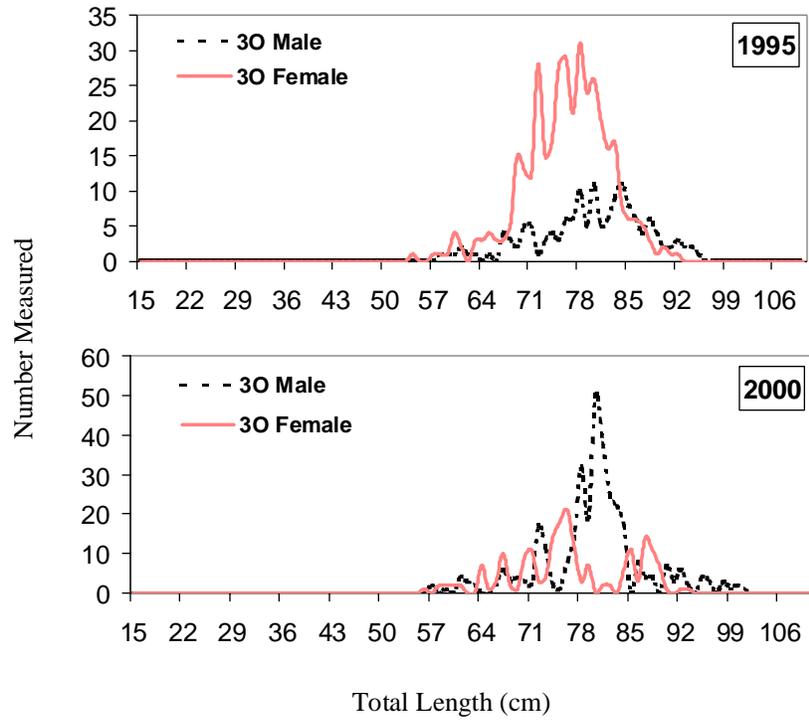


Fig. 29c. Length frequencies of Canadian commercial skate catches for lines in NAFO Div. 3O, 1995 and 2000. X-axis represents lengths of skate in centimeters. Data are from Canadian Fishery Observers.

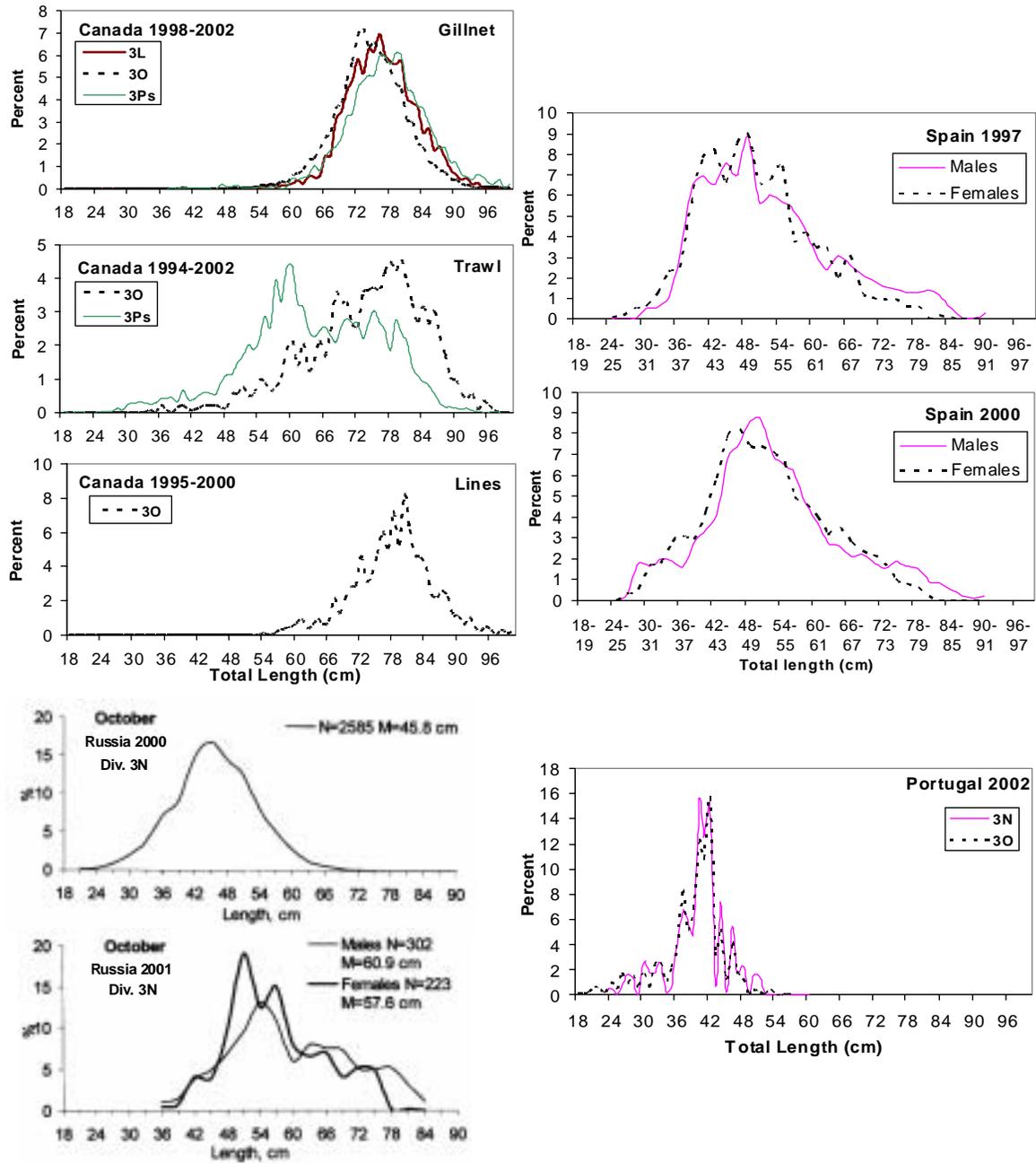


Fig. 30. Length frequencies of thorny skates in commercial catches (Canadian data from Fishery Observers; Spanish data from del Río and Junquera 2001; Russian graphs from Vinnichenko *et al.* 2002; Portuguese data from Vargas *et al.* 2003).

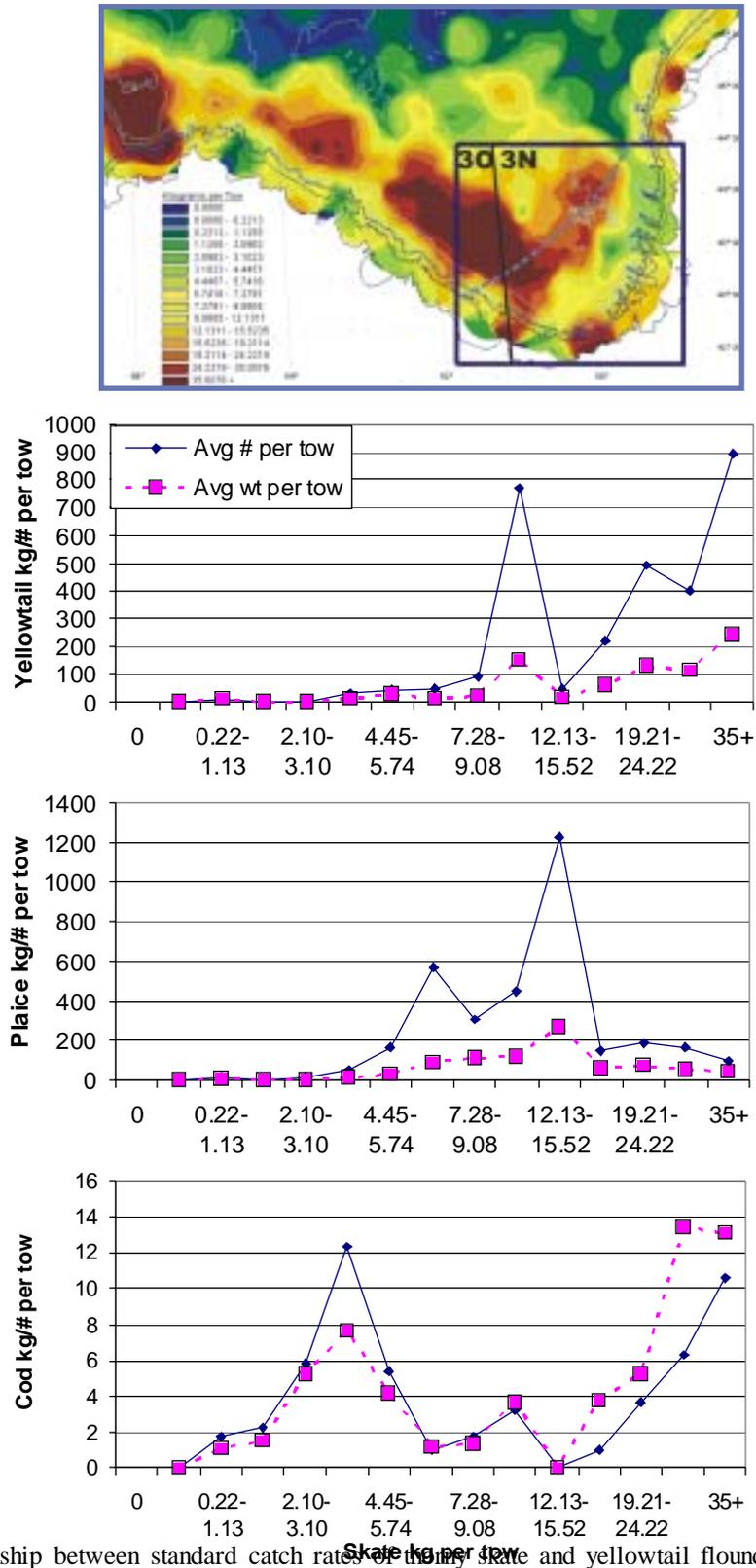


Fig. 31. Relationship between standard catch rates of herring skate and yellowtail flounder, American plaice, and Atlantic cod during fall Canadian research surveys in 2001-2002, and in the vicinity of the skate-directed fishery in the NRA (Upper Panel: box in the map).

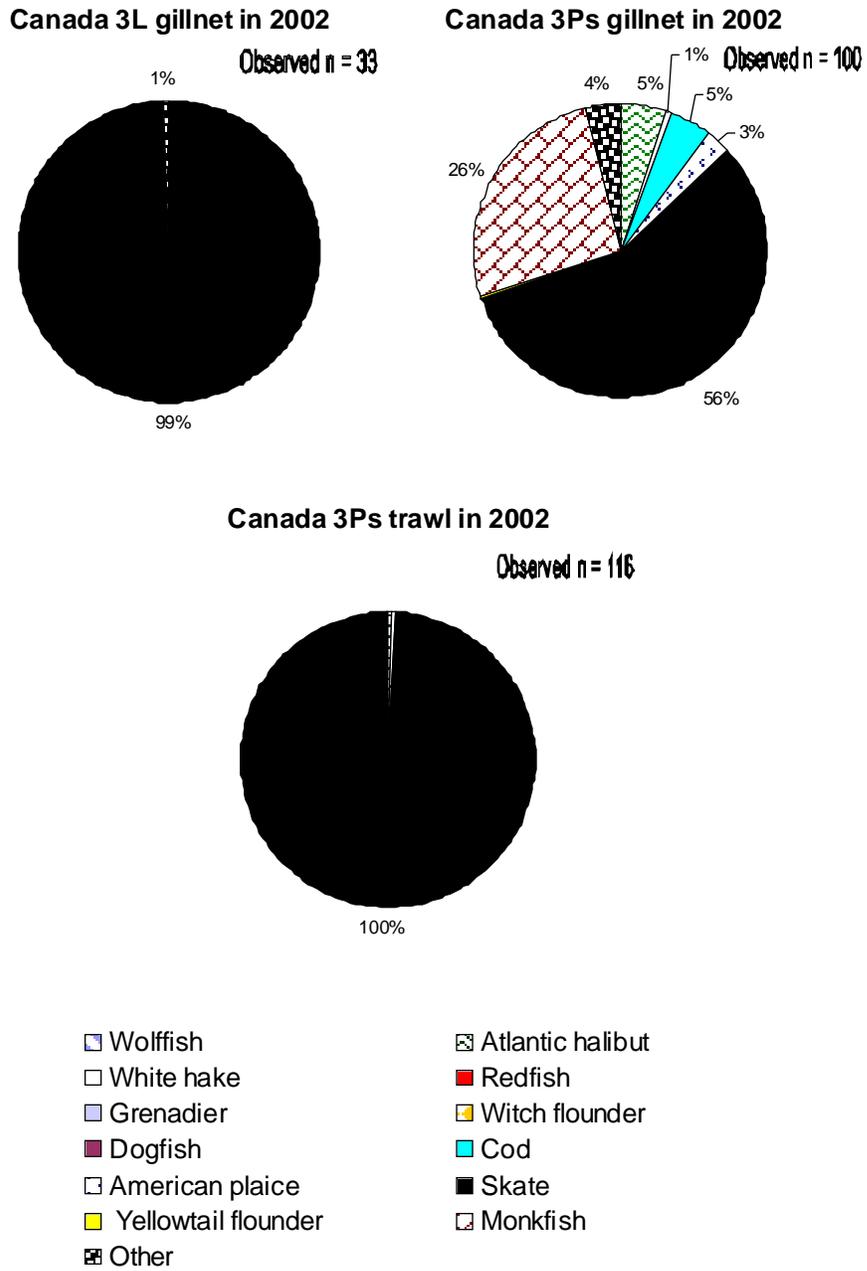


Fig. 32a. Species composition of catches in the Canadian skate-directed fishery, 2002. Data are from Canadian Fishery Observers.

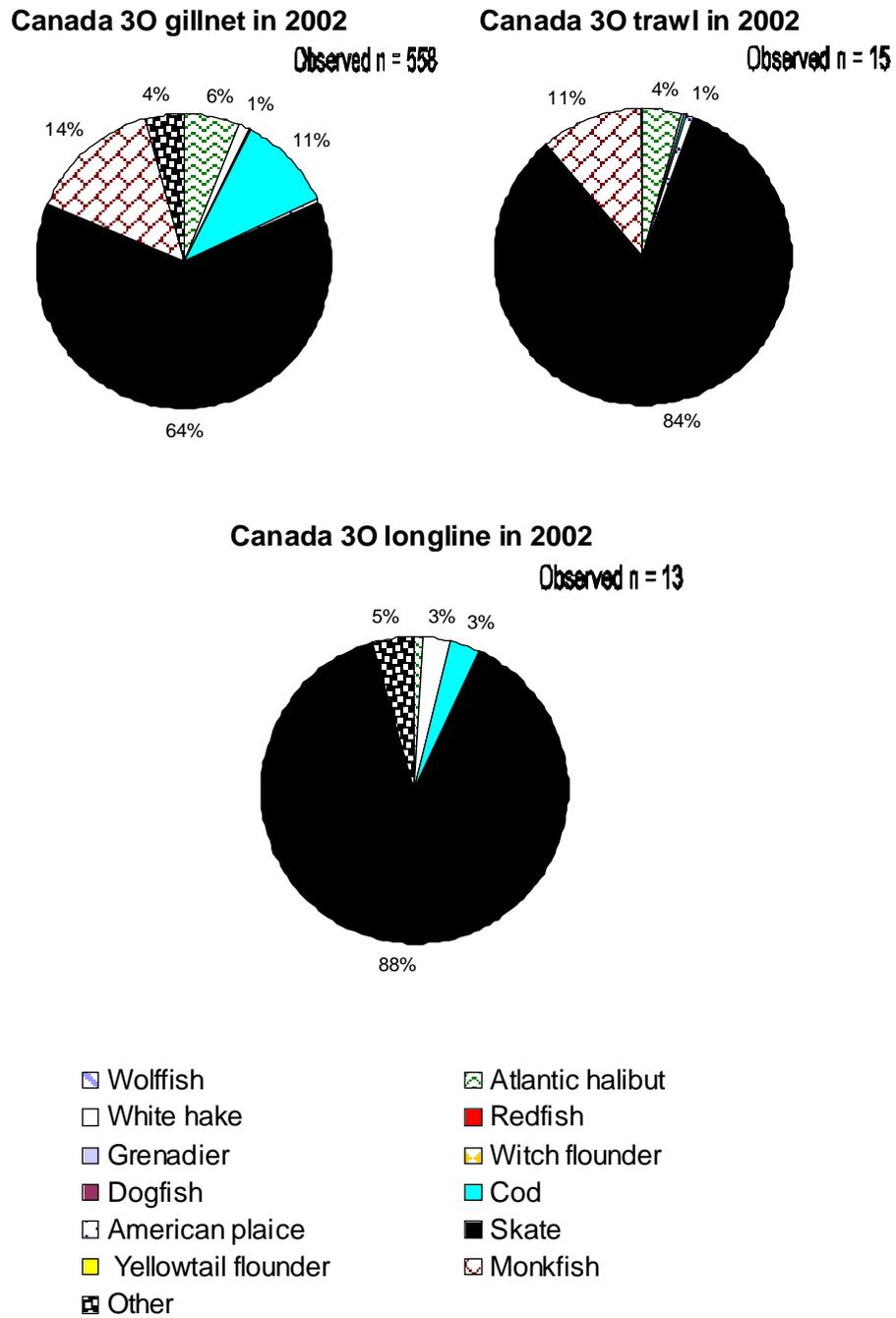


Fig. 32b. Species composition of catches in the Canadian skate-directed fishery, 2002. Data are from Canadian Fishery Observers.

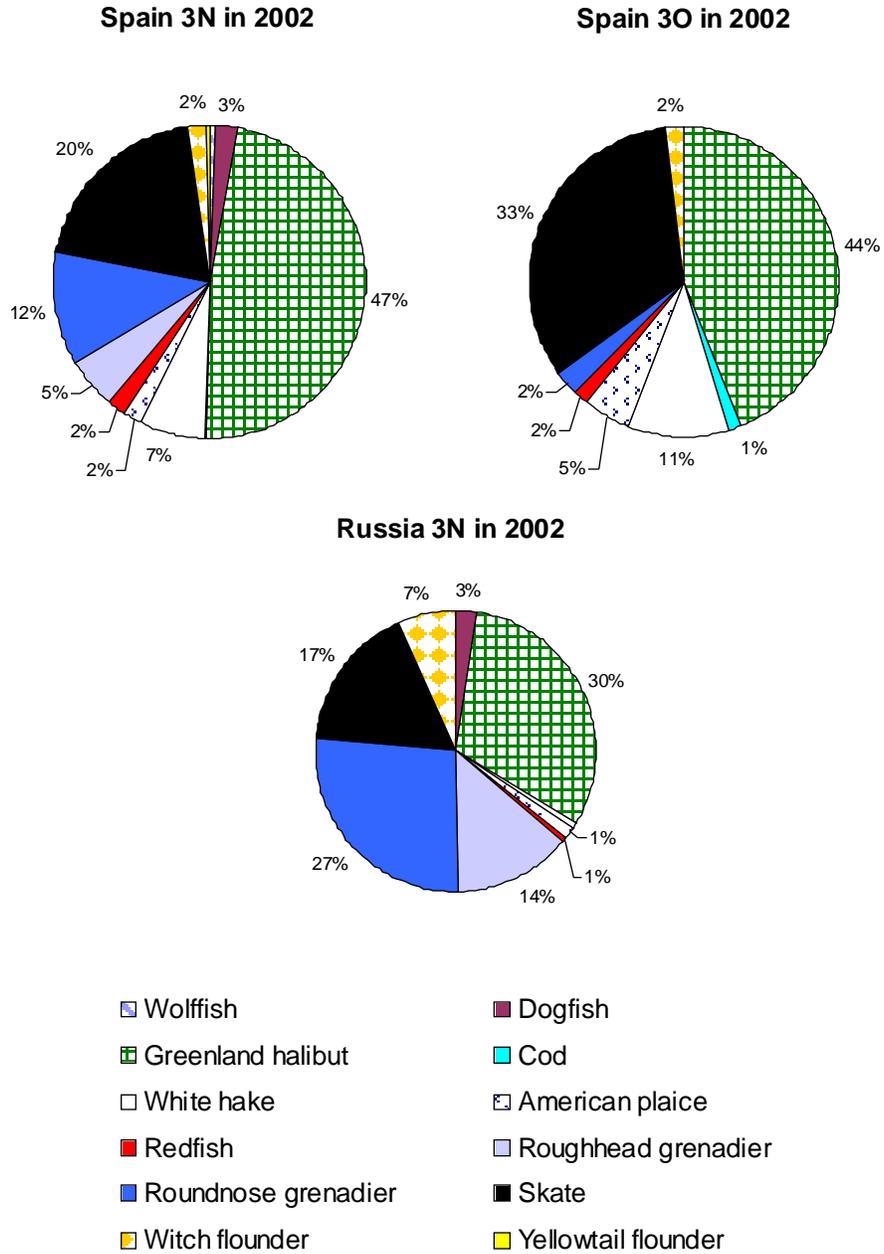


Fig. 32c. Species composition in the non-Canadian skate-directed fishery, 2002. By-catch percentages were derived from fishing logbooks during Canadian commercial vessel inspections at sea (DFO Canada – Conservation & Protection).

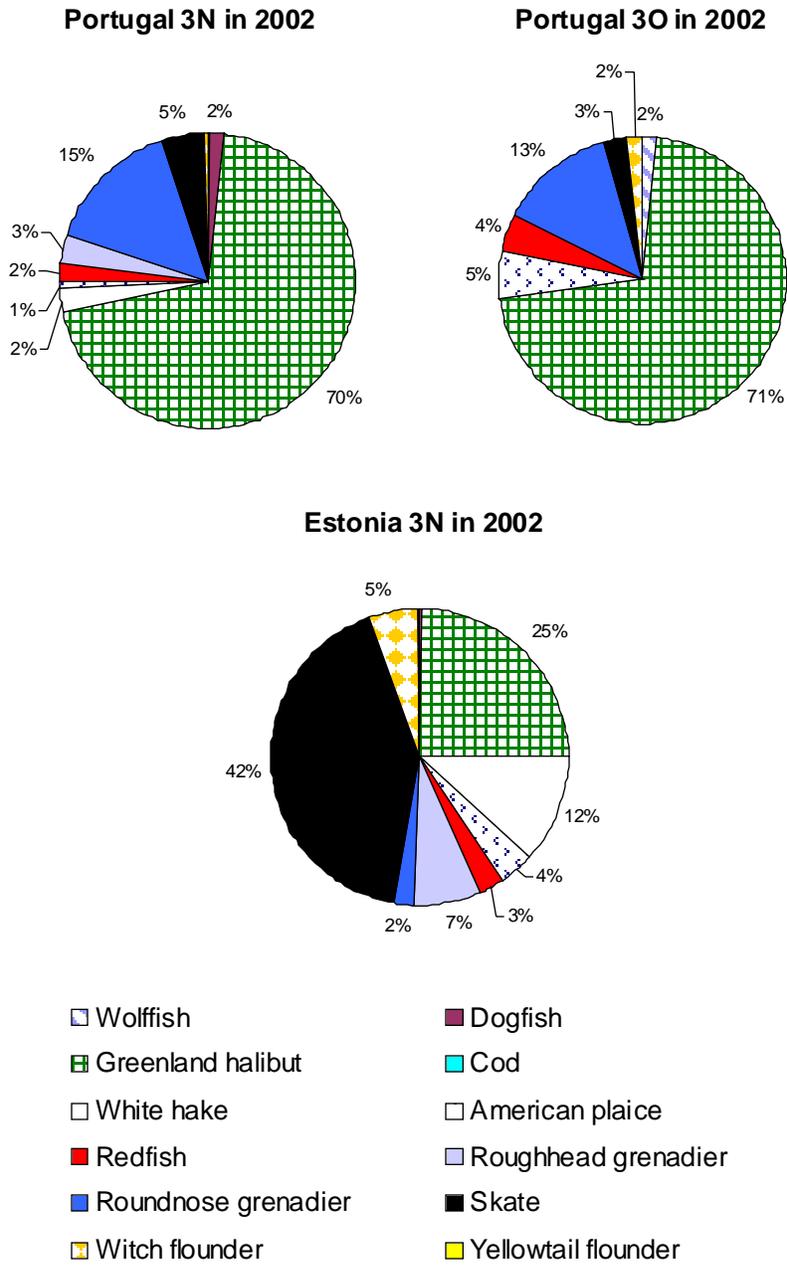


Fig. 32d. Species composition in the non-Canadian skate-directed fishery, 2002. By-catch percentages were derived from fishing logbooks during Canadian commercial vessel inspections at sea (DFO Canada – Conservation & Protection).

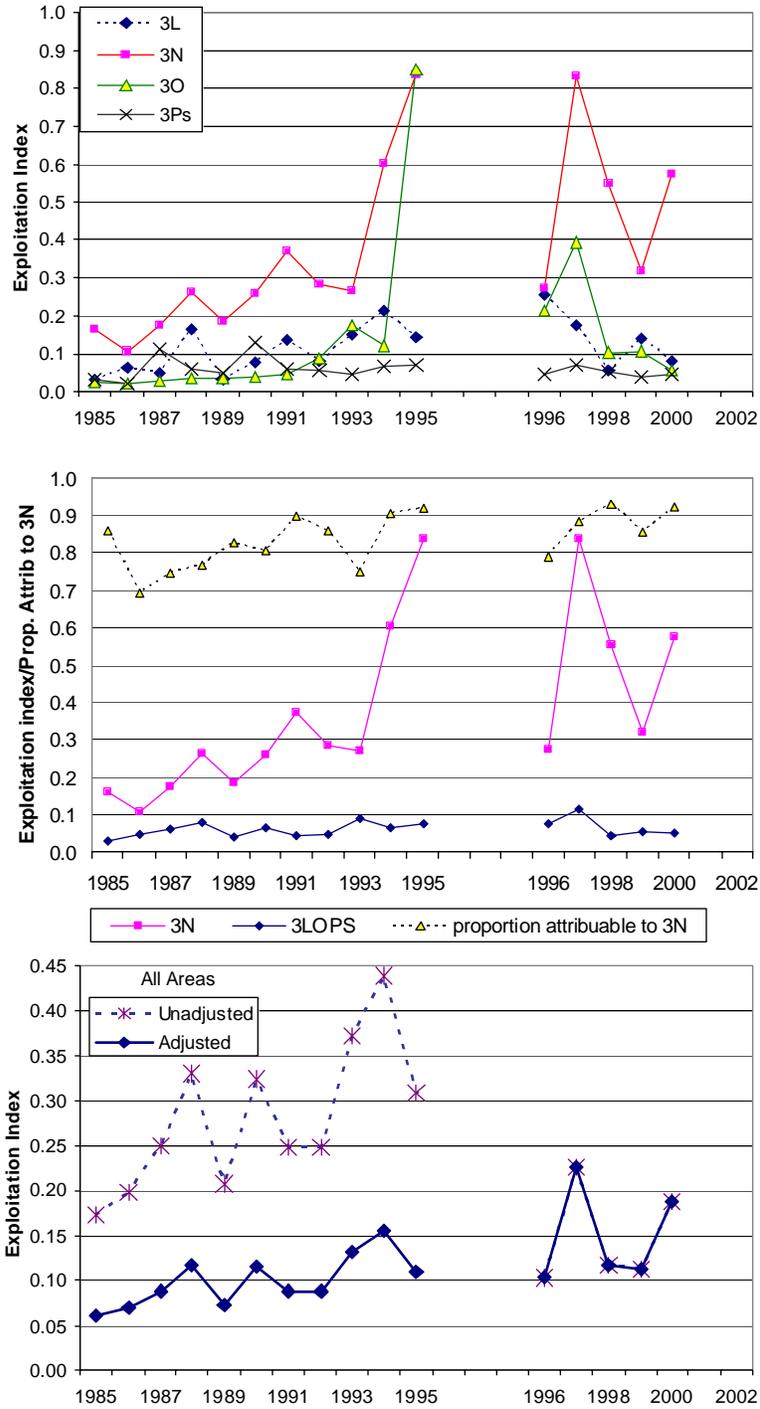


Fig. 33. Exploitation Index (total estimated catch/spring survey biomass index) for skate in NAFO Div. 3LNO and Subdiv. 3Ps, 1985-2002. Upper Panel: by NAFO Division; spring survey biomass indices converted to Campelen equivalents. Middle Panel: Exploitation Index outside 200 miles in NAFO Div. 3N versus other areas inside 200 miles. Lower Panel: for the entire stock area; solid line represents spring survey biomass indices converted to Campelen equivalents.

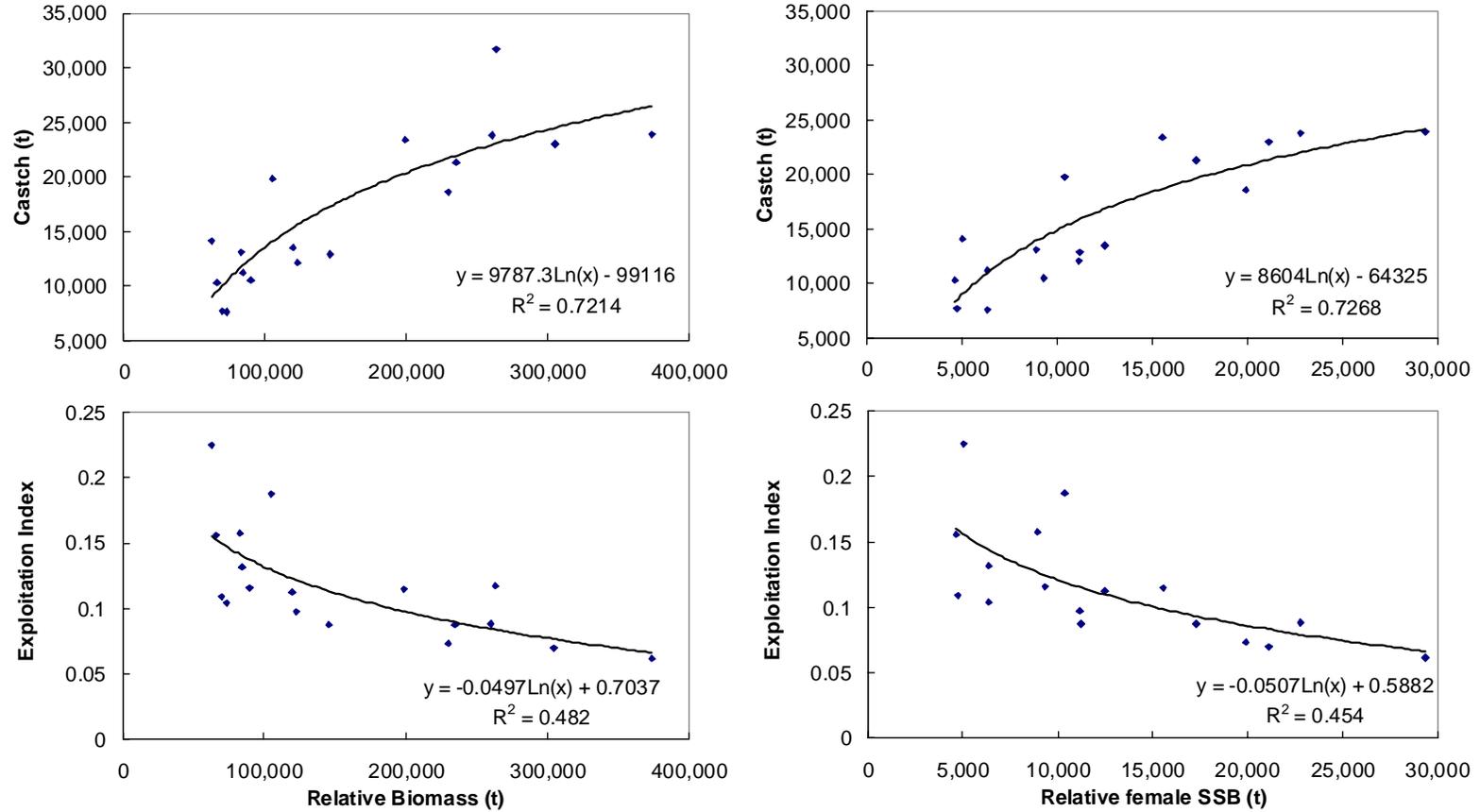


Fig. 34. Relationship between relative spring survey biomass and commercial catch (upper panels), and Exploitation Index (total estimated catch/spring survey biomass index: lower panels). The x-axes on the left panels are total relative biomass, and relative female SSB on the right panels.