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

État du stock de raie épineuse (*Amblyraja radiata* Donovan, 1808) dans les divisions 3L, 3N et 3O et la sous-division 3Ps de l'OPANO.

by

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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 mid1990s. 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 mid1980s, 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 bycatch, most of which were discarded. Reported catches of all countries combined have averaged 12 191 t (23 948-7 626 t) since 1985. In 2002, the (preliminary) reported catch was 9 838 t (3 342 t 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.

RÉSUMÉ

Ce travail sur la raie épineuse (*Raja radiata)* constitue la quatrième évaluation de cette pêche relativement nouvelle. Les indices de biomasse du stock, qui ont baissé jusqu'à un minimum historique au début des années 1990, se sont stabilisés au milieu de cette décennie. À l'automne 1995, l'utilisation d'un nouvel équipement de relevé aux caractéristiques de capture différentes a créé une discontinuité dans les séries chronologiques, et il est donc impossible de comparer la période de 1986 à 1994 à celle de 1995 à aujourd'hui. Le relevé printanier, utilisé précédemment pour estimer la biomasse et l'abondance, ne couvre peut-être pas une part considérable de la population puisqu'il ne comprend que la partie du stock qui se trouve dans la zone de relevé. En moyenne, de 1990 à 2002, les estimations de la biomasse faites à partir des relevés automnaux dans le même secteur (divisions 3LNO de l'OPANO) se chiffrent à 41 %. L'analyse de la longueur des prises effectuées au cours des relevés montrait que la gamme des longueurs était constante depuis 1985, et que leur distribution comprenait deux modes principaux au printemps et à l'automne (de 15 à 32 cm et de 65 à 83 cm; le deuxième mode correspond aux raies adultes). Depuis 1996, la distribution des longueurs ne compte plus qu'un mode, de 30 à 60 cm, soit un mélange de poissons matures et immatures. La proportion de raies de grande taille prises dans le cadre des relevés a récemment augmenté. Depuis le milieu des années 1980, l'Espagne, le Portugal et la Russie pratiquent la pêche dirigée de la raie (*Raja sp*.) sur la queue des Grands Bancs à l'extérieur de la limite de 200 milles des eaux territoriales canadiennes. Cependant, le Canada n'a établi qu'une pêche dirigée limitée de la raie sur le sud-ouest des Grands Bancs et sur le sud du banc de Saint-Pierre après le déclin des populations de poissons de fond pêchés traditionnellement. Avant 1993, les raies dans les eaux canadiennes n'étaient prises qu'accidentellement, et la plupart étaient rejetées. Depuis 1985, le total des prises déclarées par tous les pays s'élève en moyenne à 12 191 t (de 7 626 à 23 948 t). En 2002, le total (préliminaire) des prises déclarées se chiffrait à 9 838 t, dont 3 342 t pour le Canada (rejets compris). La distribution des raies établies à partir des données de relevés montre que la flottille canadienne pêche dans environ le tiers de la zone à forte densité de raies au printemps, principalement en bordure de la plate-forme où les raies sont plus grandes. Les flottilles étrangères pêchent à l'automne dans un autre secteur, situé sur la queue des Grands Bancs (à l'extérieur de la zone de 200 milles) et capturent des raies plus petites.

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 (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 bycatch 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, where < 50% of skate in commercial catches are thorny, and the predominant skate species is winter, *A. 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 (*A. 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 English Channel, including 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 at 50-150 m, and shallowest in the fall (refer to the discussion on migration above; 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 are on average 40% lower in spring than in fall; and double the bycatch rates of skate occur 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 Divisions 3L, 3N, 3O, and Subdivision 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 Subdivision 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 (*A. 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 bycatch of thorny skate taken in Spanish commercial catches on the Tail of the Grand Banks (NAFO Division 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 bycatch 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 was limited, until recently. Templeman (1984b) indicated that size at maturity was considerably larger for thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), as compared to those in northern areas. 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) indicated that, for thorny skate on the Grand Banks (NAFO Div. 3N) in 1997-2000, length at 50% maturity was observed to be 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 Divisions 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 Division 3N, 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, in order to identify differences in sexual maturity with size. 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 they can live at least 20 years. A similarly sized species, winter skate (*A. 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 Divisions 3L, 3N, 3O, and Subdivision 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). 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 mid1980s), and where thorny skate are most densely concentrated.

Kulka and Mowbray (MS 1998) reported that significant bycatches 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 mid1980s, 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 mid1980s, Kulka (1982, 1984, 1985, 1986a, 1986b, 1989) reported that about 3,000 t of skate were taken annually as bycatch in the Canadian offshore fisheries, but were mostly discarded. Kulka and Mowbray (MS 1998) subsequently estimated that an average of about 5,000 t was discarded annually by the Canadian fleet during the 1980s and early 1990s; although only a few hundred tonnes were recorded in Canada's annual landings statistics during that period.

Although often kept by non-Canadian fleets, skates were taken only as bycatch until the mid1980s. 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. Bycatches 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 Division 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 km^2; with about 9 000 km^2 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 t in 2003), skate fisheries in the NRA are unregulated. This has allowed Spain to increase its skate catches from 4 700 t in 1999 to 10 700 t in 2000 (del Rio and Junquera MS 2000); and possibly maintain catches >10 000 t 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 t in 2000 and 2 600 t in 2001 during May to December in NAFO Division 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 bycatch.

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 bycatch (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 bycatch policies, a licensing system, and Total Allowable Catch (TAC).

Kulka et al. (MS 1996) and Kulka and Mowbray (MS 1998) examined bycatch of skates in individual catches from 1988-1998, as recorded by fisheries observers. They reported that otter trawls yielded the greatest proportion of bycaught skates, while gillnets caught the least. Excluding thorny skate, rajid bycatch was small and variable among areas. Regardless of gear type, other skate species were: spinytail (*Bathyraja spinicauda*), averaging 10% of the skate bycatch; barndoor (*Dipurus laevis*) at 4%; smooth (*R. senta*) at 2%; and winter (*R. 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 bycatch 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 bycatch in that fishery. Therefore, mortality due to fishing north of the Canadian regulated area has been lower during the early to mid1990s, relative to previous years. 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.

This paper updates biological and fishery data to 2002: information necessary for a current assessment of 3LNOPs skate. Similar to previous assessments of this stock (Atkinson MS 1995; Kulka et *al.* MS 1996; Kulka and Mowbray MS 1998), a virtual population analysis (VPA) 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 or most other traditional stock assessment methodologies; and 3) landings for this species appear to be consistently under-reported, especially prior to 1994. Structure of the 3LNOPs stock and life history characteristics, such as growth rate, age-at-maturity, fecundity, and reproductive life span, remain unknown for Northwest Atlantic thorny skates.

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; which 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 Divisions 3LNO and Subdivision 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 Divisions 3LNO commenced in 1971; with the inclusion of Subdivision 3Ps (comprising St. Pierre Bank) since 1972. Fall surveys of NAFO Division 3L began in 1981, and then commenced for Divisions 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.

Research data from stratified random surveys in NAFO Divisions 3LNO and Subdivision 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 in both time series: these missing data are denoted by blank cells on biomass and abundance tables. The total area surveyed in 1996-2002 was 294,589 km^2; in 1994-96 was 283,321 km^2; and in 1986-93 was 255,542 km^2.

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 Divisions 3LNOPs, sexed length-weight relationships of thorny skate generated by del Rio *et al.* (2002; from Spanish spring trawl surveys in 2001 for Divisions 3NO) were utilized in STRAP1 calculations. These calculations assumed that weight at length remained constant throughout the entire survey period.

SPANS GIS 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 Divisions 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. 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; they have not been weighted by stratum area or extrapolated to survey abundance estimates.

Fishery data

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) datafiles for Canadian landings; Canadian Fishery Observer database for species composition and discards;

NAFO STATLANT-21A for reported non-Canadian landings; and C&P commercial inspections data (Department of Fisheries and Oceans Canada (DFO) - Fisheries Management Branch - Conservation and Protection Division).

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 (*Urophysis 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.

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 Divisions 3LOPs) were then compared to indices for non-Canadian fleets fishing outside 200 miles (NAFO Division 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 Subdivision 3Ps for any year, or from Divisions 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, 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 Division 3O and Subdivision 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 1/3rd 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 Division 3O and Subdivision 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 mid1980s, then declined rapidly in 1990-1995; mostly in Divisions 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 Divisions 3N, 3O, and Subdivision 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 Divs 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 Divs. 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 Divisions 3N and 3O, and biomass appears to have been relatively stable in Subdivision 3Ps.

A comparison of spring and fall biomass estimates (a ratio of estimates in NAFO Divisions 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%; which is 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; Table 2). The trend has been downward since the beginning of spring surveys in 1971 to the mid1990s. In the early to mid1970s, 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 Division 3O; greatest in Divisions 3L and 3N. During the early to mid1990s, 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 Divisions 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; 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 Subdivision 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 mid1990s. 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. 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 seems that recruitment in this area has been low; following the decline in biomass there. For the southern Grand Banks (Divs. 3N and 3O), this mode was also small or largely absent after 1995 in spring and fall. However, a mode of 10-35 cm skates was present across all; although narrower in range (10-20 cm) since 1996. This suggests that, after 1995, recruitment (presence of substantial numbers of small fish) occurred mostly on the St. Pierre Bank (Subdivision 3Ps).

Distribution

Within the designated stock area (NAFO Divisions 3LNO and Subdivision 3Ps), the distribution of thorny skate has undergone significant changes since the early 1980s (Fig. 10: spring; Fig. 11: 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 Division 3L (around the southern extent of Newfoundland's Avalon Peninsula) 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. 12). 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, 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 mid1990s, 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 Grand Banks (southwest edge, 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 Figure 10 with Figure 11, 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 Subdivision 3Ps. A second concentration of thorny skate was also located in the centre of the Banks: straddling the line between Divisions 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

Subdivision 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.

The Fishery

Thorny skate are caught in a wide variety of fisheries over an area extending well beyond the managed 3LNOPs stock: Figure 13 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. Figure 13 indicates that thorny skate are taken as bycatch as far north as Davis Strait. North of Latitude 52^{o}, skate catch rates were low. 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 bycatch of larger skates. Most bycatch in the shrimp fishery is discarded, but survival rates of discarded fish are unknown. South of Latitude 52^{o}, higher skate catch rates were observed as far south as Latitude 48^{o}, on the northern section of the Grand Banks. Between Latitude 46^{o} and 48^{o}, a large area was not fished, or skate bycatch 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: Fig. 10; Fig. 11; Fig. 13), and also on the northern part of St. Pierre Bank.

Figure 14 indicates that locations of Canadian gillnet (upper panel), longline (middle panel), and otter trawl fisheries (lower panel) were similar. These maps illustrate where each of the gears was deployed in the mixed monkfish/white hake/skate/Greenland halibut fisheries for 1999-2002. 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.

A spatial representation of non-Canadian effort outside of Canada's 200-mile-limit is presented in Figure. 15. These data were recorded from Spanish fishing logs by Canadian Fishery Officers during vessel inspections at sea in 1995-1999. The maps indicate that fishing effort encompassed most of the available shallow Bank to the 200-mile-line; where skate concentrations straddle the line in fall. That portion of the Bank where skate catch rates were highest was primarily a skate-directed fishery. This on-shelf effort occurred mainly in June-December; when thorny skate 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 skate catch rates were higher. Locations fished since 1999 are probably similar to those in 1998-1999; given that most of the available area on the Tail of the Grand Banks (where skate are densely aggregated) is now covered by the fleet. In addition to this directed effort on the Tail of the Grand Banks, Canadian inspection data from non-Canadian logbooks showed skate catches along the entire eastern shelf edge of the Grand Banks (outside 200 miles; Fig. 15). This skate bycatch was taken in a fishery directing mainly for Greenland halibut.

Skate catches of all countries after 1984 are illustrated in Figure 16, 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 t (peak catches); 1992-1996, when skate catches dropped under 12,000 t, and declined to less than 7,000 t in 1996; and 1997-2002, when the directed efforts of several countries increased outside of 200 miles (Fig. 16). 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. 17). After 1991, 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. 16). 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 bycatch: averaging 61 t per year (Fig. 18). Much of this bycatch came from mixed fisheries for Greenland 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 t. In 2002, the total skate catch was 2 486 t: slightly higher than the previous four years (Fig. 18).

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. 15). Most of that directed fishery is prosecuted in August-December. The remaining non-Canadian skate catches were bycatch 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. 19).

In 1994, the first year of the Canadian skate fishery, most of the skate catch were taken in the fall (Fig. 20). 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 in fall. All gears were fished in a narrow range of depths; averaging 140m. However, skate bycatch 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 (Fig. 10).

Annual Canadian catches have remained fairly stable; being regulated by quota. In contrast, the skate fishery outside Canada's 200-mile-limit is unregulated. In 1997-2002, the Canadian allocation was set at 45.8% for mobile gear (otter trawl), and 54.2% for fixed gear (gillnets; longlines). Canadian skate fishery policies and regulatory measures for 2002 are summarized in Table 5.

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 the landed products 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 21 is 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 22 indicates that, where data were available, average length of commercial skates was similar over all years for each of the gear types.

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. 23). 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 mid1980s to about 15% in 1996-2002. This period of increased exploitation is concurrent with the period of thorny skate decline in NAFO Div. 3LNOPs.

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 area and 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 mid1990s 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 behaviour of thorny skates when encountering research survey gear, 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. 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 occured (hence the increasing catch rates observed in the commercial fishery). 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.

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 (thus giving no indication of a stock decline). 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 commercial 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, 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.

Causes for the decline of thorny skate on the Grand Banks 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 bycatch in a large fishery targeting Greenland halibut. Skate bycatch 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 bycatch 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). 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 pressures. Simon and Frank (1996) have shown that thorny skate on the Scotian Shelf has also declined since 1982 and, similarly for that stock, the reasons are unclear.

CONCLUSION AND PROGNOSIS

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). 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 is not greatly different from more fecund species. As for any species, thorny skates are susceptible to over-exploitation. However, because of their low reproductive potential, the recovery of skate population(s) from depletions (caused by natural phenomena; human activities) 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 the 3LNOPs stock would be a much longer process than for more fecund demersal species.

In managing a commercially exploited species, it is important to have some knowledge of the reproductive biology, spatial distribution (and where commercial catches are taken in relation to this distribution), stock structure, and nature of commercial catches in terms of amounts, skate size and age. Templeman (1884a, 1984b, 1987b) provided information on some of these topics, 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 Rio *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.

The analyses of spatial dynamics have revealed changes in the thorny skate population that would otherwise be difficult or impossible to detect. Hyper-aggregation was observed after the mid1990s, 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.

However, 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 t: 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.

Deficiencies

There remain a number of important limitations to published knowledge of thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps. 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 available data, it is not possible to determine the current exploitation rate, or what level is most appropriate for a sustainable thorny skate fishery. This analysis presents an Index of Exploitation as a proxy.

For these reasons, available data are not suitable for analysis by traditional stock assessment methodologies. The ability to assess thorny skate in 3LNOPs is limited by a paucity of information on its life history, and uncertainties regarding commercial skate catch history. 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. Sampling of commercial skate catches at sea should be enhanced through the Fishery Observer Program, 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 in the non-Canadian commercial fishery (which occurs where the skate are aggregated). 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 mid1990s, and has undergone distributional changes that may reflect stress on the population(s). Given its low but stable biomass, hyper-aggregating distribution, and spatially restricted recruitment, this stock is not showing any signs of recovery; and possibly is 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. 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 commercial 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

The Canadian Total Allowable Catch (TAC) for the thorny skate stock in 3LNOPs is 3000 t. Low commercial value and limited markets result in this TAC not being 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, skate catch reports from this area may be unreliable.

A Canadian skate-directed fishery is a relatively recent development. Relative to other groundfish fisheries, the 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. In contrast, the non-Canadian skate fishery outside 200 miles has expanded in recent years.

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.

Summary

- The abundance of thorny skate increased from the early 1970s to the mid1980s, then declined to its lowest level in the mid1990s. 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 (mid1980s 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 mid1970s; 1.3 kg in the mid to late 1980s; and 0.5 kg in the mid1990s. 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 Division 3L) since 1996. The largest occurrence of small skates is presently found in NAFO Subdivision 3Ps.
- Since the mid1990s, 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 mid1980s 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. The period of decline coincided with the decline of many other demersal species.

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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
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 Subdivision 3Ps in the fall. Fall surveys in Division 3L commenced in 1981, and in 1990 in Divisions 3NO.

Biomass (tonnes)

Year	Div.3L	Div.3N	Div.3O	All Divisions
1981	-51.57%			-132.75%
1982	42.16%			-39.06%
1983				
1984	88.41%			8.75%
1985	27.44%			-112.06%
1986				
1987	6.61%			-120.37%
1988	35.00%			-92.02%
1989	-7.98%			-139.56%
1990	52.60%	29.62%	36.46%	40.61%
1991	57.84%	72.18%	-31.09%	35.33%
1992	70.85%	56.50%	-36.68%	31.65%
1993	64.53%	47.79%	45.39%	49.80%
1994	75.81%	79.99%	9.56%	56.61%
1995	90.25%	97.27%	71.50%	84.56%
1996	65.47%	61.54%	3.90%	35.63%
1997	47.32%	77.47%	51.35%	61.42%
1998	36.91%	61.53%	-7.82%	25.88%
1999	46.54%	19.49%	-26.84%	1.41%
2000	20.94%	54.48%	-0.14%	30.89%
2001	36.77%	14.90%	4.95%	12.60%
2002	22.48%	73.54%	6.33%	42.03%
Average:	41.42%	57.41%	9.76%	-5.93%
1996-2002: (Campelen)	39.49%	51.85%	4.53%	29.98%

Abundance (thousands)

Year	Div.3L	Div.3N	Div.3O	All Divisions
1981	0.89%			-45.66%
1982	40.95%			-54.79%
1983				
1984	89.33%			19.11%
1985	26.71%			-84.13%
1986				
1987	51.59%			-31.96%
1988	59.57%			-20.62%
1989	47.46%			-14.67%
1990	62.37%	-63.39%	24.58%	27.17%
1991	52.73%	27.12%	-18.58%	30.33%
1992	60.78%	39.02%	-44.14%	38.99%
1993	54.86%	45.07%	63.69%	55.31%
1994	63.80%	64.97%	37.86%	57.89%
1995	83.46%	92.23%	63.81%	80.46%
1996	55.64%	53.13%	49.65%	52.06%
1997	49.41%	55.62%	48.78%	51.09%
1998	12.93%	52.01%	-14.59%	13.03%
1999	20.82%	36.43%	-13.17%	10.58%
2000	0.19%	48.99%	28.54%	31.96%
2001	32.67%	23.78%	20.84%	23.63%
2002	21.50%	72.61%	-34.36%	24.88%
Average:	44.38%	42.12%	16.38%	13.23%
1996-2002: (Campelen)	27.59%	48.94%	12.24%	29.60%

Mean weight (kg)

Year	Div.3L	Div.3N	Div.3O	All Divisions
1981	-52.94%			
1982	2.05%			
1983				
1984	-8.57%			
1985	0.99%			
1986				
1987	-92.93%			
1988	-60.76%			
1989	-105.51%			
1990	-25.97%	56.92%	15.76%	18.45%
1991	10.82%	61.82%	-10.55%	7.17%
1992	25.68%	28.66%	5.17%	-12.03%
1993	21.43%	4.95%	-50.41%	-12.35%
1994	33.18%	42.89%	-45.55%	-3.04%
1995	41.07%	64.90%	21.25%	20.96%
1996	22.16%	17.94%	-90.87%	-34.26%
1997	-4.12%	49.24%	5.03%	21.12%
1998	27.55%	19.84%	5.91%	14.77%
1999	32.49%	-26.65%	-12.08%	-10.25%
2000	20.79%	10.76%	-40.13%	-1.59%
2001	6.09%	-11.64%	-20.08%	-14.44%
2002	1.25%	3.37%	30.28%	22.83%
Average:	-5.26%	24.85%	-14.33%	1.33%
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 t; first report for this country); EU (6 040 t in 3NO; countries/areas undifferentiated); EU (11 184 t in 3L; countries undifferentiated); and Estonia (328 t 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 Divisions 3LNO and Subdivision 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 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’)	**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				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		

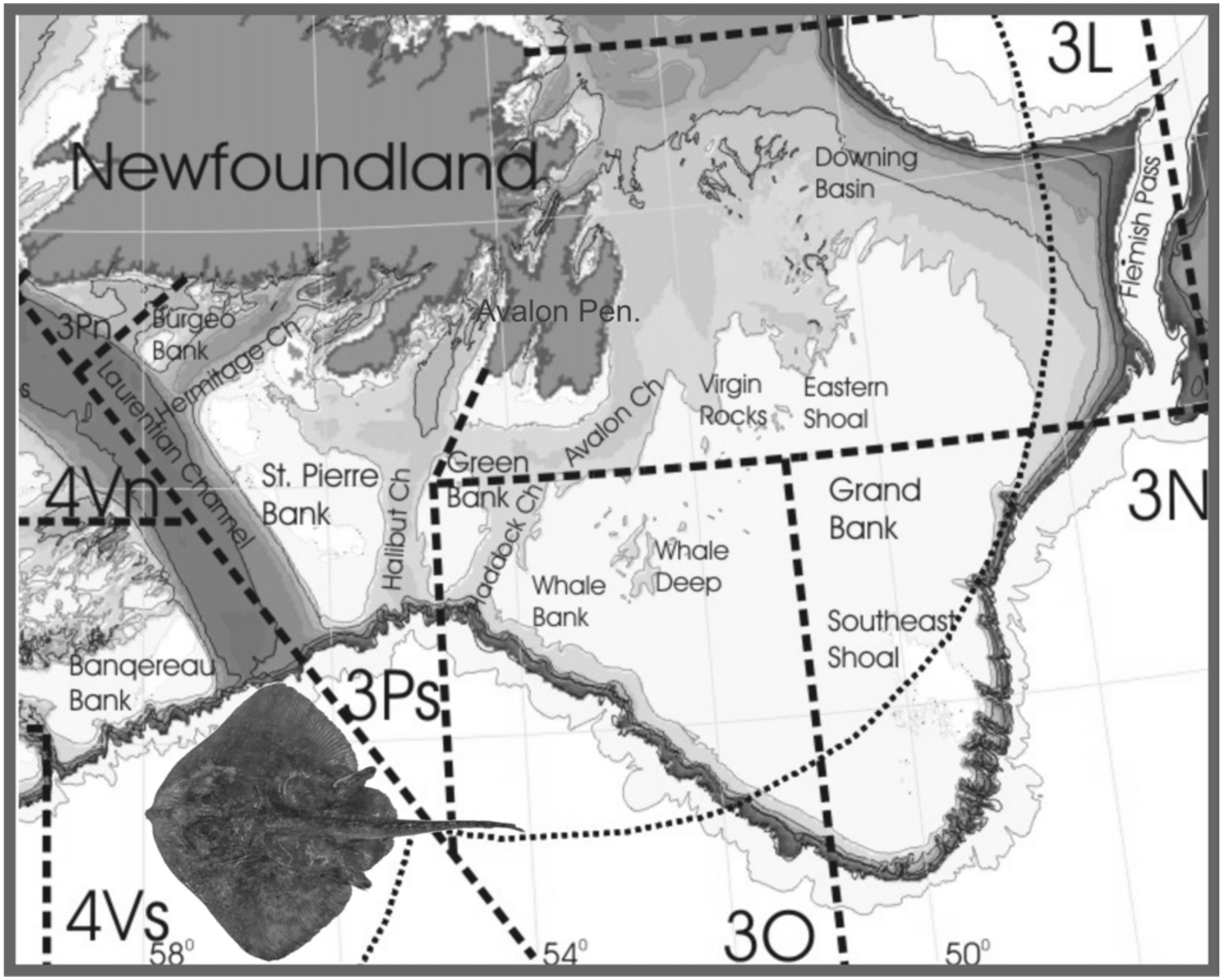


Figure 1. The Grand Banks, showing locations referenced in the text, bathymetry, Canada's 200-mile-limit, and NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps (image of thorny skate, lower left).

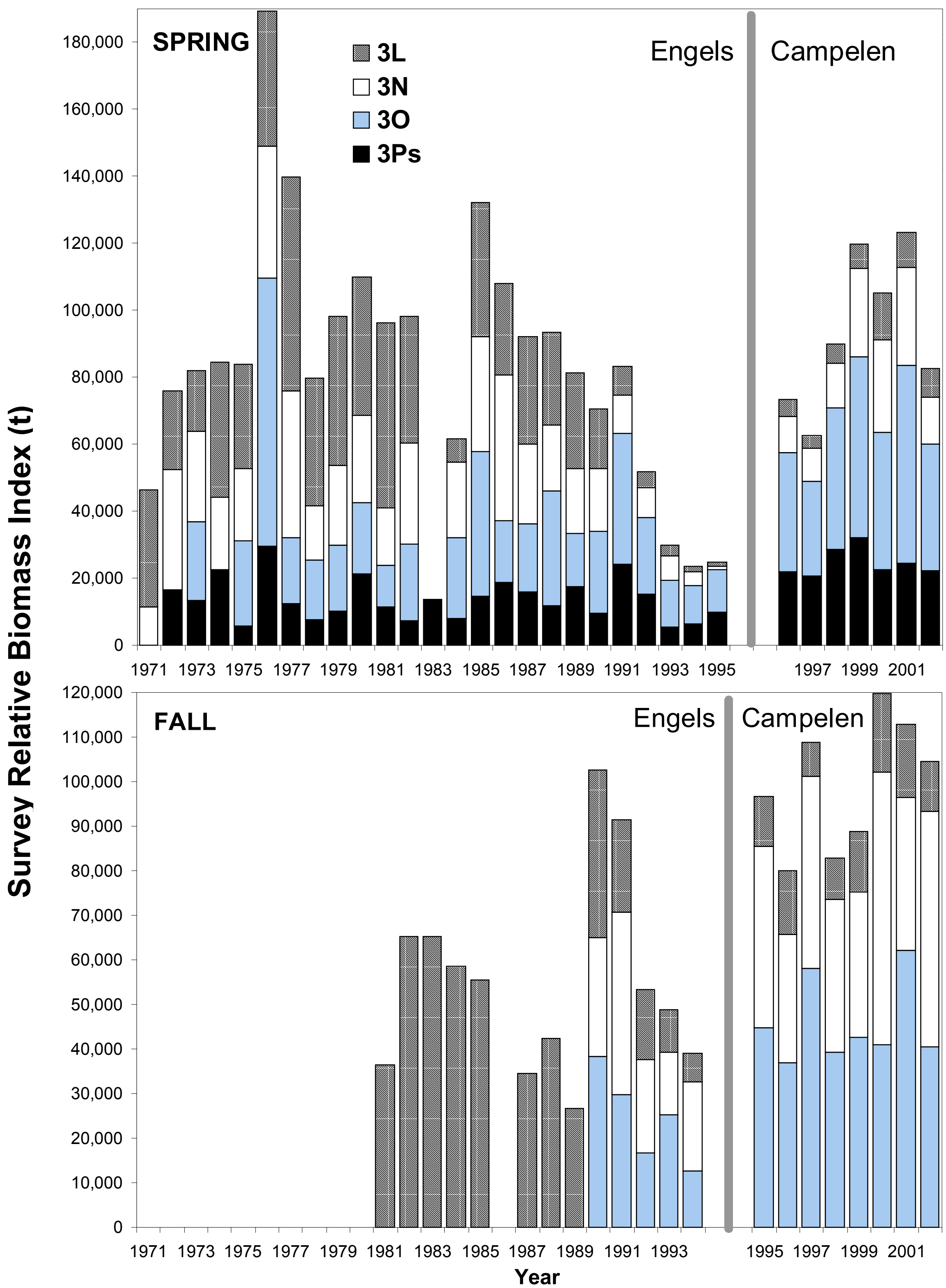


Figure 2. Spring and fall research survey relative biomass indices for thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps, 1971-2002.

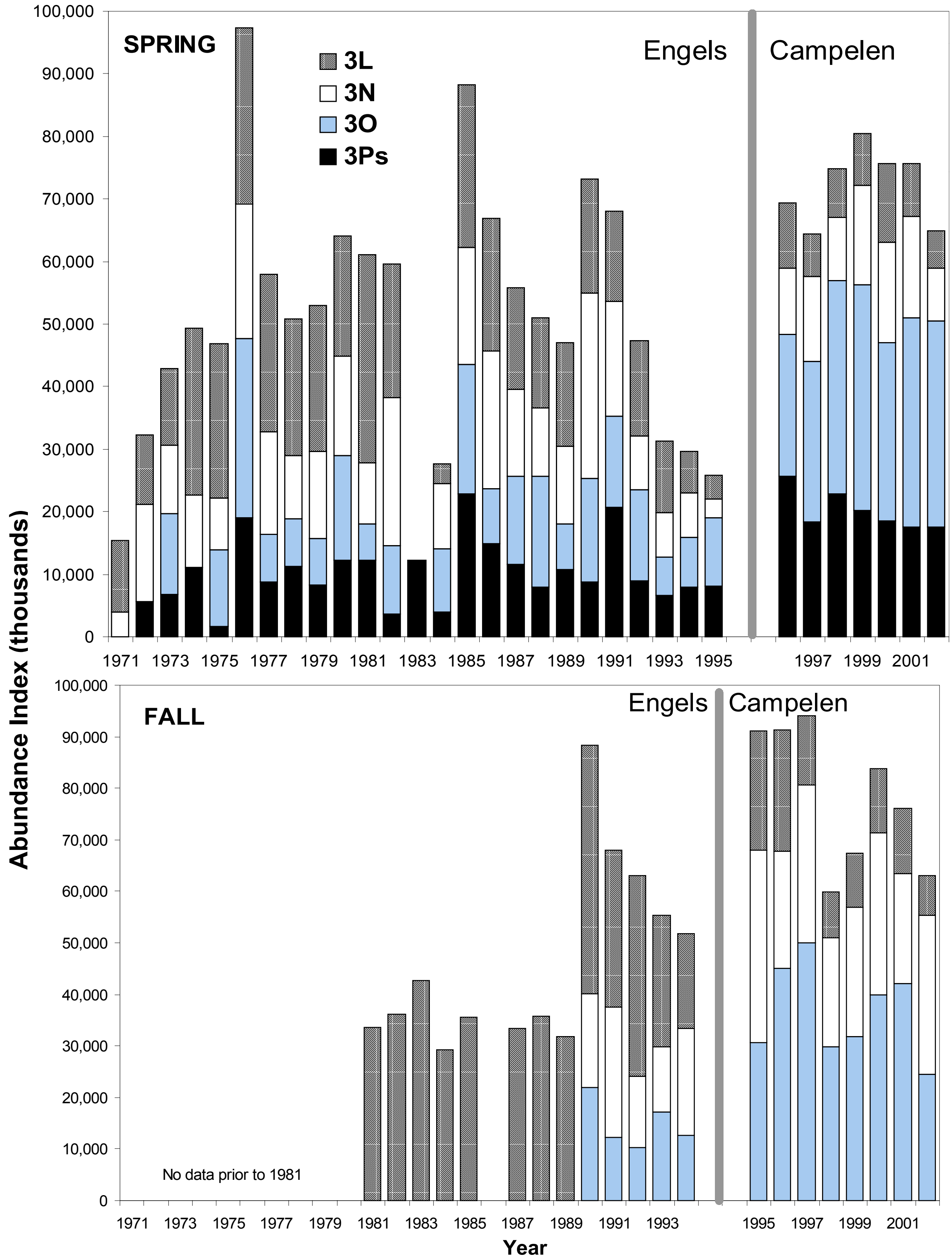


Figure 3. Spring and fall research survey abundance indices for thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps, 1971-2002.

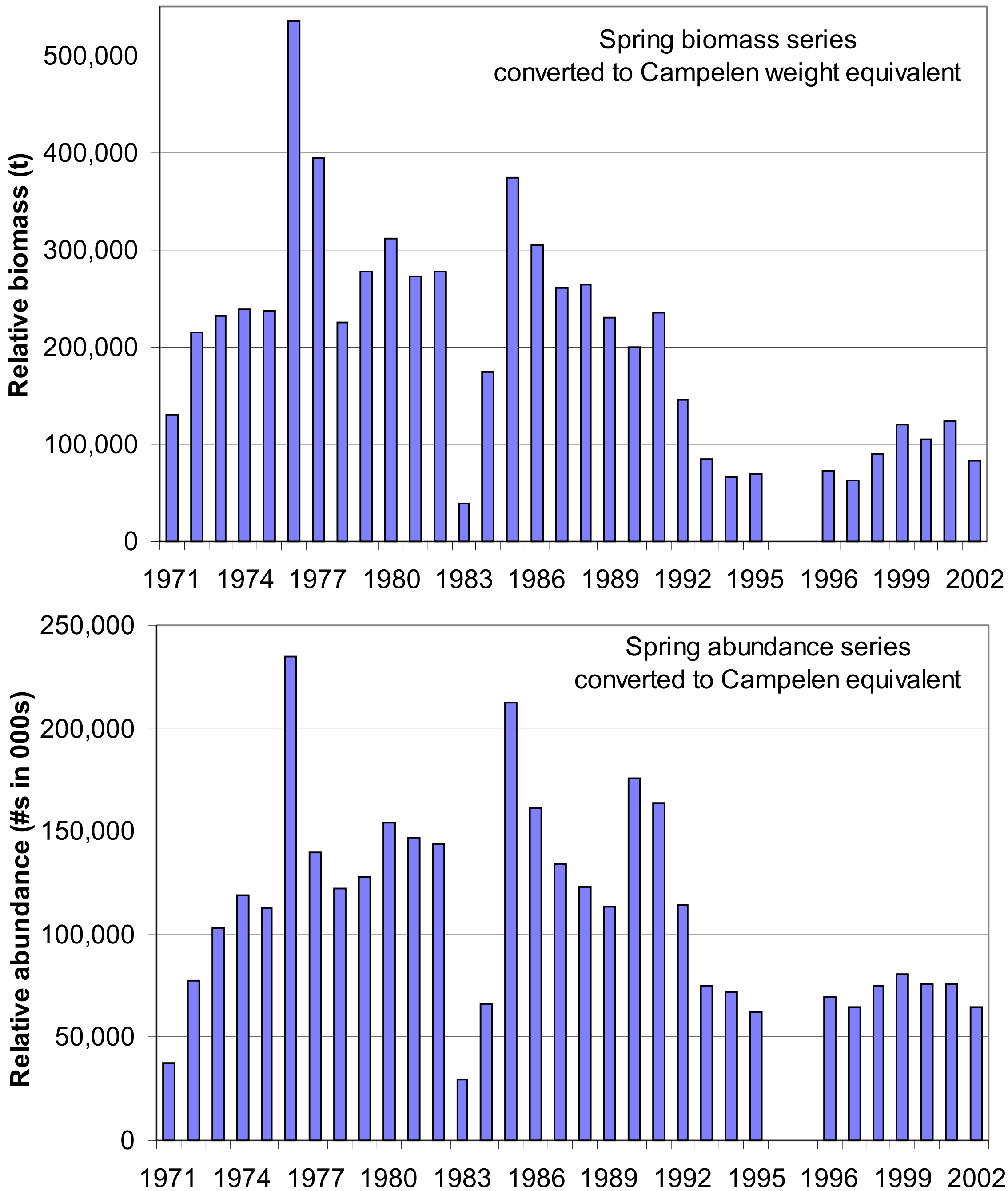


Figure 4. Relative biomass of thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps, with Engles estimates converted to Campelen equivalents. Some Divisions were not sampled in 1971, 1972, 1974, and 1983.

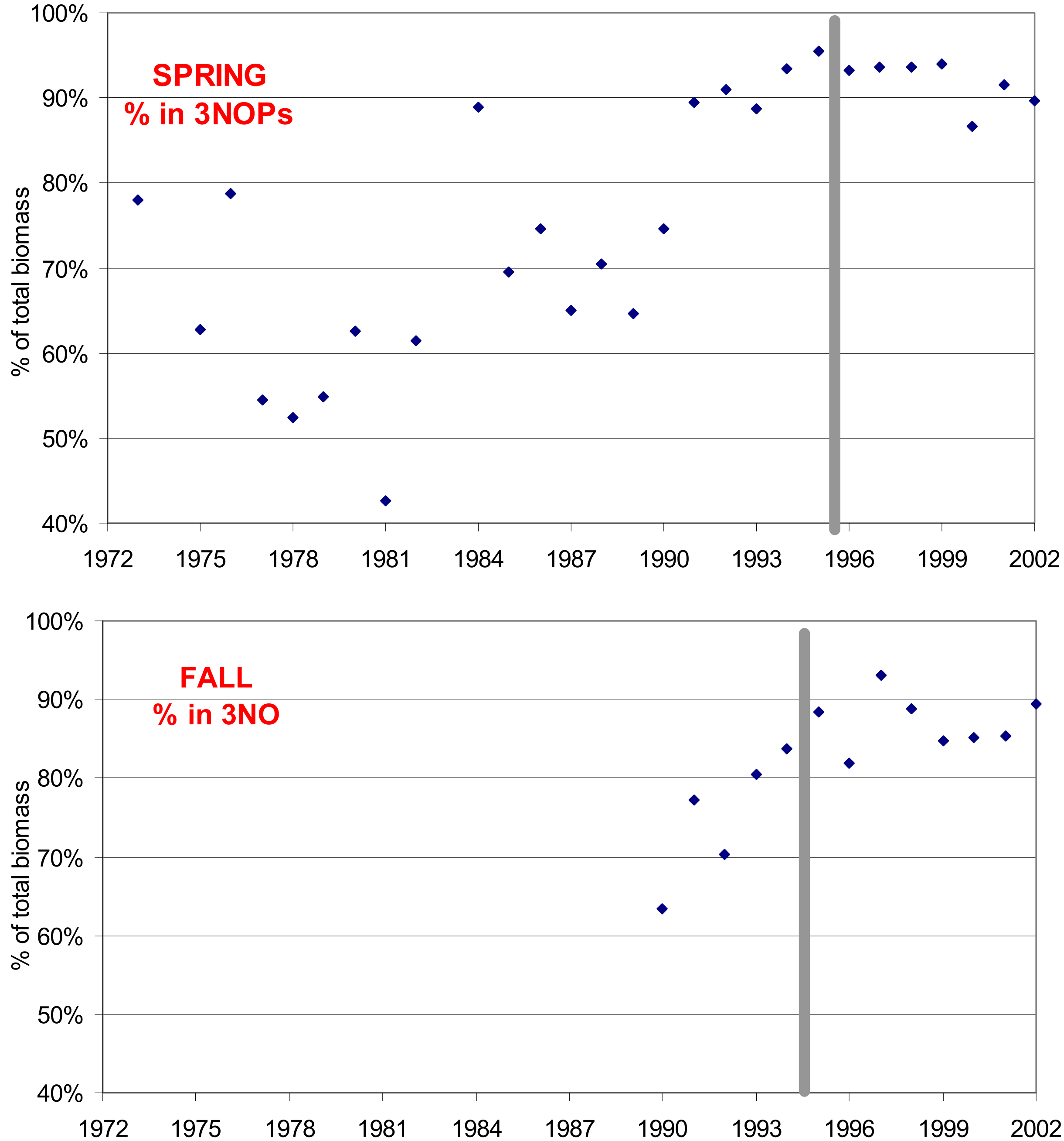


Figure 5. Upper Panel: Proportion of thorny skate that occurred in NAFO Divisions 3NO and Subdivision 3Ps in relation to the entire stock area (3LNOPs) in the spring. Lower Panel: Proportion of thorny skate that occurred in NAFO Divisions 3NO in relation to the entire stock area (3LNO) in the fall.

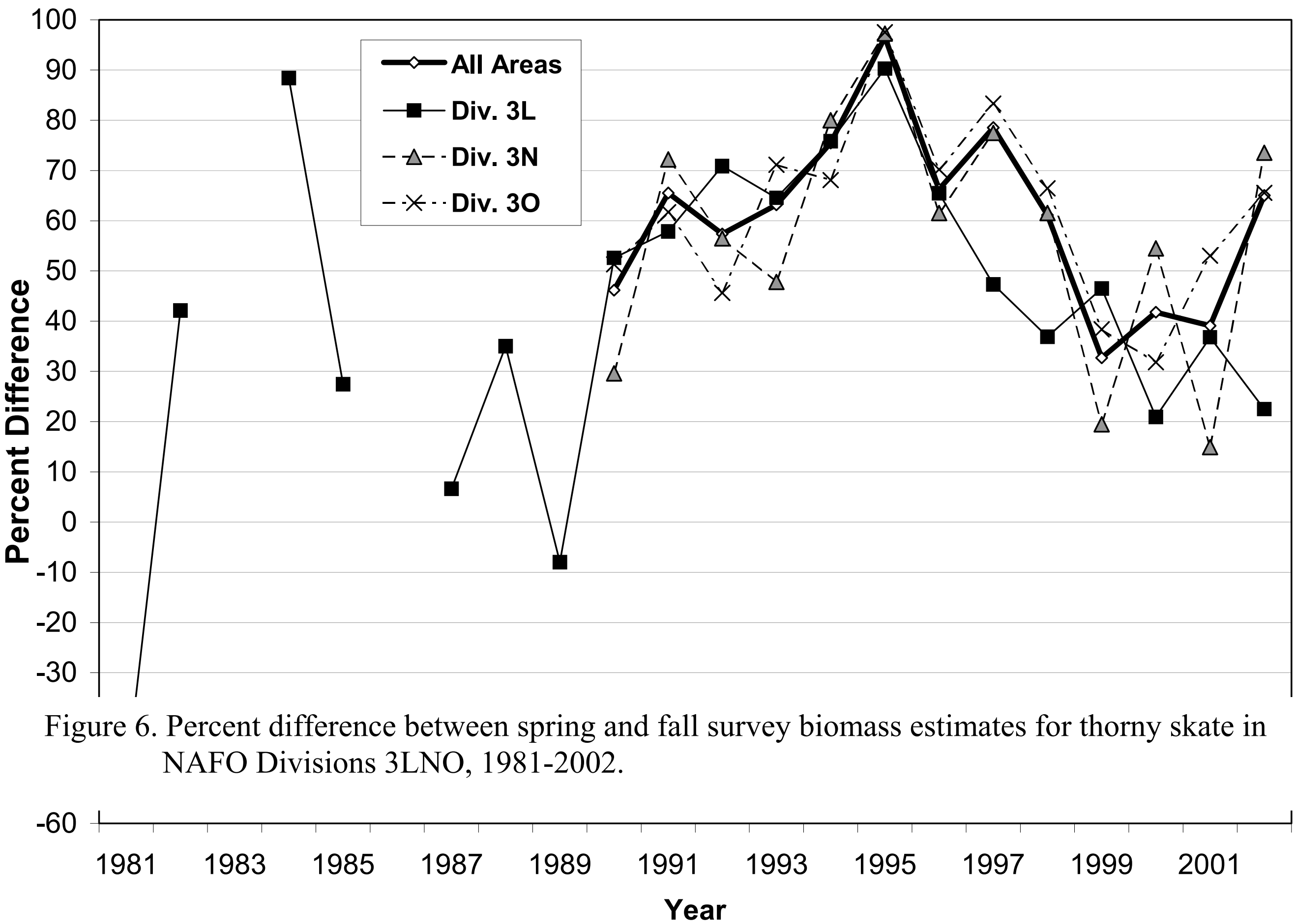


Figure 6. Percent difference between spring and fall survey biomass estimates for thorny skate in NAFO Divisions 3LNO, 1981-2002.

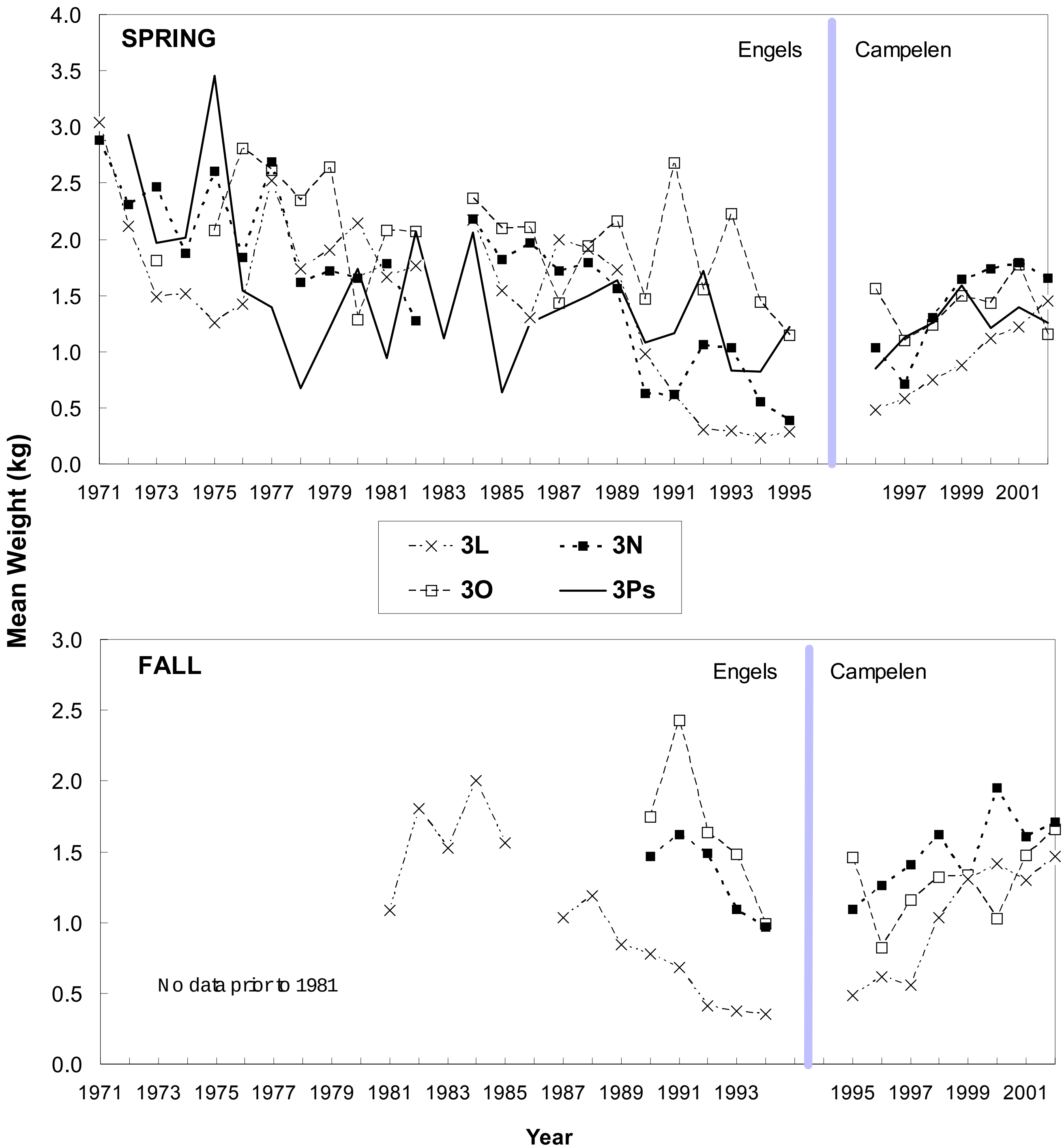


Figure 7. Mean weight of thorny skate in spring (1971-2002) and fall (1981-2002) surveys in NAFO Divisions 3LNO and Subdivision 3Ps,.

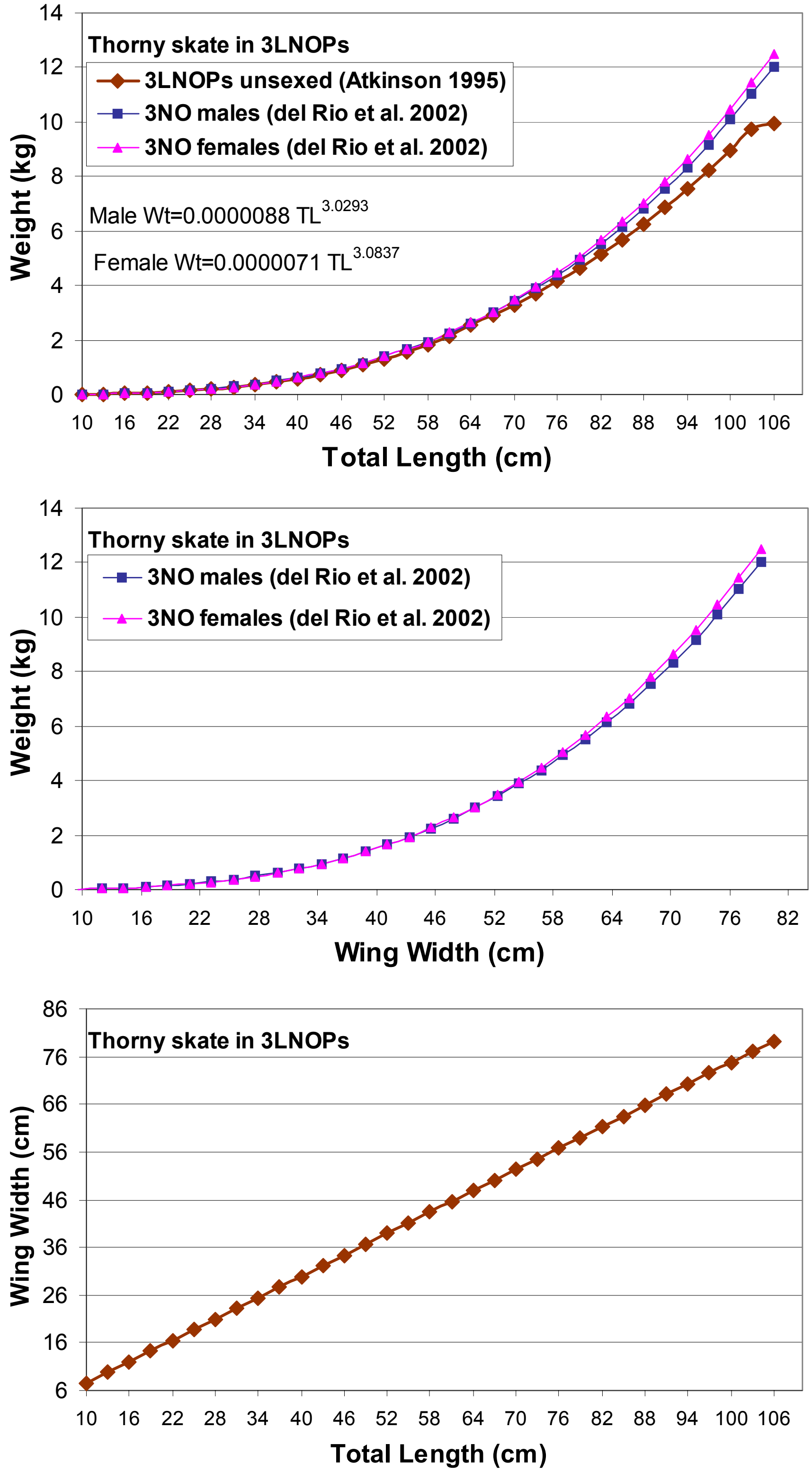


Figure 8. Total length, average weight, and wing width relationships for thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps (after Atkinson 1995, and del Rio *et al.* 2002).

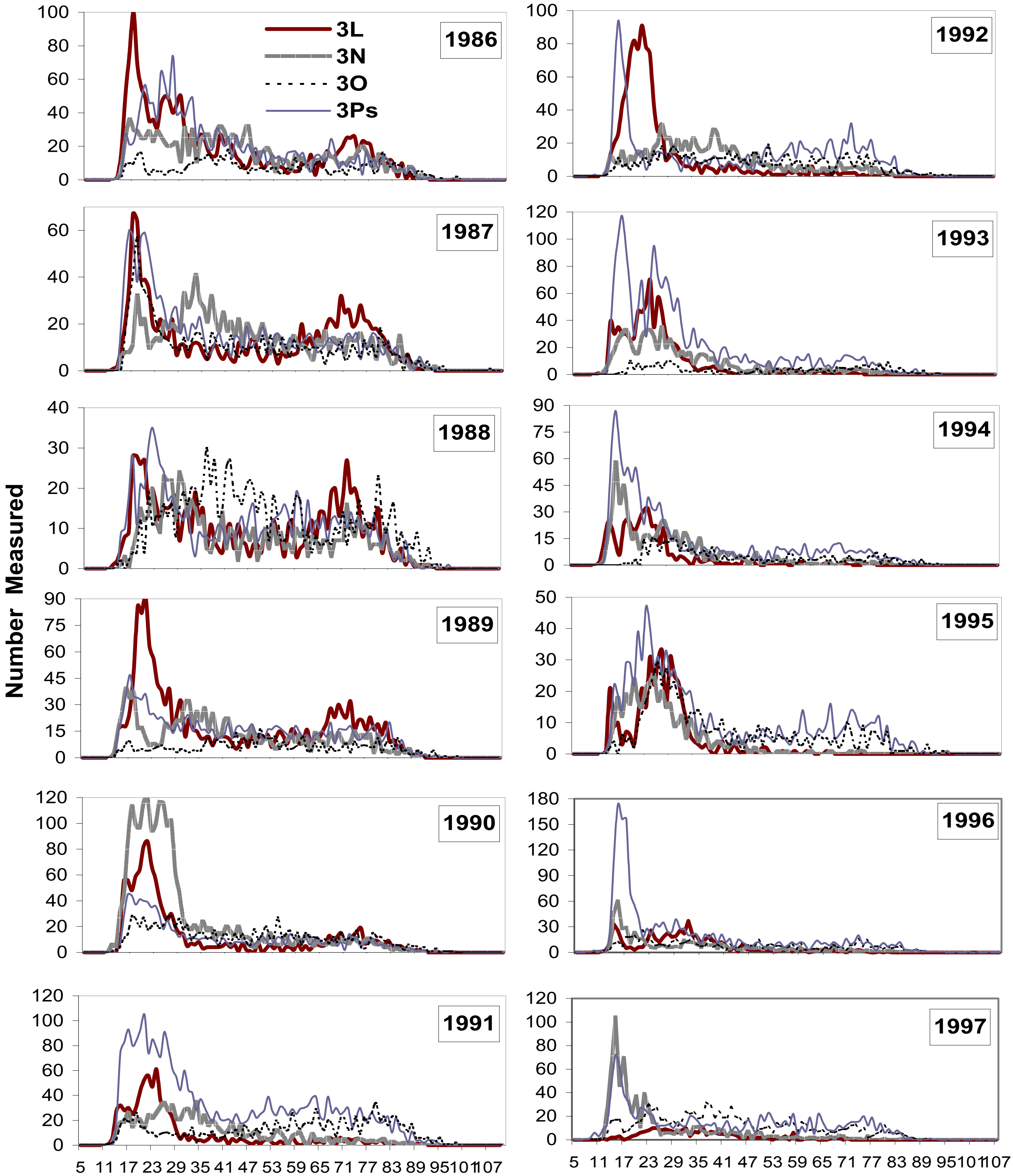


Figure 9a. Length frequencies of thorny skate caught by spring research vessel surveys in NAFO Divisions 3LNOPs, 1986-2002. X-axis represents the lengths of skate in centimeters.

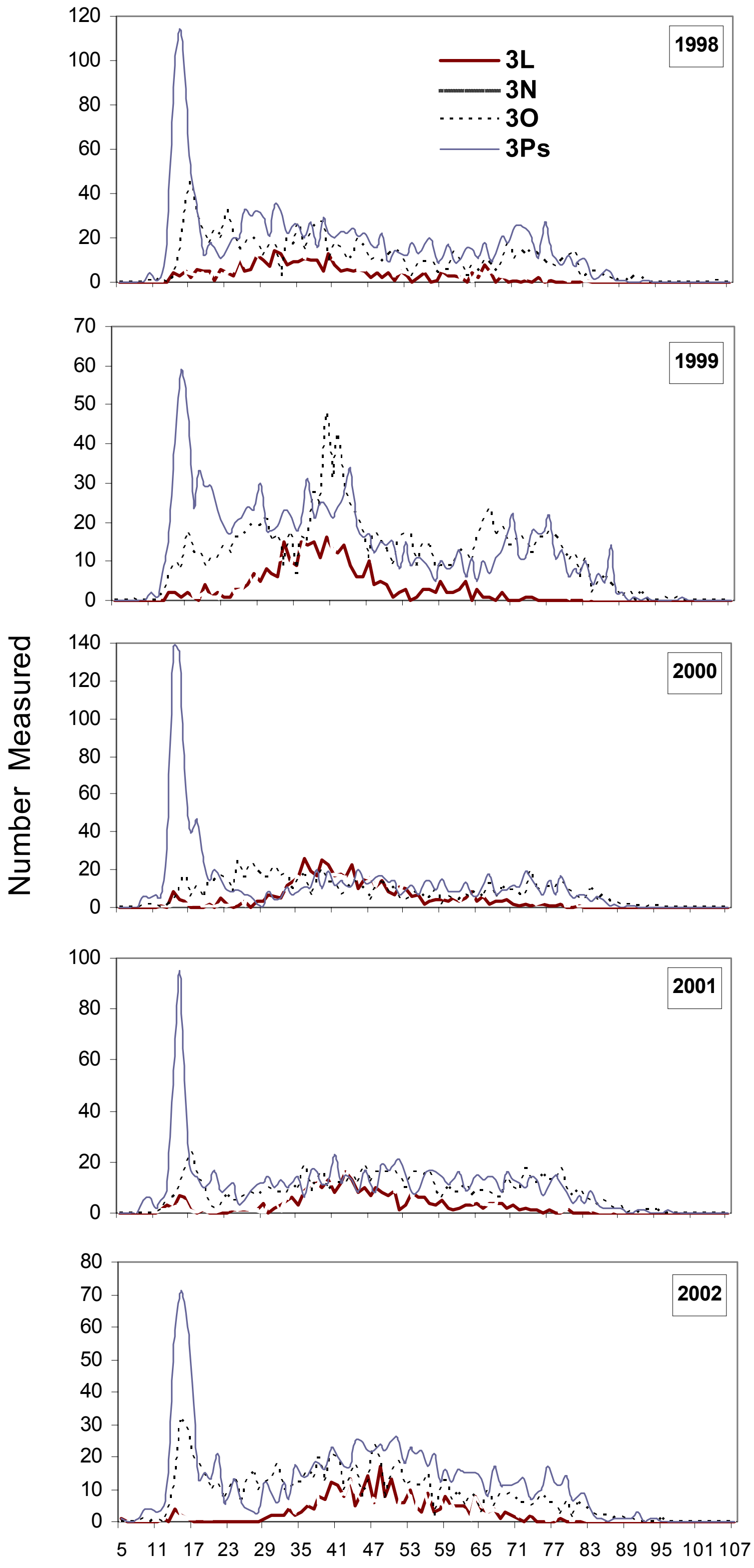


Figure 9a – continued (1998-2002).

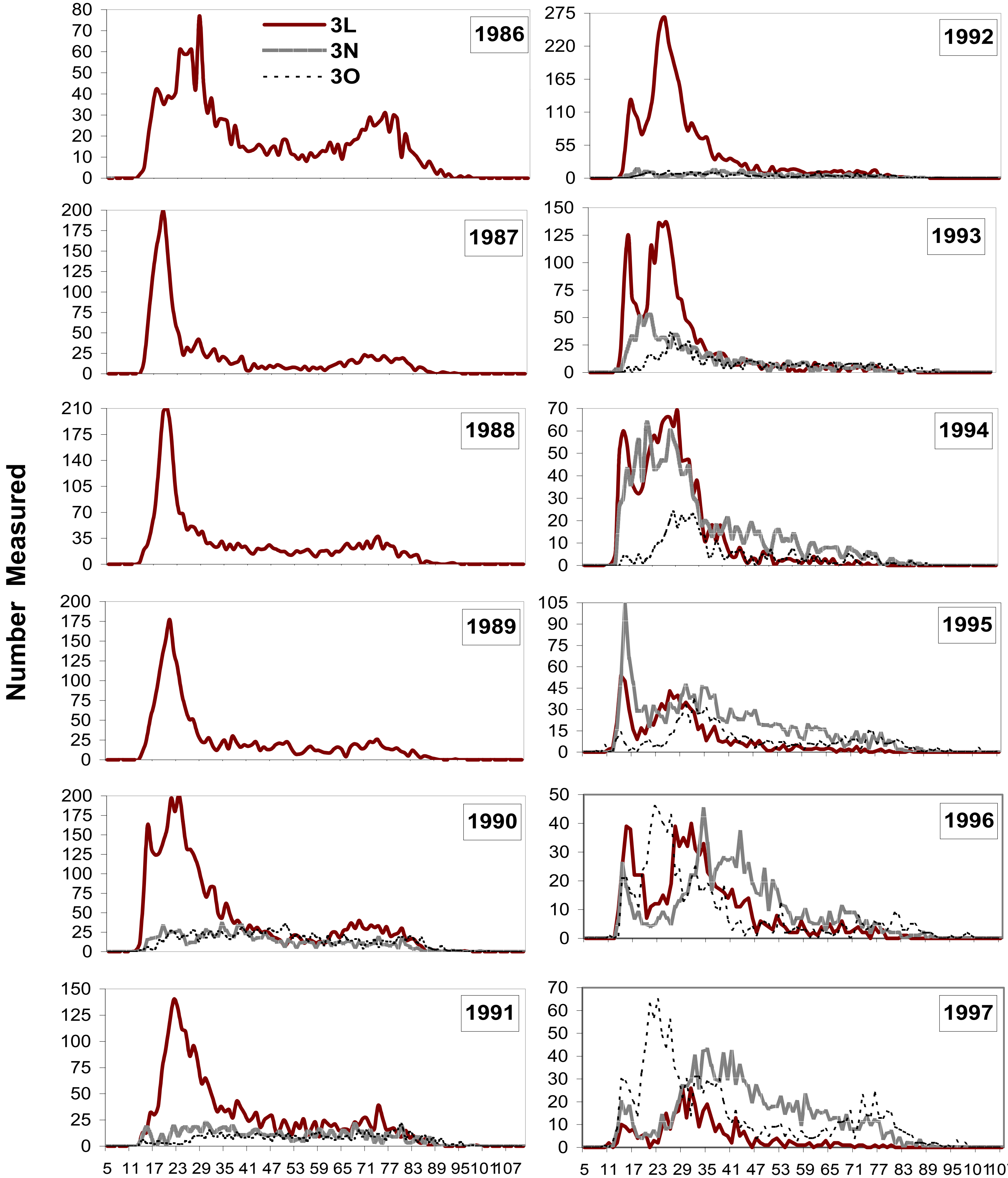


Figure 9b. Length frequencies of thorny skate caught by fall research vessel surveys in NAFO Divisions 3LNO, 1986-2002. X-axis represents the lengths of skate in centimeters.

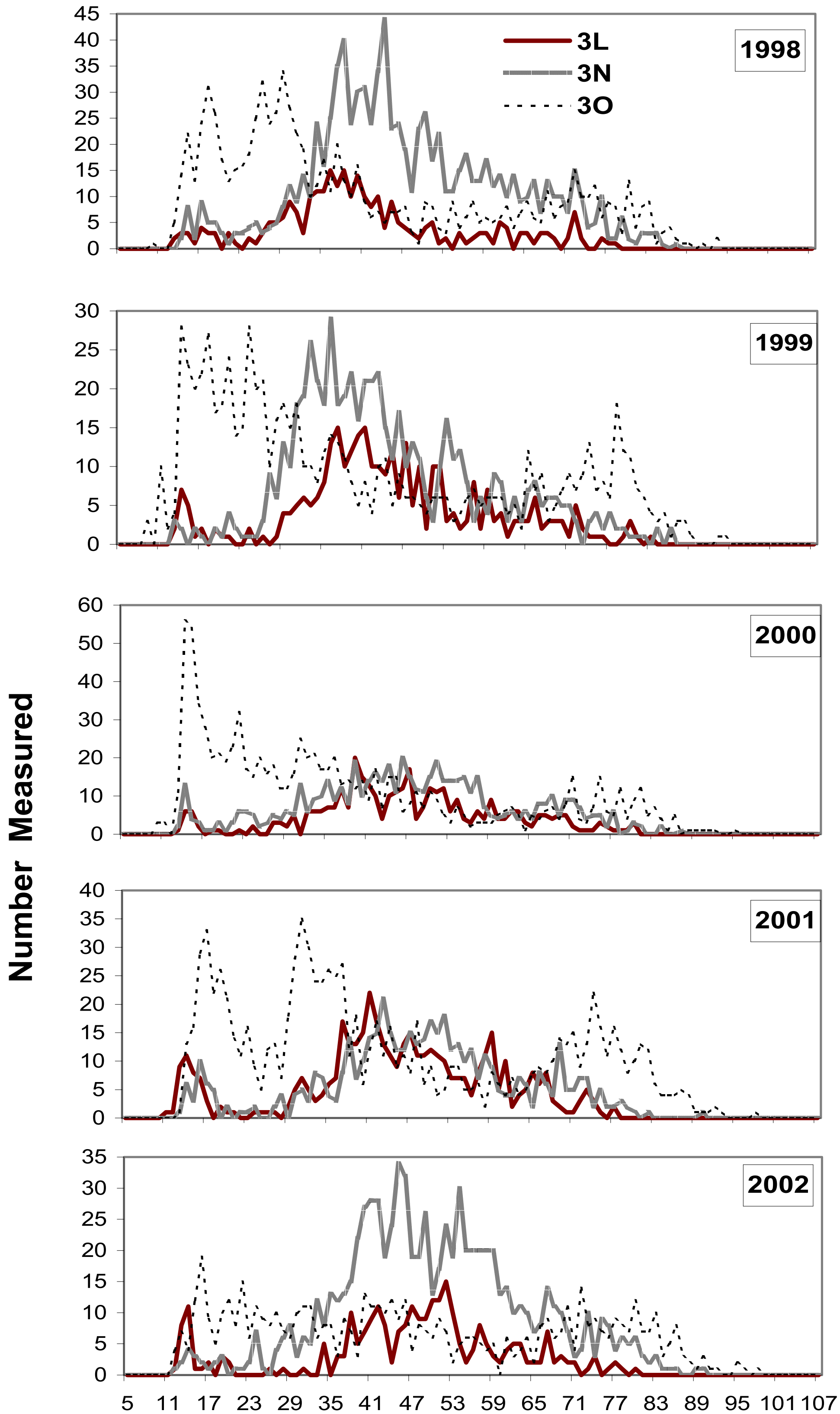
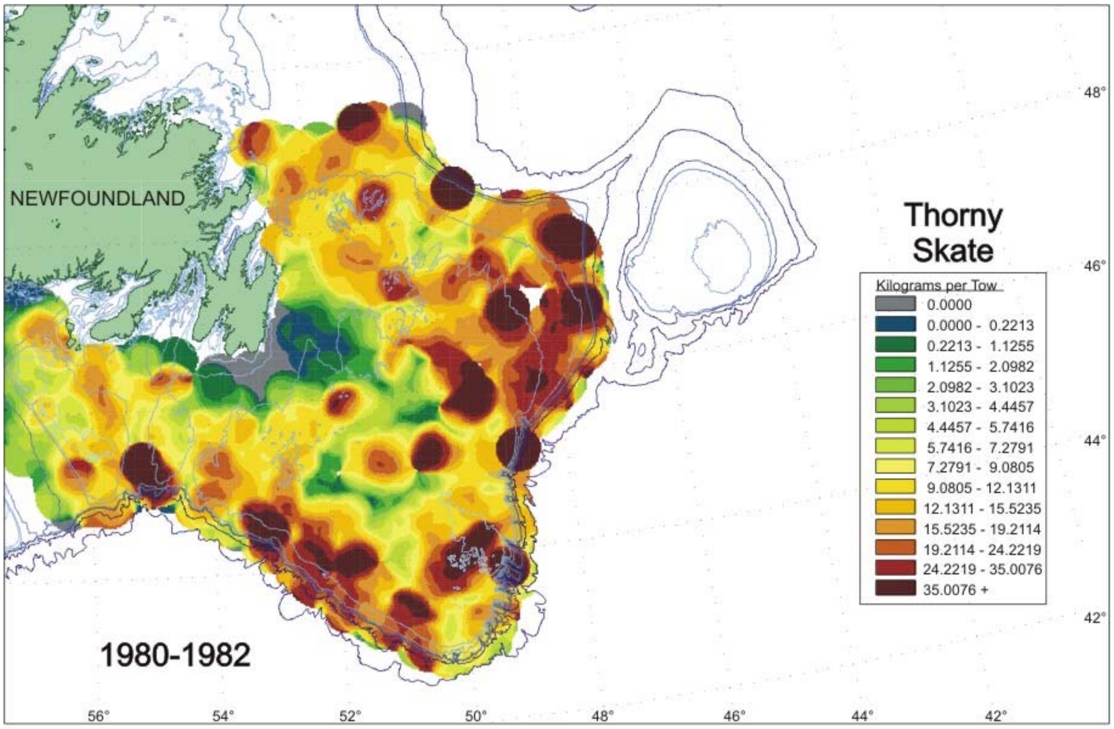


Figure 9b – continued (1998-2002).



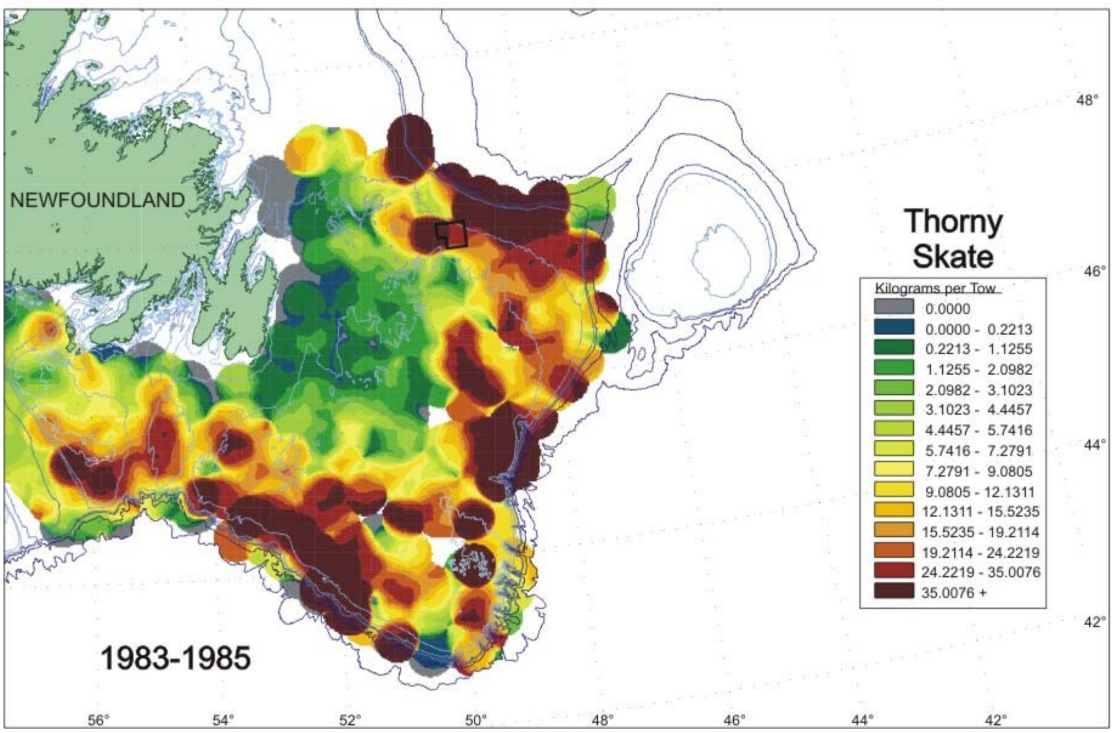


Figure 10a. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on spring surveys in 1980-1982 and 1983-1985 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.

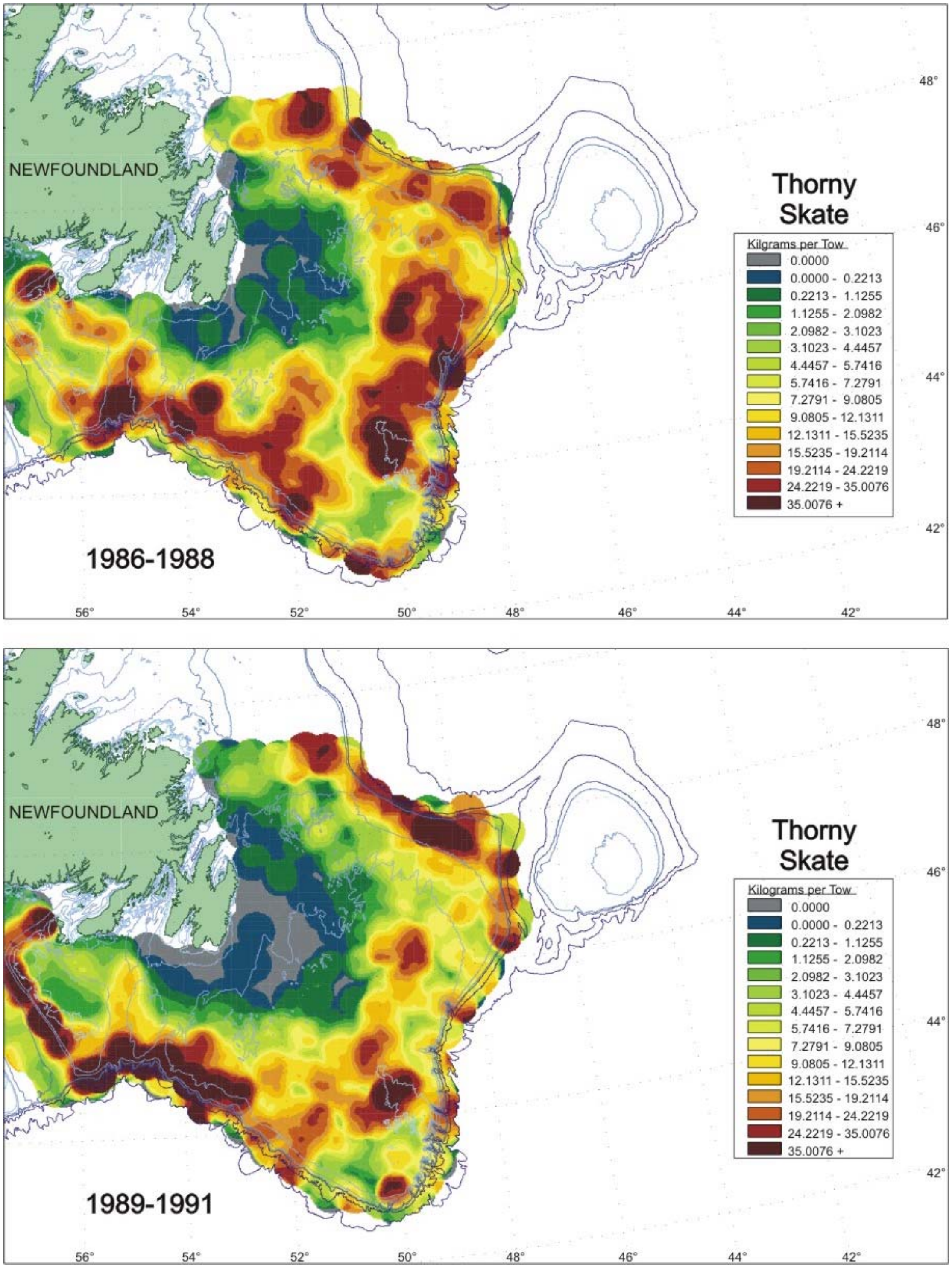


Figure 10b. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on spring surveys in 1986-1988 and 1989-1991 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.

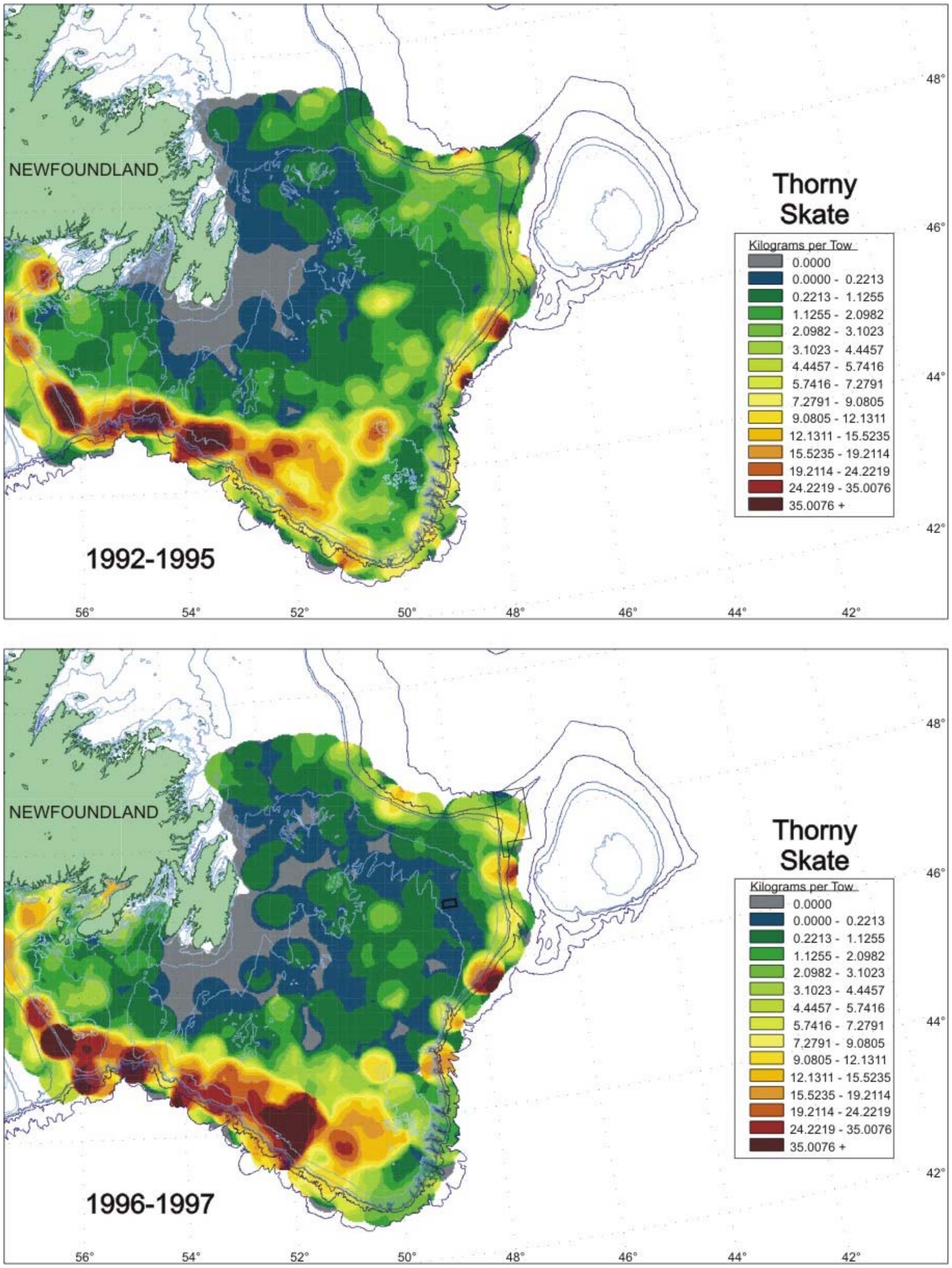


Figure 10c. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on spring surveys in 1992-1995 and 1996-1997 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.

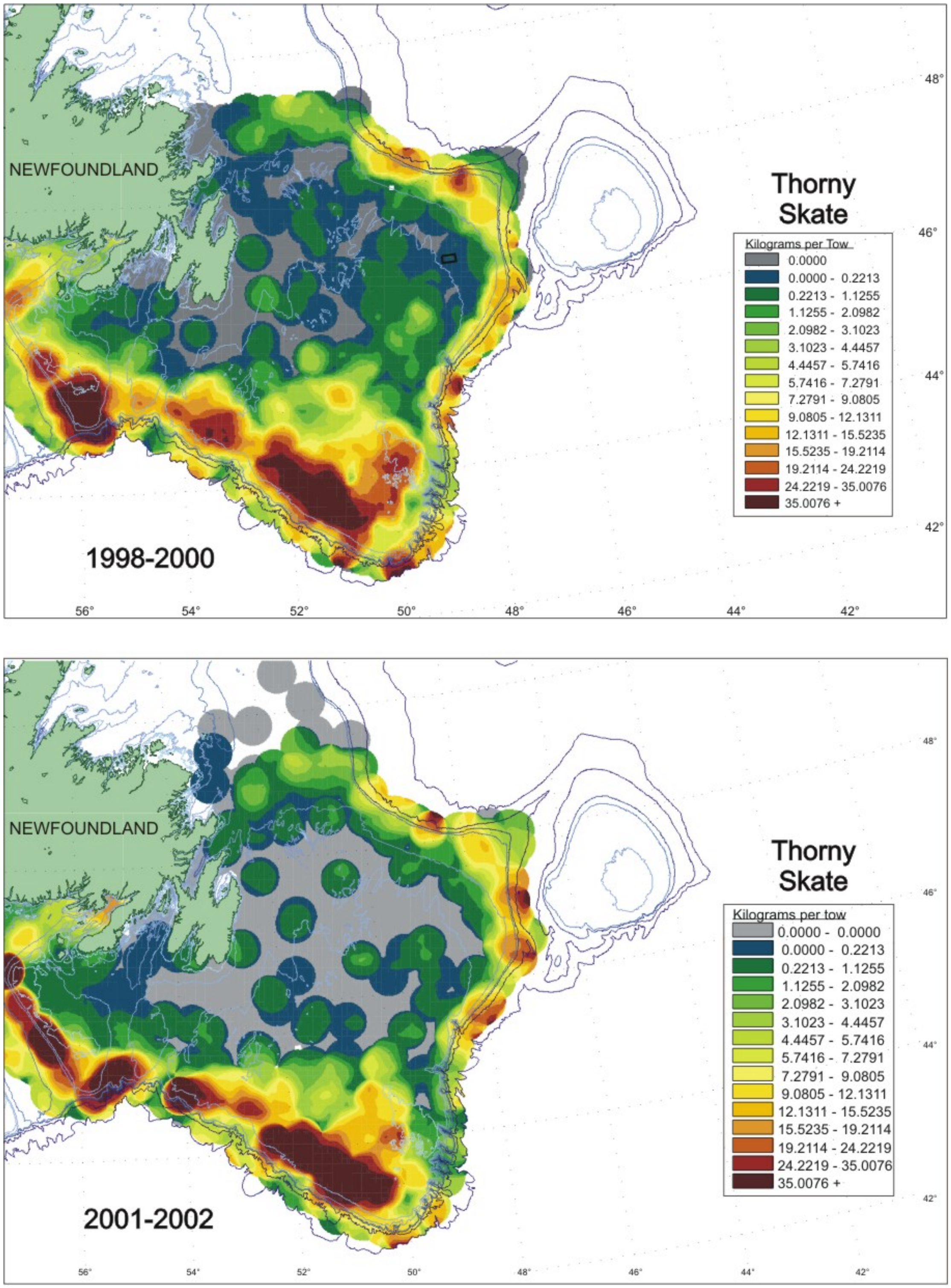
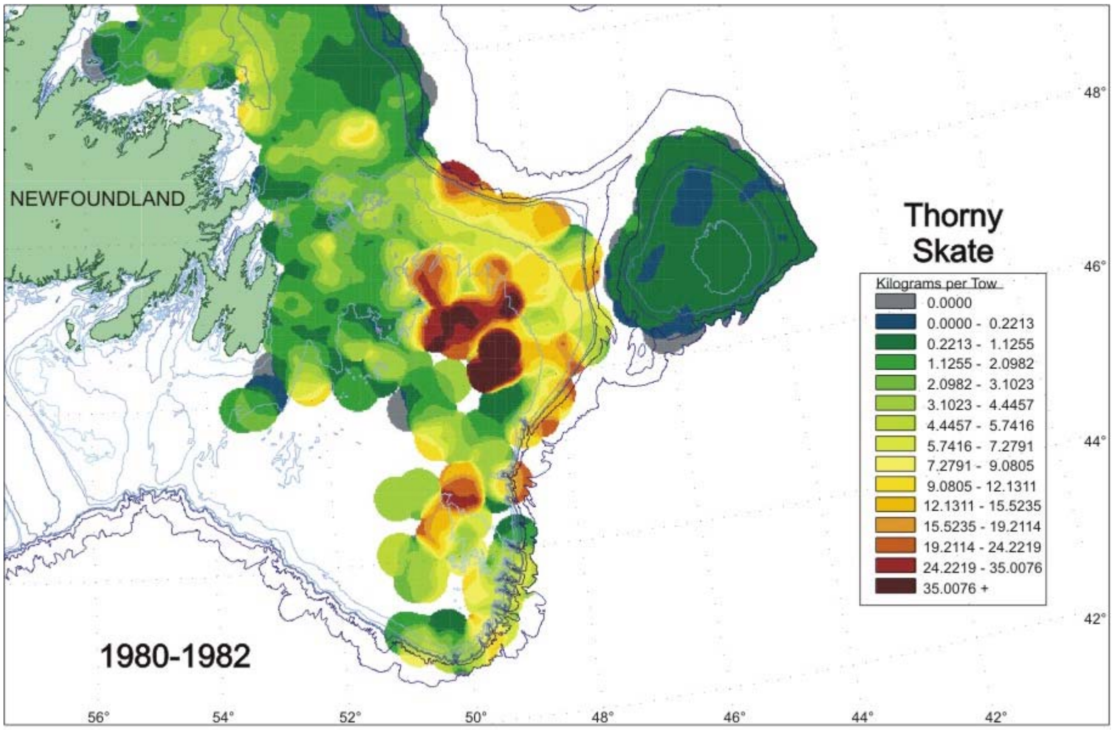


Figure 10d. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on spring surveys in 1998-2000 and 2001-2002 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.



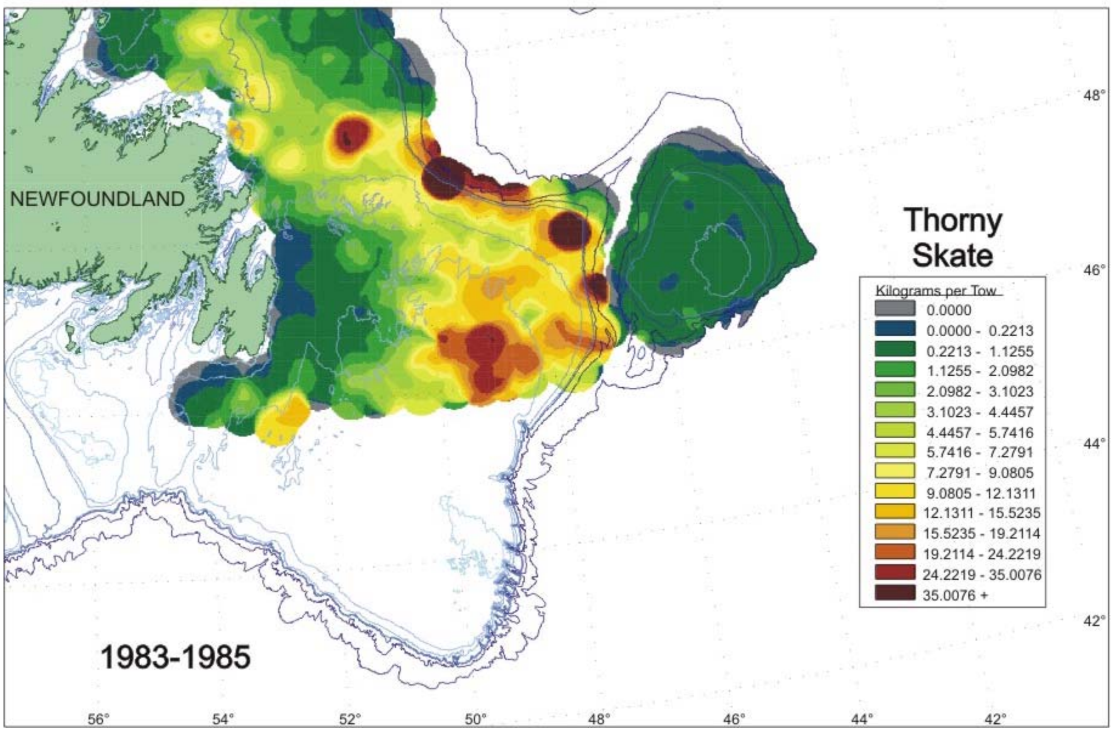
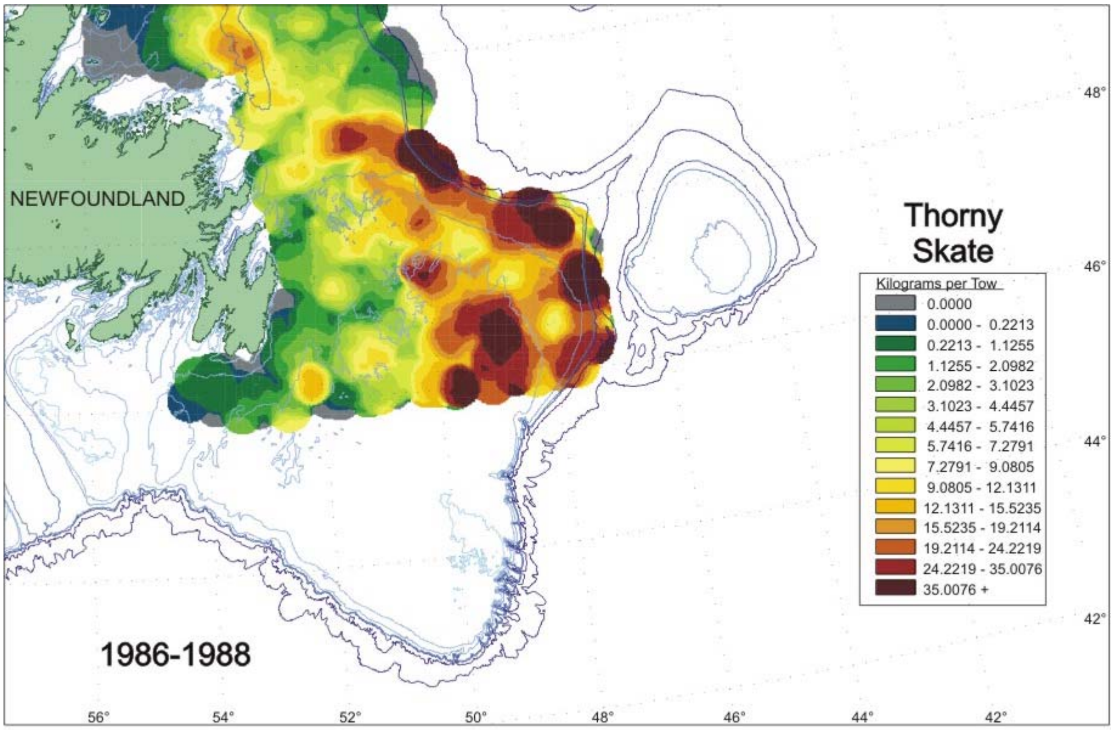


Figure 11a. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on fall surveys in 1981-1982 and 1983-1985 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.



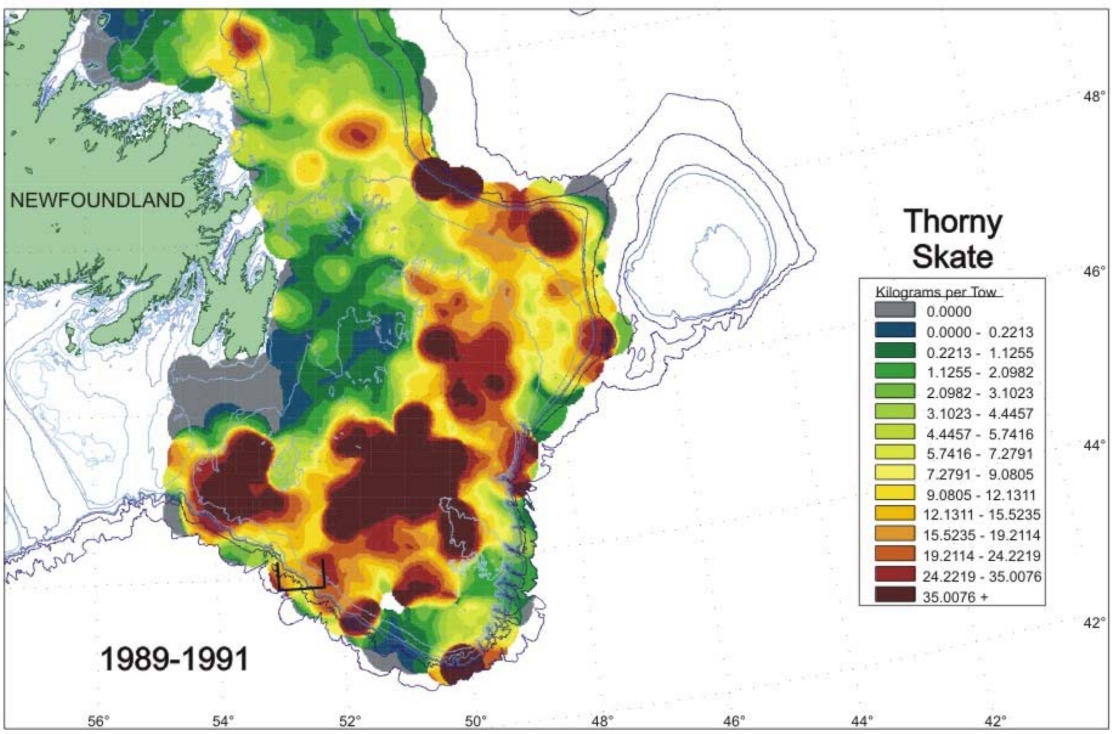


Figure 11b. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on fall surveys in 1986-1988 and 1989-1991 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.

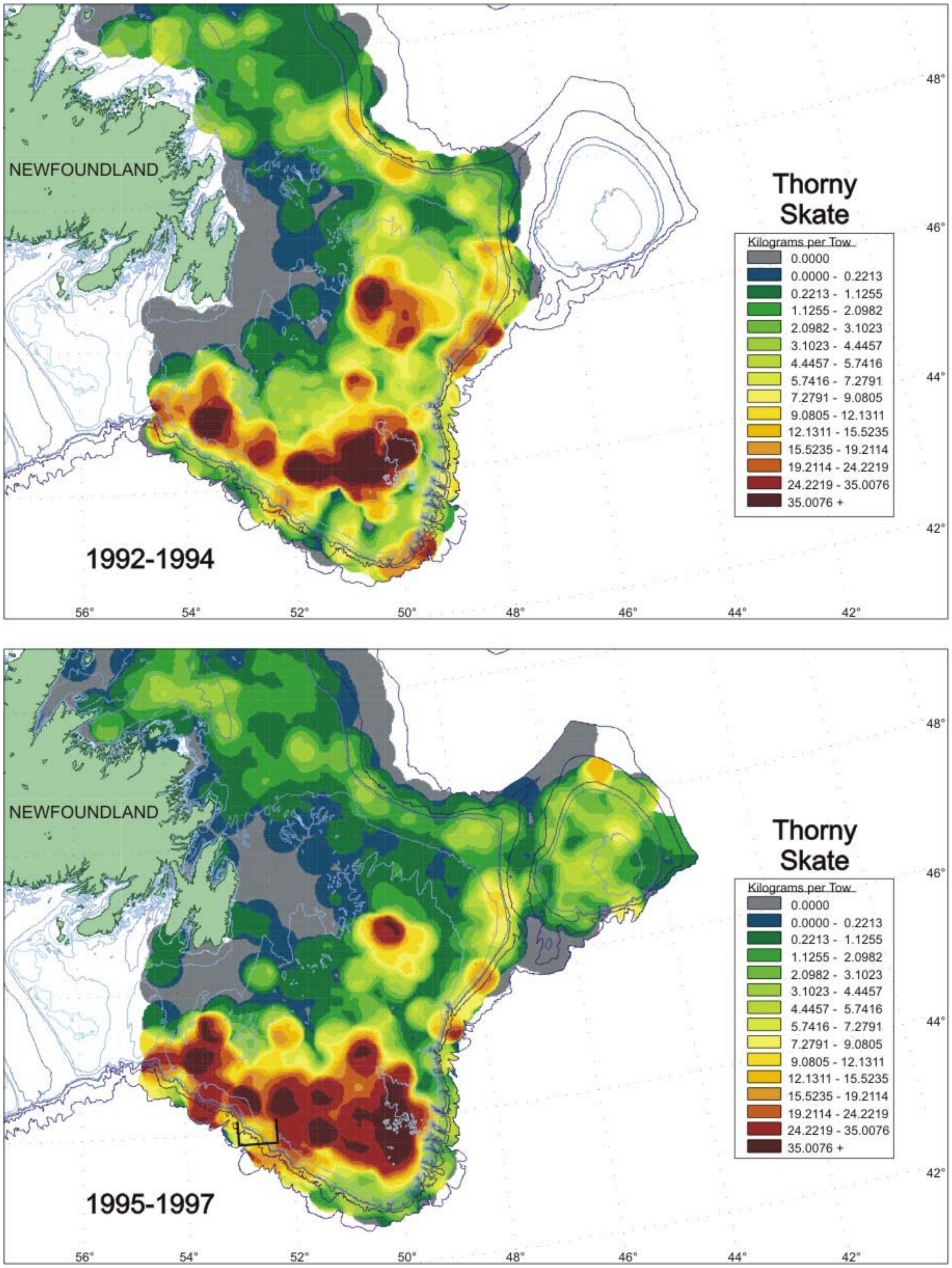


Figure 11c. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on fall surveys in 1992-1994 and 1995-1997 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.

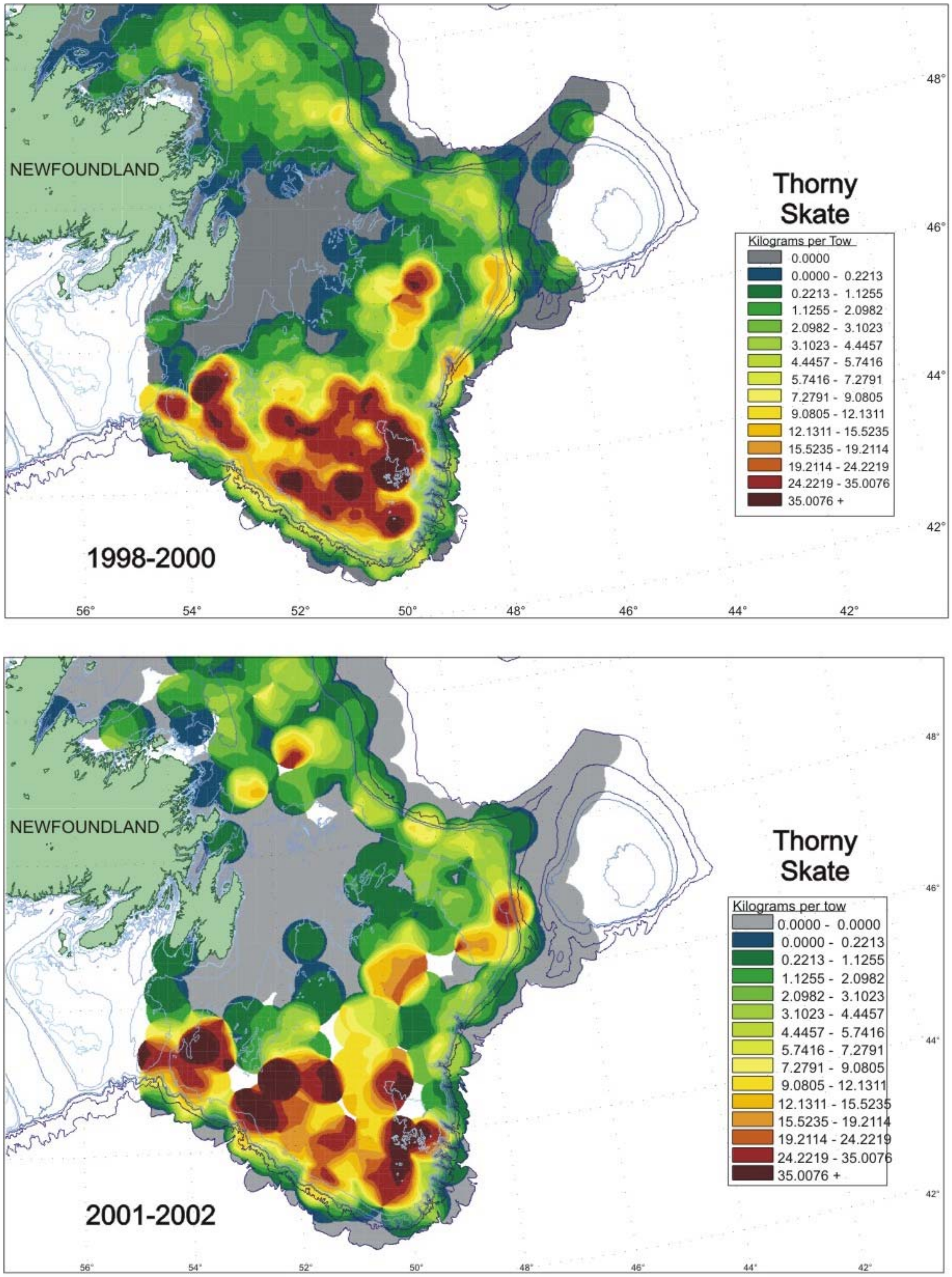


Figure 11d. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on fall surveys in 1998-2000 and 2001-2002 (years combined). Green represents low catch rates (in kg per tow); red represents high catch rates. Grey denotes sampled areas with no skate catches; white depicts unsampled areas.

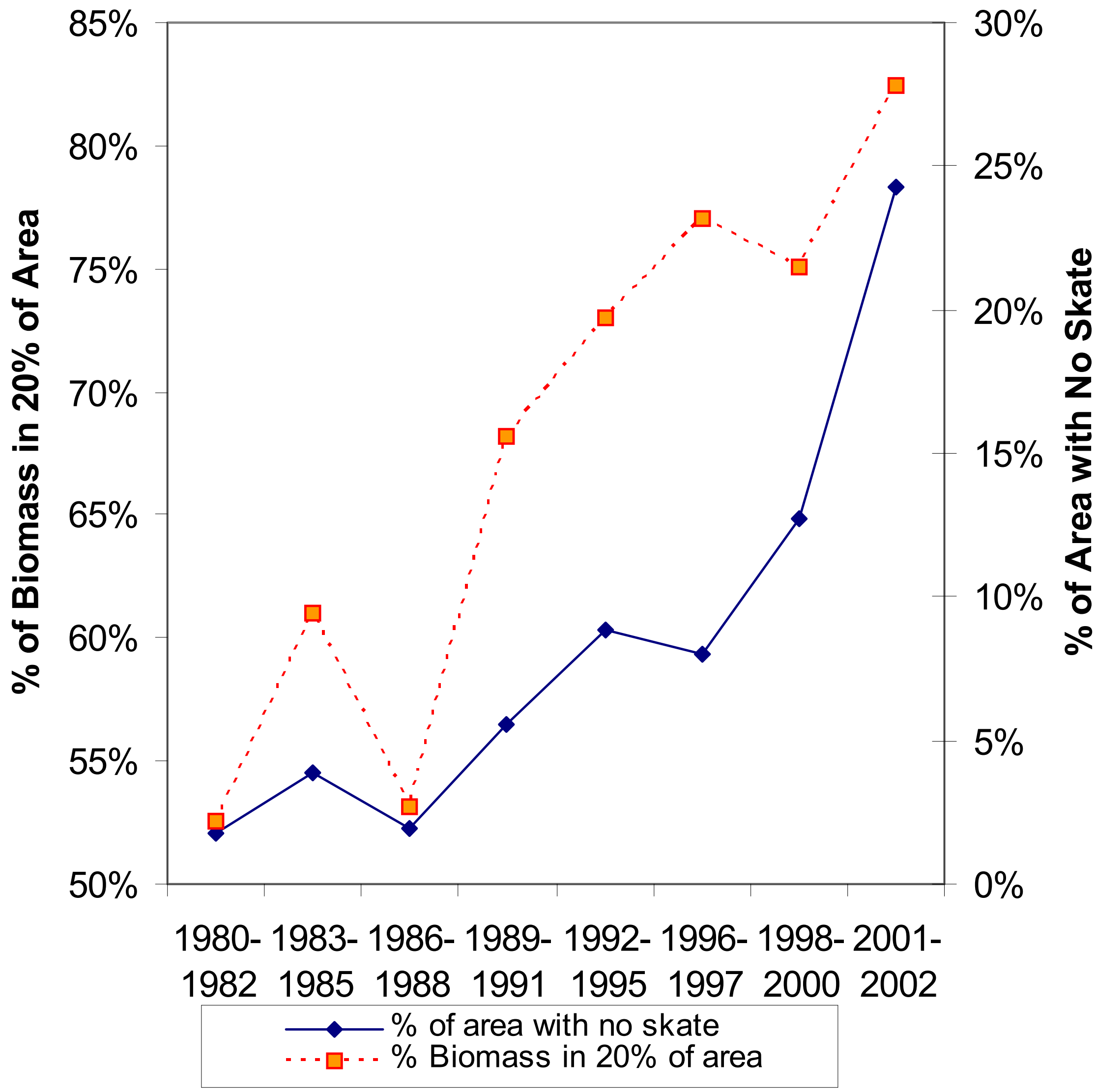


Figure 12. Changes in area of occupancy, based on spring research surveys in 1980-2002: percent of the stock area (3LNOPs) without thorny skate (solid line), and percent of biomass contained within 20% of the total stock area (dotted line).

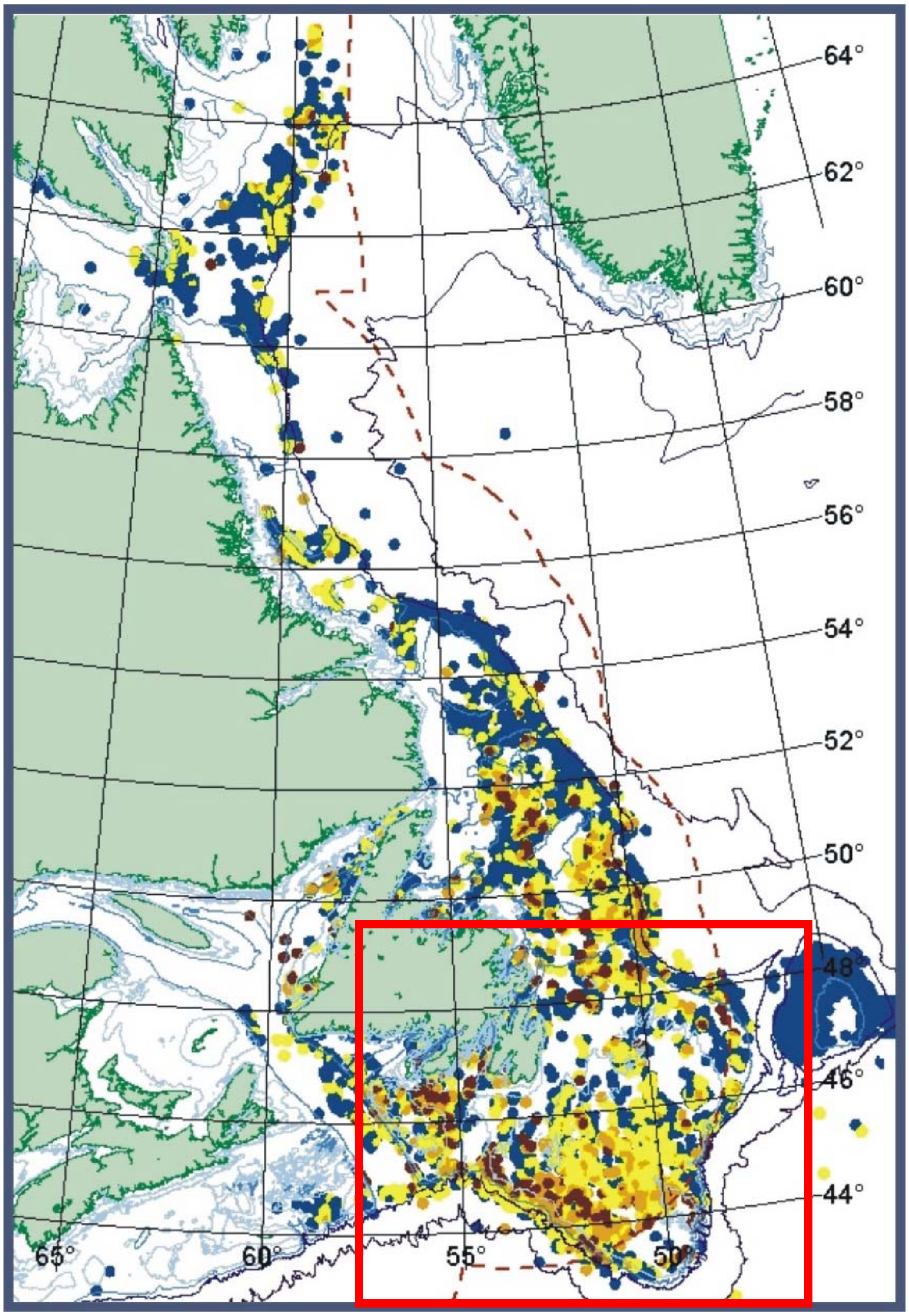


Figure 13. Distribution of thorny skate catches in all commercial fisheries north of the Laurentian Channel, 1992-2002. Data are from Canadian Fishery Observers.

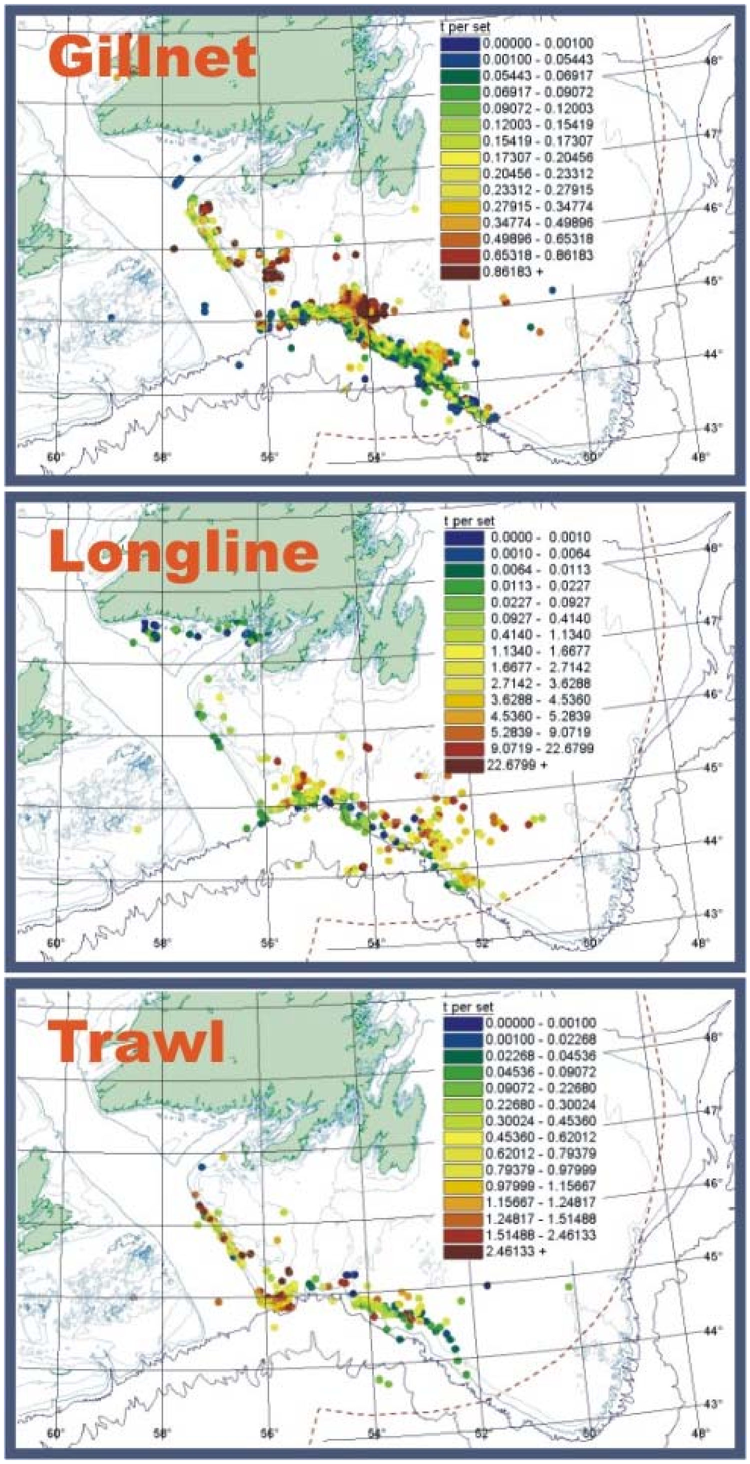


Figure 14. Distribution of thorny skate catches by gear in the skate/monkfish/white hake/halibut mixed fishery on the Grand Banks, 1999-2002. Red areas denote locations with higher catch rates. Data are from Canadian fishing logs.

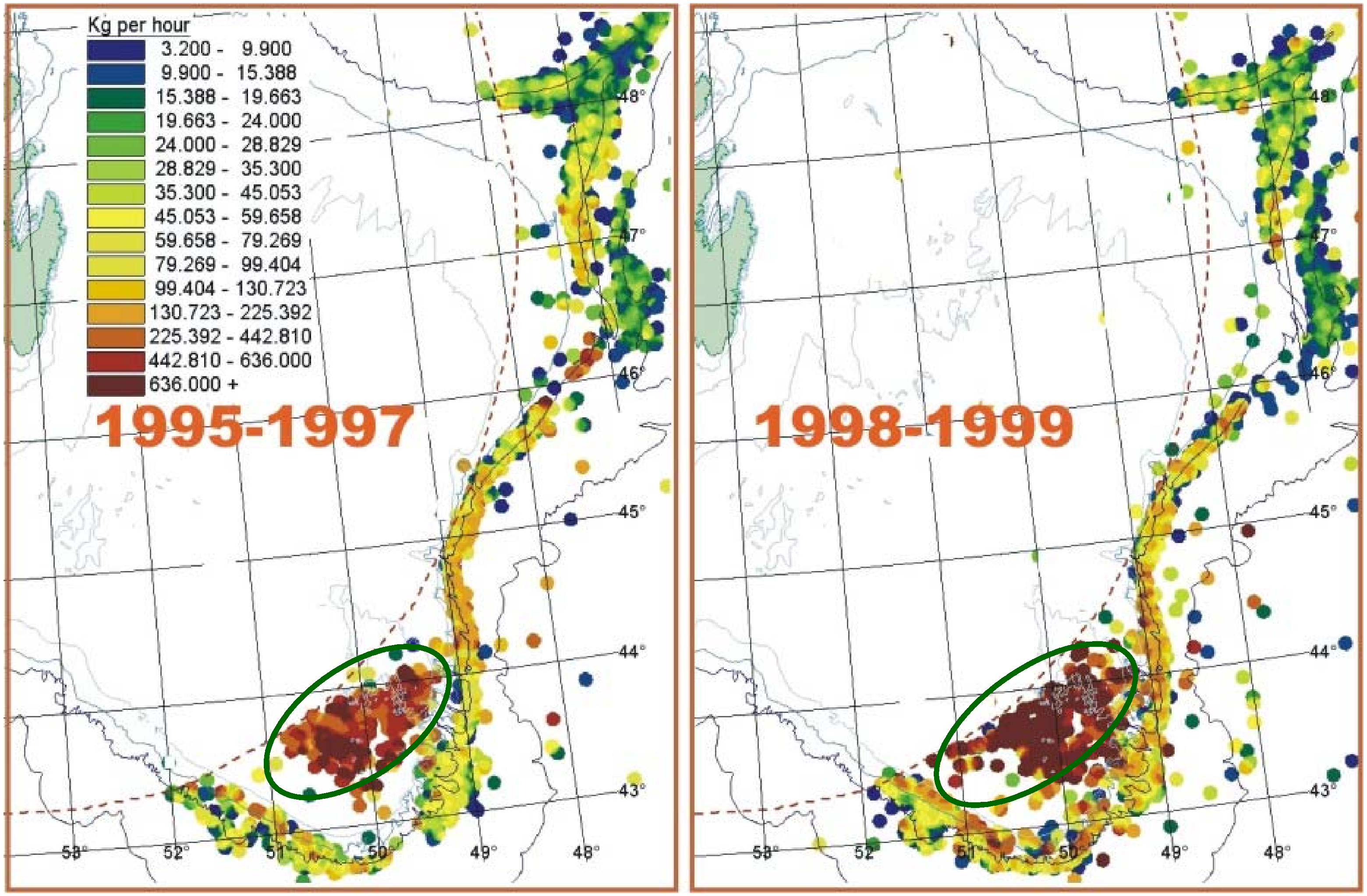
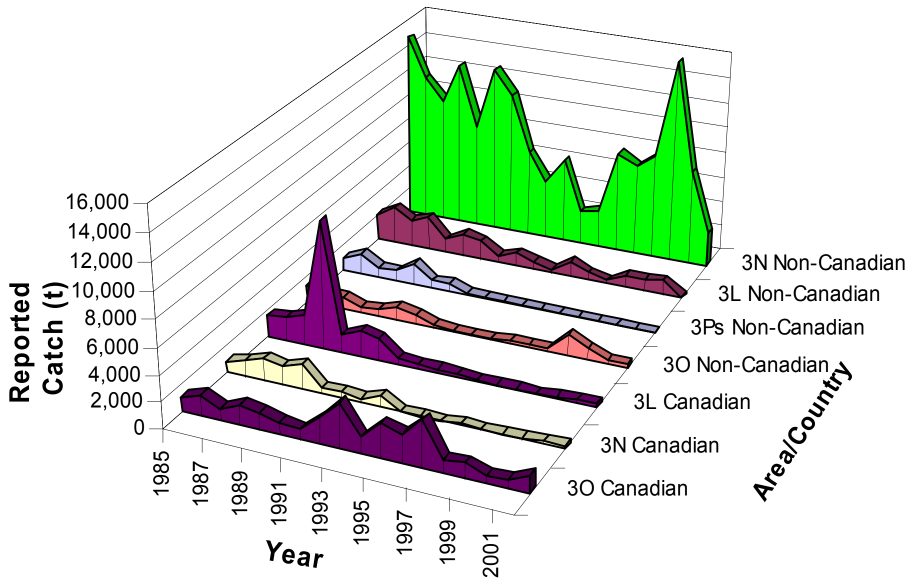


Figure 15. Skate catch rates for the non-Canadian otter trawl fishery outside Canada's 200-mile-limit, 1995-1999: directed (encircled) and bycatch (shelf edge).



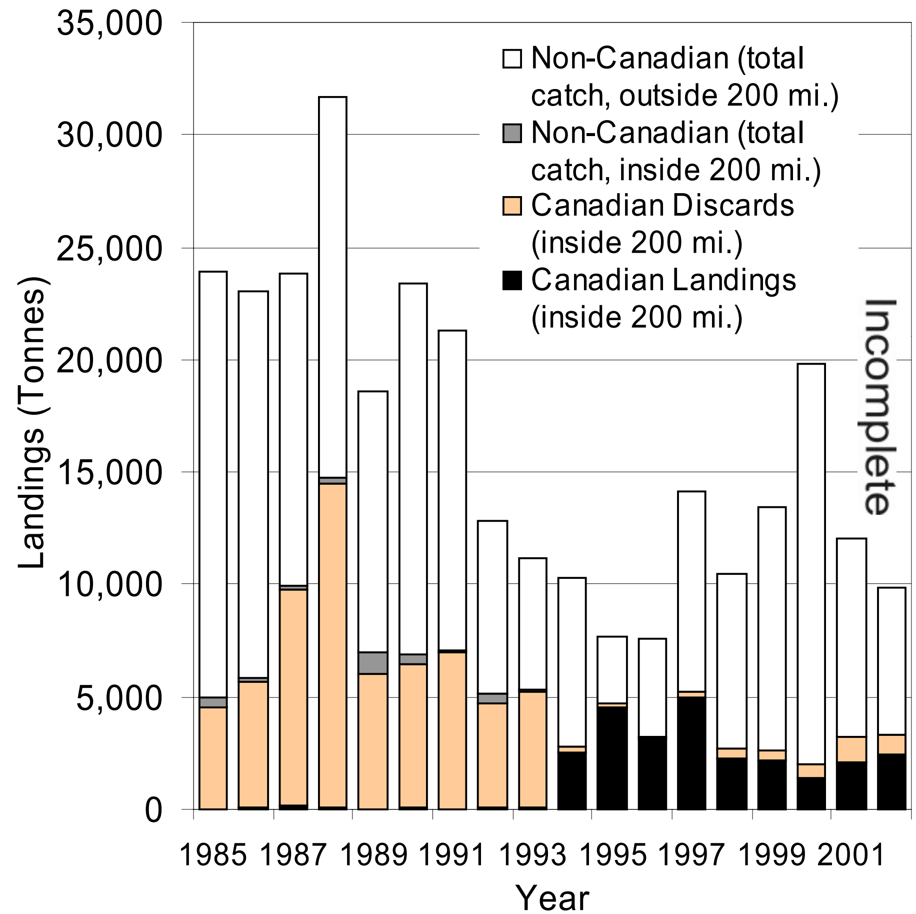


Figure 16. Reported catches of skate in NAFO Divisions 3LNOPs by all countries, 1985-2002. Skate data are not speciated. Non-Canadian data for 2001 and 2002 (striped portion of vertical bars) are preliminary.

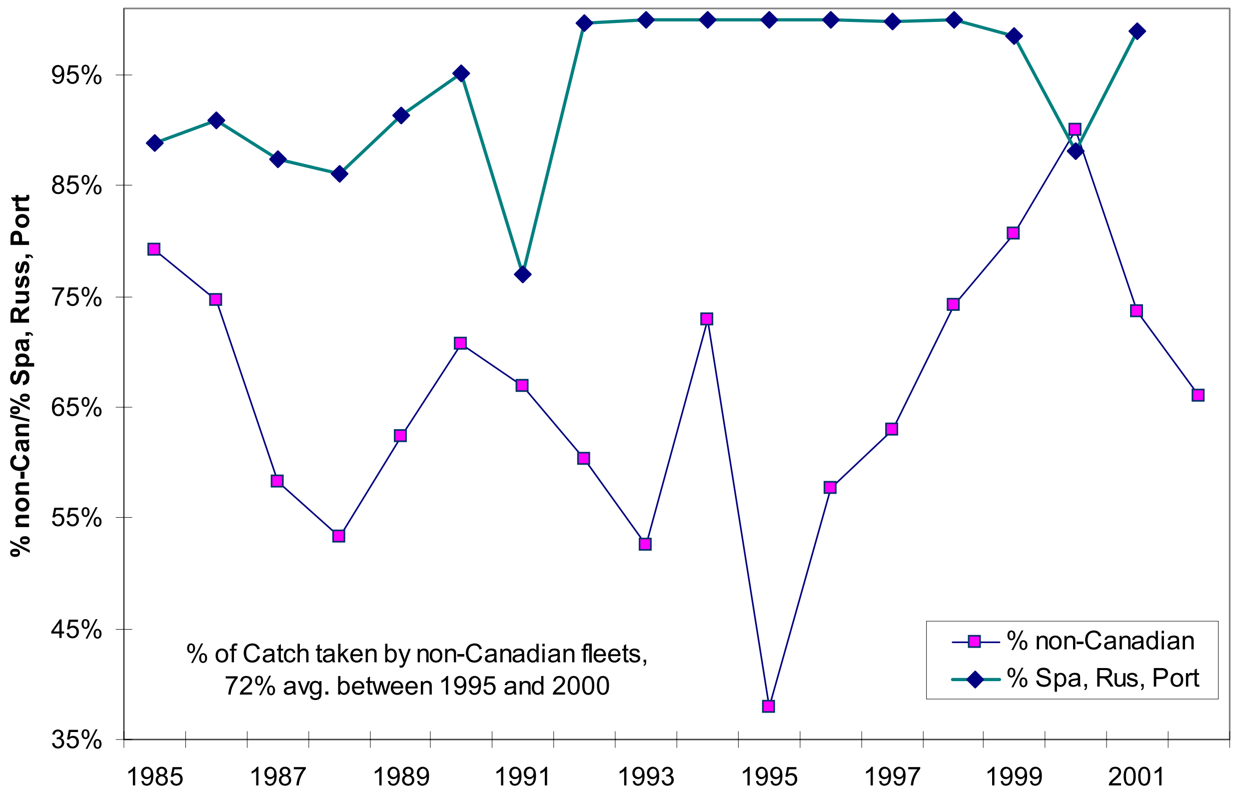
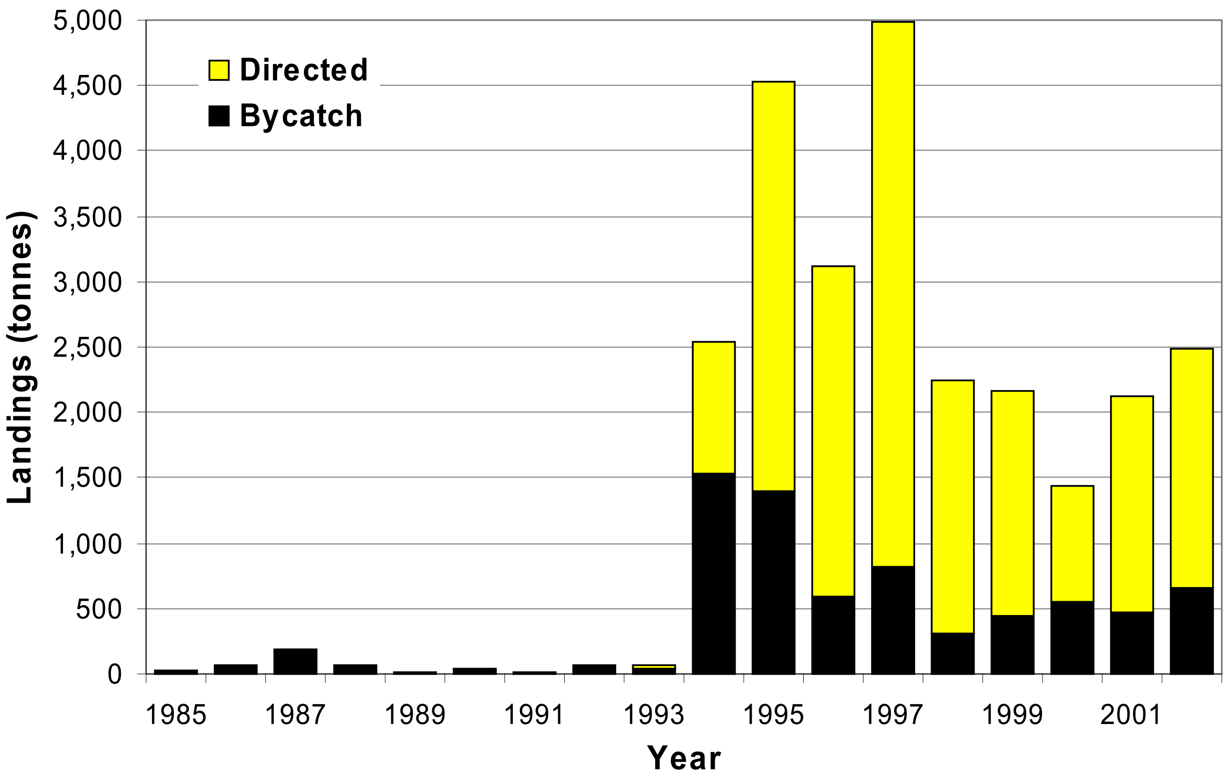
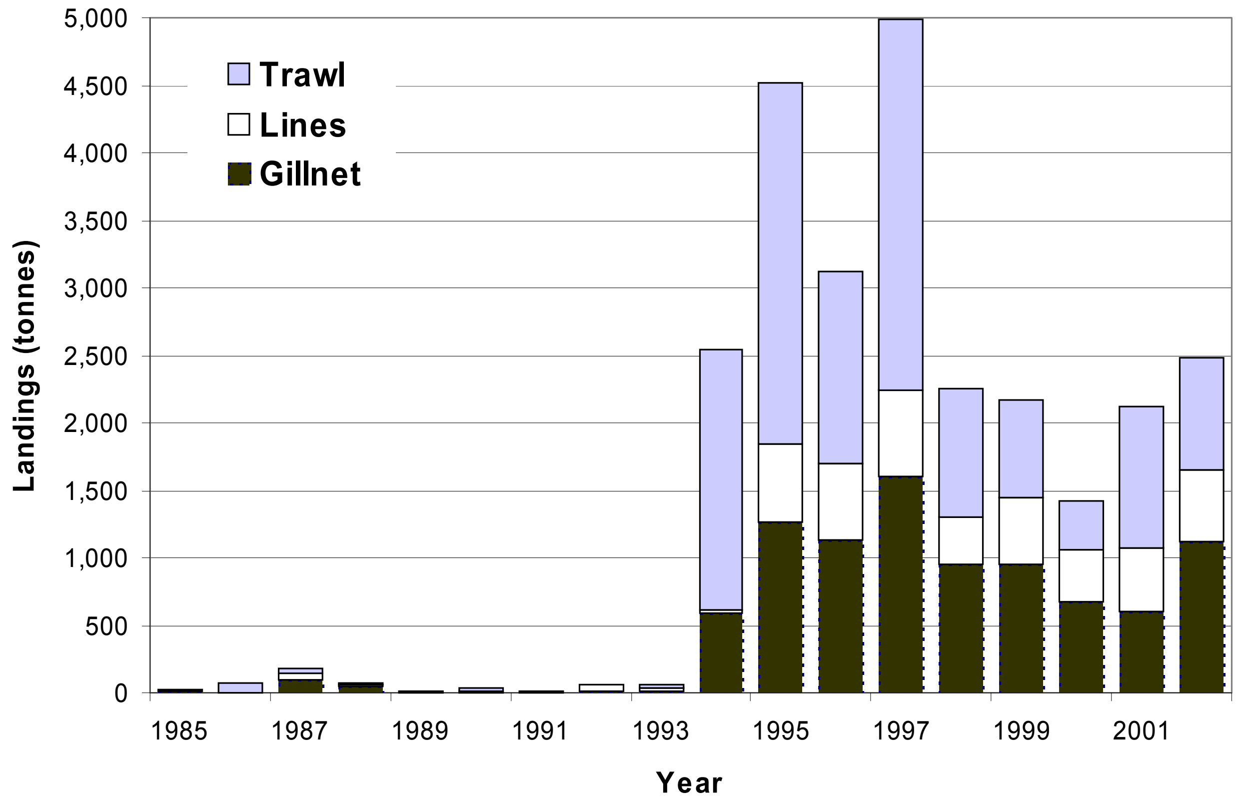


Figure 17. Percent of total skate catches taken by non-Canadian fleets (from DFO C&P commercial inspections), and percent of non-Canadian catches taken by Spain, Portugal, and Russia, 1985-2002 (from NAFO STATLANT-21A). Catches from twelve other countries comprised the remainder. Non-Canadian data for 2001 and 2002 are preliminary.



	3L		3N		3O		3Ps		All Divisions		
Year	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

Figure 18. Directed and non-directed Canadian skate landings in NAFO Divisions 3LNOPs, 1985-2002. Data do not include discards at sea.



	Gillnet		Lines		Trawl		Other			**Bycatch and Directed**		
Year	Bycatch	Directed	Bycatch	Directed	Bycatch	Directed	Bycatch	Directed	**Total**	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

Figure 19. Canadian skate landings in NAFO Divisions 3LNOPs by gear type and mode (directed or bycatch), 1985-2002. Data do not include discards at sea.

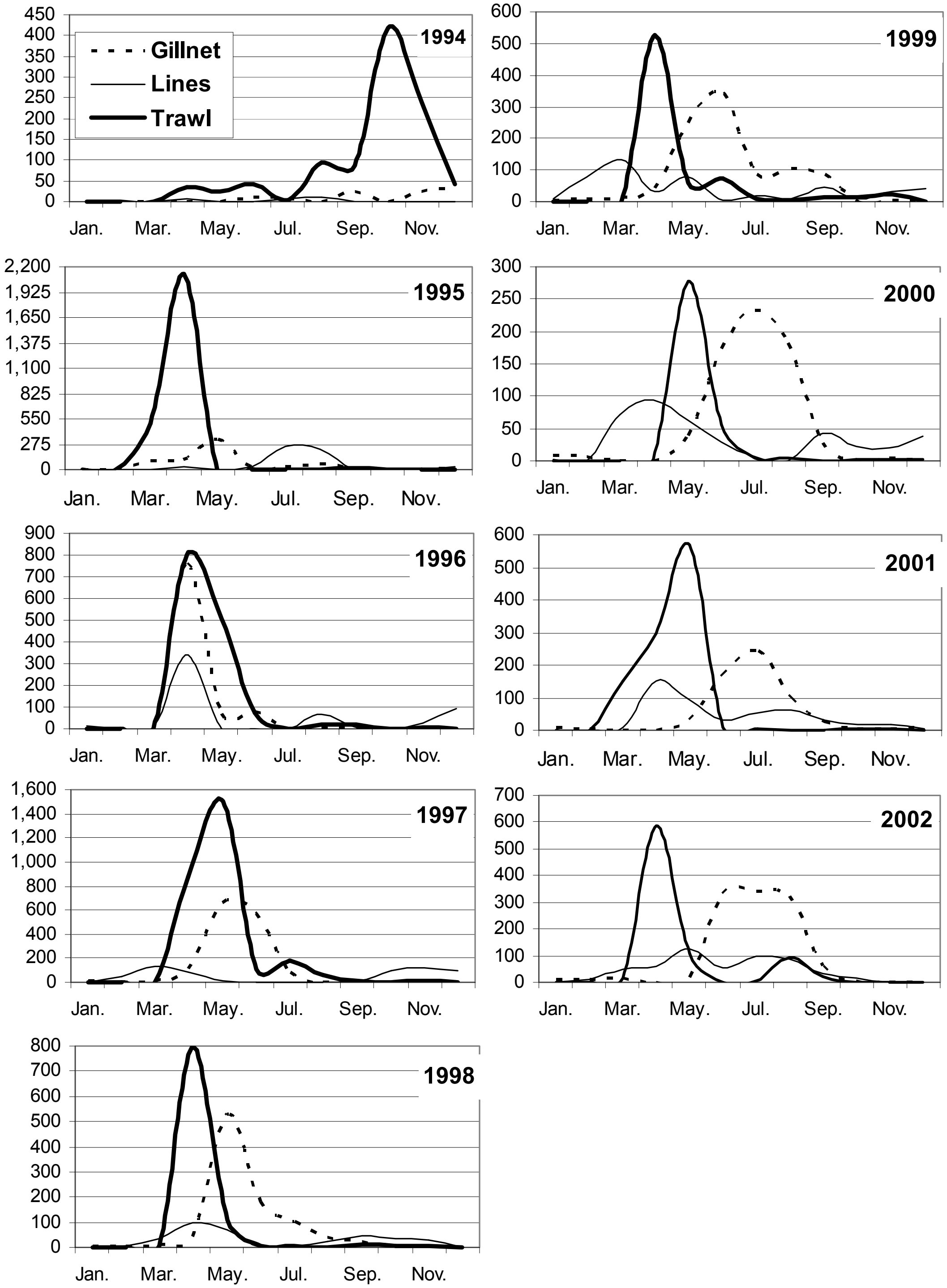


Figure 20. Monthly Canadian landings of skate in NAFO Divisions 3LNOPs, 1994-2002. Landing records for which no month was recorded are excluded.

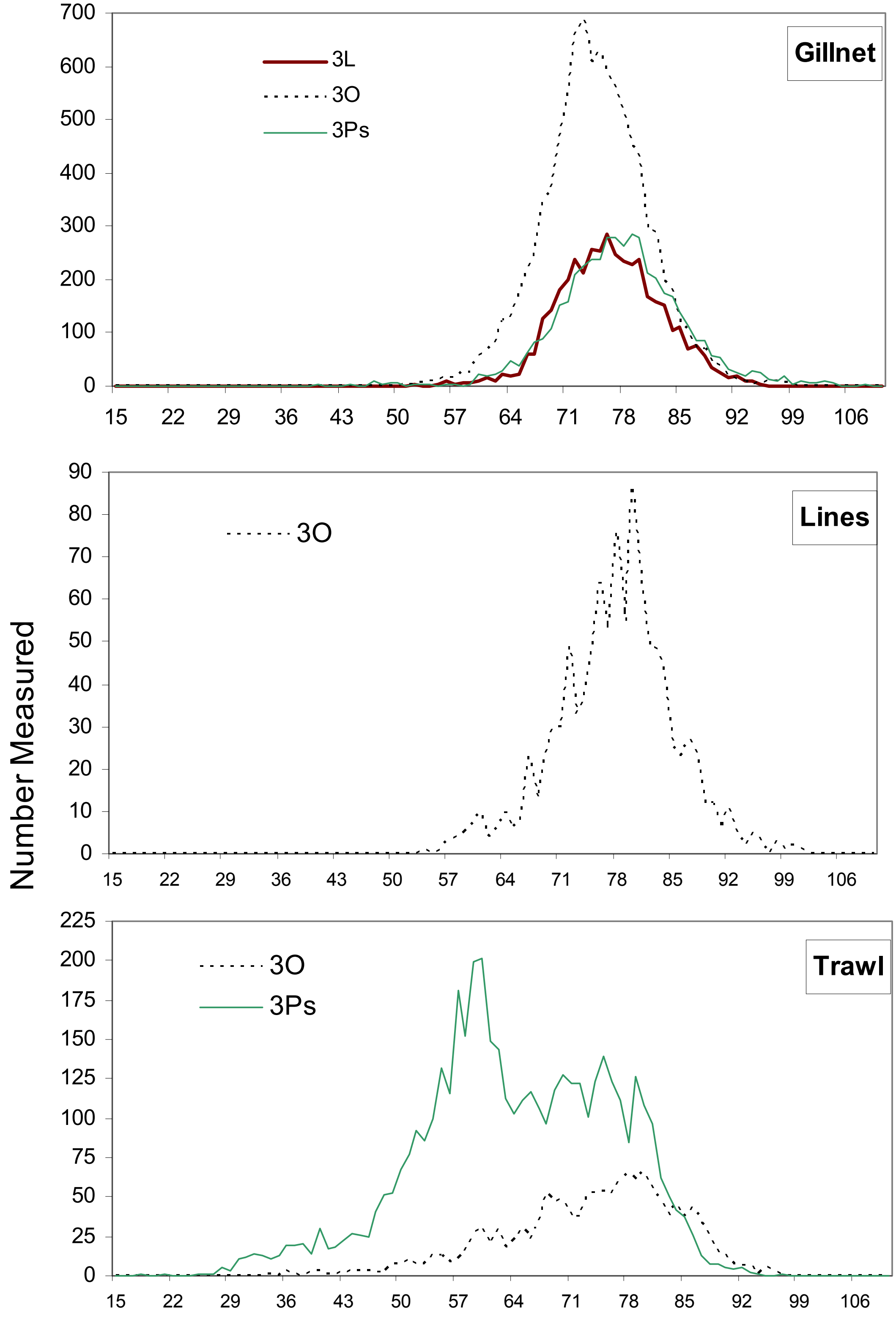


Figure 21. Length frequencies of commercial skate catches in NAFO Divisions 3LOPs for Canada. Data are from Canadian Fishery Observers, 1994-2002.

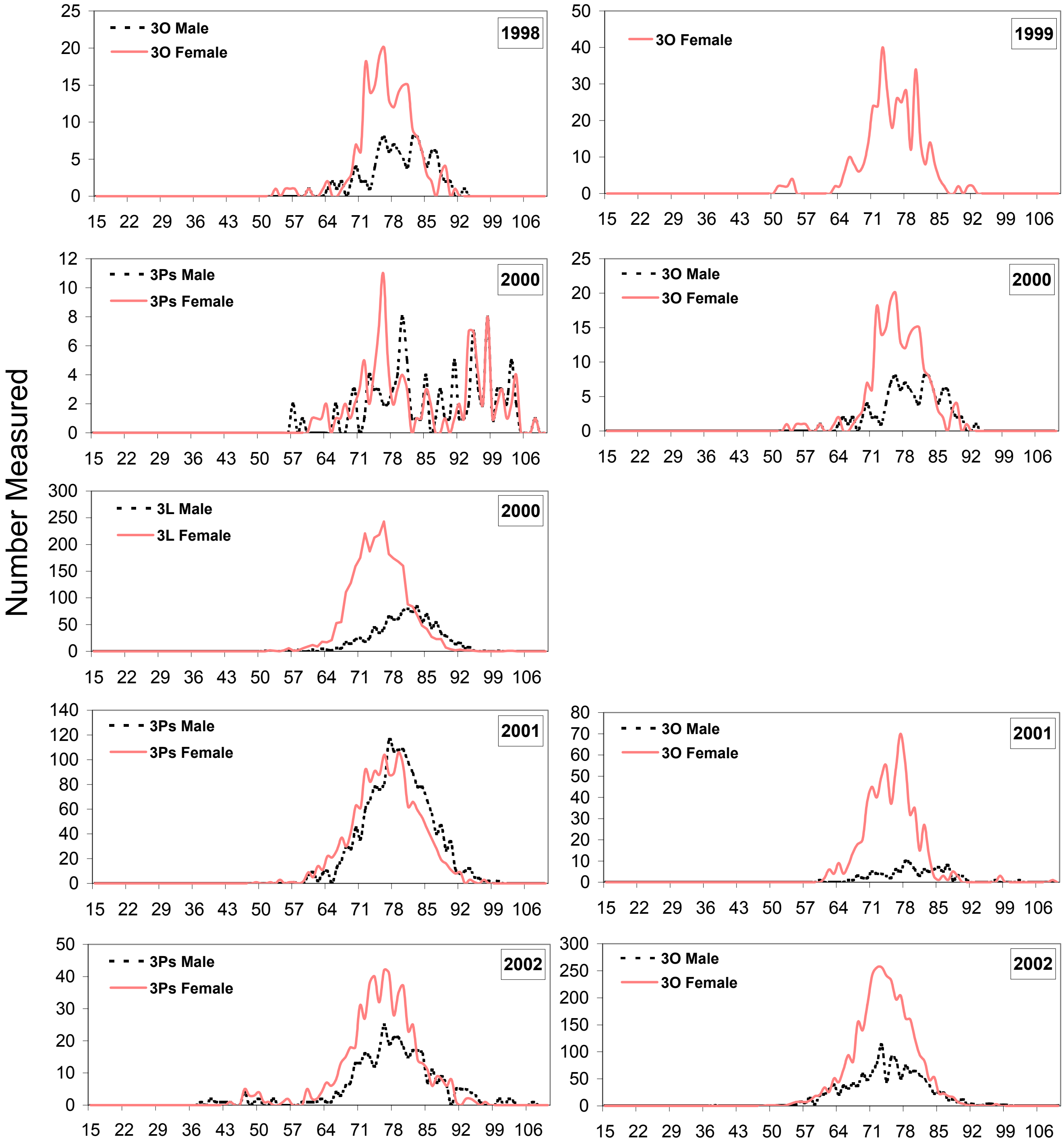


Figure 22a. Length frequencies of commercial skate catches for gillnets in NAFO Divisions 3LOPs, 1998-2002. X-axis represents lengths of skate in centimeters. Data are from Canadian Fishery Observers.

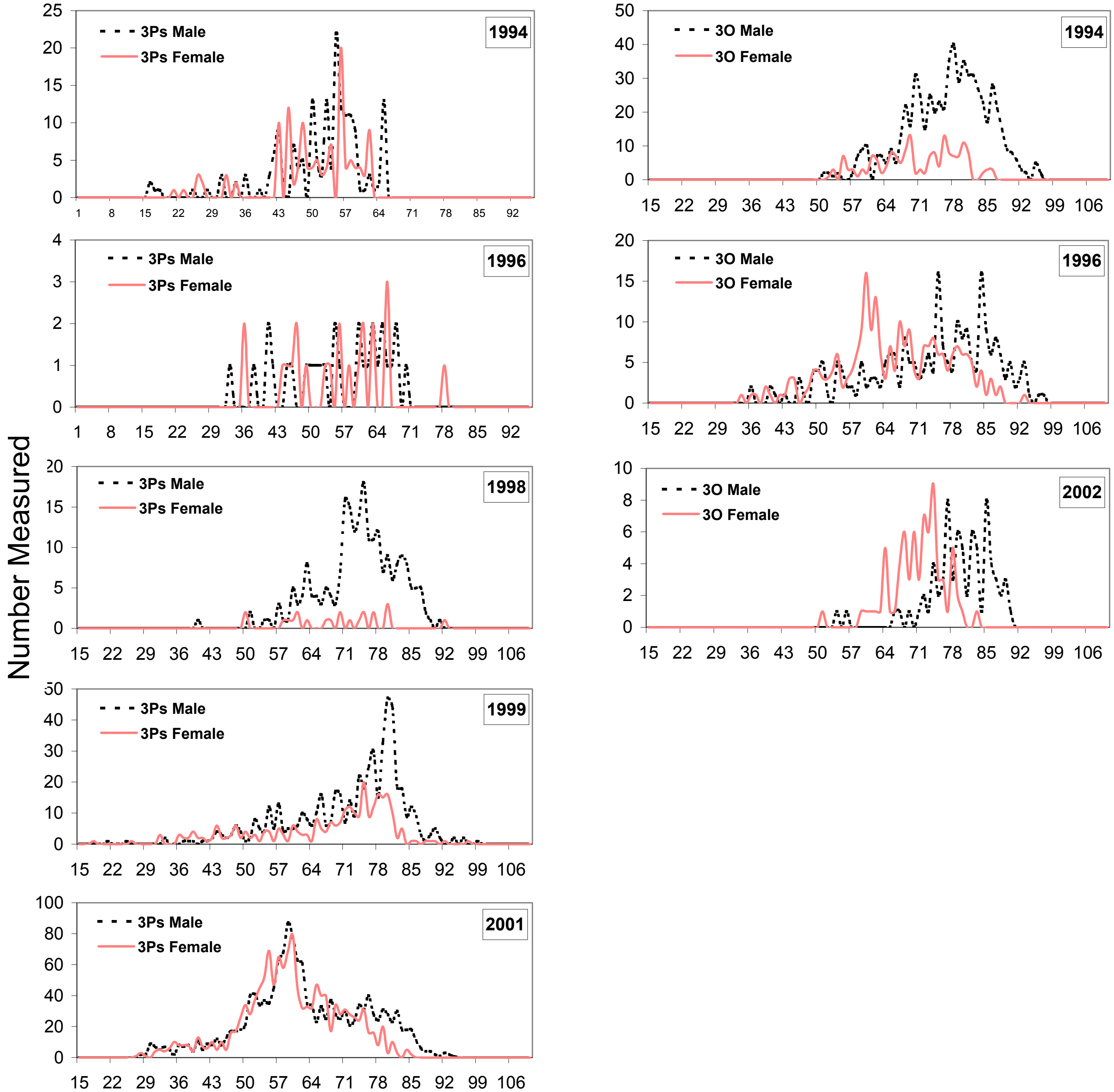


Figure 22b. Length frequencies of commercial skate catches for trawls in NAFO Divisions 3OPs, 1994-2002. X-axis represents lengths of skate in centimeters. Data are from Canadian Fishery Observers.

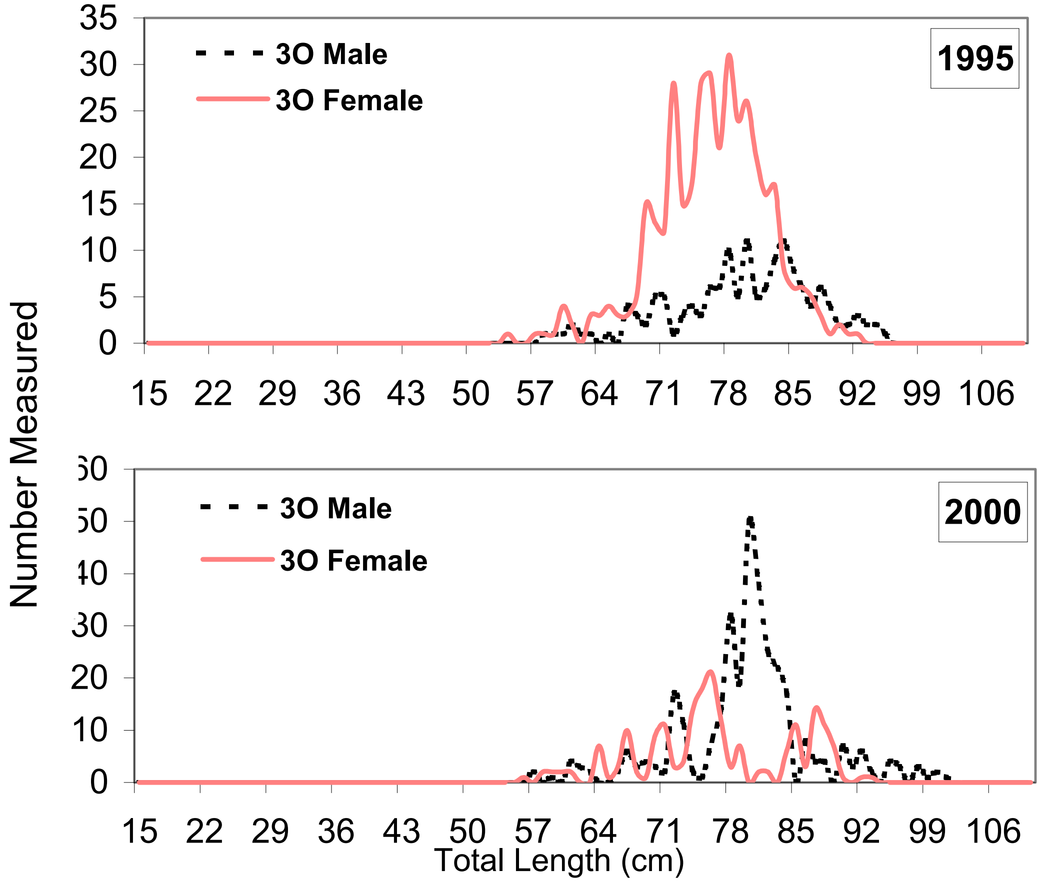


Figure 22c. Length frequencies of commercial skate catches for lines in NAFO Division 3O, 1995 and 2000. X-axis represents lengths of skate in centimeters. Data are from Canadian Fishery Observers.

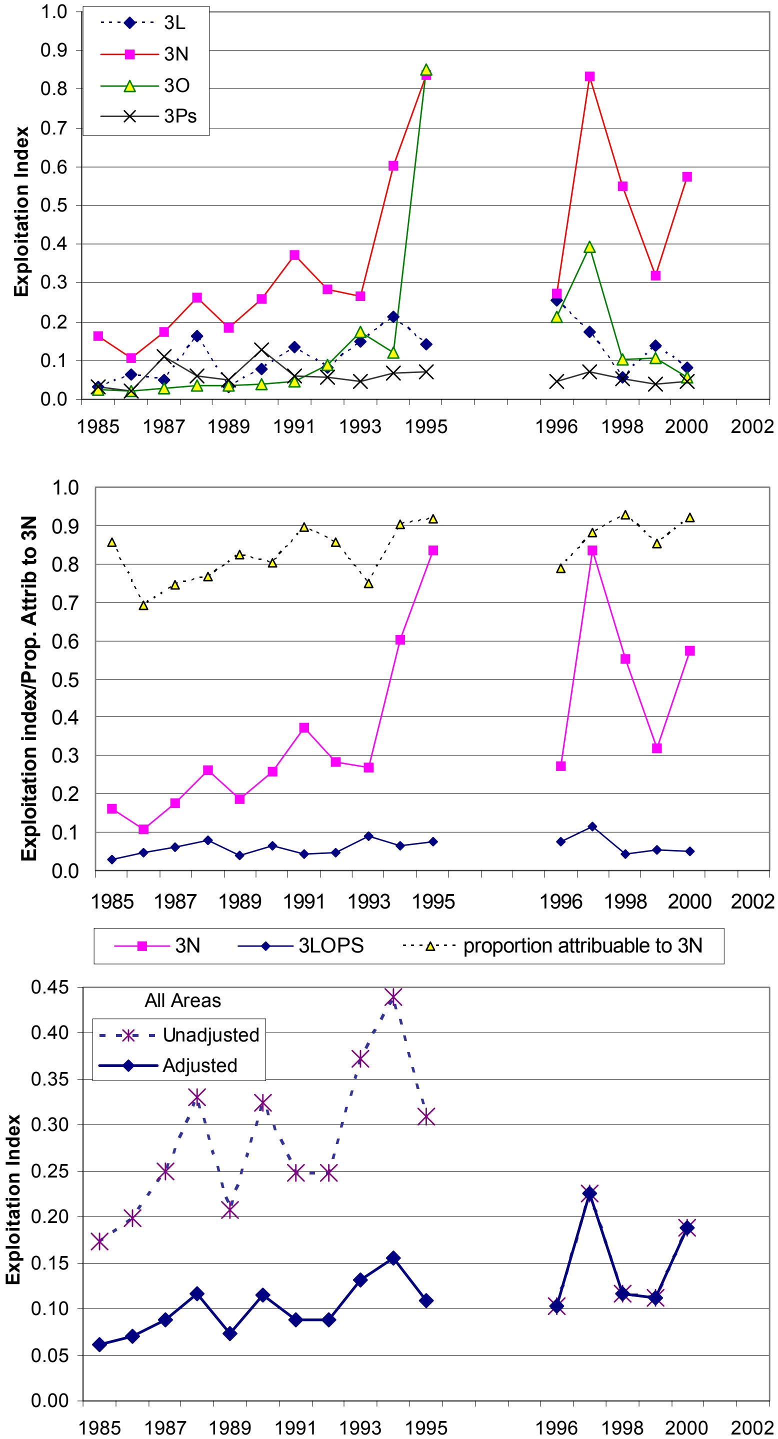


Figure 23. Exploitation Index (total estimated catch/spring survey biomass index) for skate in NAFO Divisions 3LNO and Subdivision 3Ps, 1985-2002.

Upper Panel: by NAFO Division; spring survey biomass indices converted to Campelen equivalents.

Middle Panel: Exploitation Index outside 200 miles in NAFO Division 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.