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Thorny skate (*Amblyraja radiata* Donovan, 1808) on the Grand Banks of Newfoundland

by

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Abstract

This evaluation of thorny skate (*Amblyraja radiata)* represents the fifth assessment of this relatively new fishery, first prosecuted in 1994. The stock biomass indices, following a decline to their lowest historic level in the early-1990s have stabilized since the mid-1990s. However, a change in research survey gear (in the fall of 1995) with different catch characteristics has created a discontinuity in the survey time series, preventing a comparison between two periods. 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 (1990-2003), fall survey estimates of biomass for the comparable area (NAFO Divisions 3LNO) were 41% higher. 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. There is a linear relationship between female spawning stock and young of the year, demonstrating a stock-recruitment relationship. Production modeling suggest that a harvest exceeding 12 000 t is not sustainable. Since the mid-1980s, Spain, Portugal, and Russia have prosecuted a directed fishery for skate (*Raja* sp.) outside Canada's 200-mile-limit on the Tail of the Grand Banks. However, Canada only established a limited directed fishery for skate on the southwestern Grand Banks and southern St. Pierre Bank after the decline of traditionally exploited groundfish resources. Prior to 1993, skates in Canadian waters were taken only as by-catch, most of which were discarded. Reported catches of all countries combined have averaged 15 377 tons (7 651-23 420 tons, as agreed by Scientific Council) since 1985. In 2003, the (preliminary) reported catch was 17 394 tons (3 502 toons for Canada, including discards, 13 416 tons as the STACFIS estimate in Div. 3LNO). A comparison of skate distribution from research survey data with commercial grounds indicates that the Canadian fleet fishes about one third of the area where skate are greatly aggregated in the spring, primarily along the shelf edge where skate are largest. Non-Canadian fleets fish a separate area on the Tail of the Grand Banks (outside 200 miles) in the fall, catching smaller skates.

Introduction

Thorny skate (*Amblyraja radiata* Donovan, 1808, Family Rajidae) is a boreal/arctic species in the north Atlantic. In the eastern Atlantic, they are distributed from western Greenland, around Iceland to the Barents Sea, including the English Channel, the North Sea, the western Baltic, and as far south as Cape Town, off of South Africa (Froese and

Pauly, 2003) and there are referred to as starry ray. Details of its distribution in the North Sea have been reported by Shreman and Parin (1994).

In the western Atlantic, thorny skate are 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; Kulka and Miri, 2003). There, thorny skate comprise about 90% of the Rajids caught in research survey trawls. Historically more widespread on the Grand Banks (Fig. 1), thorny skate presently reach their greatest density on the shallower southwestern bank and shelf break, and into the Laurentian Channel in late fall and winter, and along outer reaches of the banks in spring and summer.

Thorny skate have undergone a decline over their entire western Atlantic range. In the Gulf of Maine, thorny was one of 4 skate species regarded as overfished (SAW 30, 20xx, SAFE 2001) On the Scotian Shelf, Simon et *al*. (2003) reported a decline in the survey indices for winter (*Leucoraja ocellata*) and for thorny skate taken there in a mixed skate fishery. On the Grand Banks, Kulka and Miri (2003) indicated that thorny skate have had a low but stable abundance since the early-1990s, having undergone a substantial decline in the late-1970s to late-1980s. Thorny skate was observed to have declined to a greater degree in the northern extent of its range. Ratz and Stransky (2002) noted a reduction in by-catch levels of thorny skate in several fisheries west of Greenland, with the degree of decline in survey indices similar to what was observed on the Grand Banks.

Catches of this species are unregulated in the NRA (Northwest Atlantic Fisheries Organization Regulatory Area) and it is there that the largest catches have been taken across the entire range. A 3 000 tons quota, in place within Canadian waters since 1997, is allocated between NAFO Div. 3NO and Subdiv. 3Ps (Fig. 1), resulting in relatively stable removals inside Canadian waters.

Review of the Biology

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 on the Grand Banks forming fairly dense, continuous concentrations on the southern Grand Banks and outer St. Pierre Bank (NAFO Div. 3N, O and Subdiv. 3Ps) and historically, on the northern Grand Banks (Div. 3L) and northeast Newfoundland Shelf. Kulka and Mowbray (MS 1998, 1999) indicated that thorny skate on the Grand Banks (3LNOPs) undergo a seasonal migration, concentrating toward the Bank edge from December to June, and onto the Bank in the remaining months. This migration is synchronous over the entire area. However, in recent years, thorny skate on the northern section of the Banks (Div. 3L) and northeast Newfoundland Shelf have become increasingly separated from those on the south as the upper middle part of the Bank has become increasingly devoid of skate.

Within the managed area of the Grand Banks, NAFO Div. 3L, 3N, 3O, and Subdiv. 3Ps, similar size distribution, a continuous distribution, a synchronous migration and lack of physical barriers suggest that they constitute a single reproductive entity concentrating on the shallow section of the Grand Banks and extending from the Tail of the Banks outside of Canada's 200-mile-limit to the southern edge of St. Pierre Bank (NAFO Subdiv. 3Ps) (Kulka and Miri, 2003). As well, morphometric work carried out by Templeman (1984b, 1987a) provides no evidence of variation across the Grand Banks. Thus, thorny skate in 3LNOPs have treated as a management unit for the purpose of Canadian assessments since 1994, although separate allocations are on place for Div. 3LNO and Subdiv. 3Ps to allow access to different fleets.

Age and growth and certain life table parameters, and the effect of fishing mortality on the population of thorny skate have not been studied in any detail, although these are important for understanding population dynamics. However, other skate species have been aged with otoliths for winter skate (*L. ocellata*) on the Scotian Shelf (Simon and Frank, MS 1996), vertebrae (Correia *et al.*, 1997) for Northeast Atlantic species and with thorns (Gallagher and Nolan, 1999) for various Northeast Atlantic Rajids.

Some aspects of thorny skate biology have been examined on parts of the Grand Banks outside Canada's 200-mile-limit, and on the Flemish Cap. Del Río and Junquera (MS 2000) examined catch rates, length composition, sexual maturity, sex ratios, discards, and by-catch of thorny skate taken in Spanish commercial catches on the Tail of the

Grand Banks (NAFO Div. 3N). Del Río and Junquera (MS 2001) and del Rio (MS 2002) studied reproductive aspects in the same area. Vinnichenko *et al*. (MS 2002) also investigated size, maturity, food and feeding, based on by-catch in the Russian skate fishery on the Nose of the Grand Banks. Skates examined in those studies are likely from the same stock that is the focus of this paper.

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

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 appears to occur 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 (usually) held 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. However, upon hatching, young skates are fully developed and it seems likely that survival is much higher than eggs released by teleosts.

In NAFO Div. 3N (southeast Grand Bank), del Rio (2002) examined thorny skate females for presence of egg capsules in the oviduct, numbers and sizes of eggs in the ovary, and variations in shell gland width. His results confirmed the low reproductive potential of northwest Atlantic thorny skate. Both number and size of oocytes developing in the ovaries increased in maturing fish. In fully mature skates, number of eggs in the ovaries was 40-45, and egg diameter was approximately 12 mm. The majority of adult females from August to December had mature ovaries, but active uterine stages were almost absent. In contrast, most males were mature during that time. Del Rio suggested that thorny skate concentrations in shallow waters of the Shelf during August to December could be mating aggregations. This observation supports the seasonal migration pattern observed by Kulka and Mowbray (MS 1998), who indicated that thorny skate were concentrated on shallow sections of the Shelf from July to November, but otherwise remained along the Shelf edge.

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

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

The Fishery

The thorny skate stock management area for Canada encompasses the Grand Banks (NAFO Div. 3L, 3N, 3O, and Subdiv. 3Ps) (Fig. 1). Thorny skates are also distributed in other areas in significant densities particularly on the northeast Newfoundland Shelf (NAFO Div. 3K) where there is also a limited fishery for thorny skate. 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 non-Canadian fleets since the mid-1980s and Canadian vessels since 1994. The request for advice by FC of NAFO is for a portion of this area, namely NAFO Div. 3LNO, comprising the Grand Bank.

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

Although often kept by non-Canadian fleets, skates were taken only as by-catch until the mid-1980s. In 1985, Spain began targeting skate in a non-regulated fishery outside Canada’s 200-mile-limit on the Tail of the Grand Banks (Junquera and Paz, MS 1998; del Río and Junquera, MS 2000, 2001), where it was found in sufficient concentrations in the fall at depths less than 100 m. Reported catches increased substantially in that year. By-catches of thorny skate in other fisheries outside 200 miles (primarily Greenland halibut, *Reinhardtius hippoglossoides*) have also contributed significantly to skate catches reported to NAFO (Northwest Atlantic Fisheries Organization) by non-Canadian countries.

Catch history presented by Kulka and Miri (MS 2003) indicated that the Spanish skate fishery occurred almost entirely (98.7%) on the Tail of the Grand Banks in NAFO Div. 3N using otter trawl gear (mesh size unknown). Since July 2002, the minimum mesh size as regulated by NAFO is 280 mm for skate-directed fishing in the NRA: outside Canada’s 200-mile-limit. Kulka and Mowbray (1998.) 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 tons in 2004), skate fishery in the NRA is unregulated.

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 about 50-51 cm for males and 46-47 cm for females in 2000-2003 (Kulka and Miri, 2003). Skates of 42-49 cm TL dominated these catches. Del Rio and Junquera (MS 2001) suggested that skate fisheries in August-November are targeting spawning concentrations.

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

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

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

Purpose

Thorny skate has not previously been formally assessed at Northwest Atlantic Fisheries Organization (NAFO) Scientific Council, although specific questions posed by the Fisheries Commission (FC) of NAFO were first addressed in 2003. However, this species has been assessed within Canada since 1994. This paper constitutes the fifth time that the status of this stock has been evaluated. The purpose of this paper is to examine the possibility of formulating reference points and providing advice for thorny skate on the Grand Banks. Specifically, FC requested "The Fisheries Commission with the concurrence of the Coastal State requests Scientific Council, at a meeting in advance of the 2004 Annual Meeting, to "**provide advice on the scientific basis for the management of skates in Div. 3LNO including recommendations regarding the most appropriate TAC for 2005 and 2006**".

The challenges for this assessment in determining an appropriate level of exploitation for the current level of biomass/abundance are four-fold: a) thorny skate are data poor, lacking knowledge of demographics, in particular, age dis-aggregated information and; b) there is a great deal of uncertainty with respect to fishery-related mortality of thorny skate from the NRA; the Canadian survey trawl series used to monitor abundance and biomass changed in 1995 resulting in two uncalibrated series; and d) there are uncertainties about the population structure of thorny skate on the Grand Banks. Recent work on maturities (del Rio and Junquera, 2001; del Rio *et al.*, MS 2002) has allowed for a stage based analysis, specifically an analysis of stock recruit relationships that is elaborated in this paper. Consideration is given to ways to standardize the survey trends and to examine the relationship of those trends to catch in a production model (ASPIC Prager *et al.*, 1994). The aim is to define LRPs (Limit Reference Points) for thorny skate.

This paper also updates biological and fishery data to 2003. Particular attention is focused on NAFO Div. 3LNO, in response to the FC request. Similar to previous assessments of this stock (Atkinson, MS 1995; Kulka *et al.*, MS 1996; Kulka and Mowbray, MS 1998; Kulka and Miri, 2003), an age dis-aggregated analytical analysis for estimating stock size was not conducted for three reasons: 1) data from research vessel surveys do not contain ages of thorny skate, although lengths are recorded; 2) biological sampling of commercial catches continues to be inadequate for VPA (Virtual Population Analysis) or most other traditional stock assessment methodologies; and 3) landings for this species appear to be consistently under-reported, especially prior to 1994. However, since 1998, available data on thorny skate have been enhanced (for example, maturity studies by del Rio, 2002; more commercial information on skate catch sizes from Canadian Fishery Observers), and more comprehensive stage dis-aggregated analyses have been applied in this paper to the existing data.

Methods

Research vessel survey data

Data on thorny skate have routinely been collected during Department of Fisheries and Oceans Canada (DFO) research surveys in NAFO Div. 3LNO and Subdiv. 3Ps during the spring and in NAFO Div. 2J+3KLNO in the fall. Doubleday (1981) summarizes the stratified random design adopted by DFO - Newfoundland region after 1970 for spring surveys, and after 1976 for fall surveys. Spring surveys of NAFO Div. 3LNO commenced in 1971 with the inclusion of Subdiv. 3Ps (comprising St. Pierre Bank) since 1972. Fall surveys of NAFO Div. 3L began in 1981, and then commenced for Div. 3NO in 1990 Subdiv. 3Ps is not surveyed in the fall. While stratified 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. Both surveys use the same random stratified sampling protocol and the same gear logistics. A summary of early modifications can be found 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) and by McCallum and Walsh (1996). The latter paper provides some technical details of the Engels time series. For the Campelen series, Table 1 describes the logistical details of the spring and fall survey. These are the same surveys that are used to assess a host of other commercial species.

Survey series from NAFO Div. 3LNO and Subdiv. 3Ps were used to estimate biomass and abundance, and examine trends in average size (biomass/abundance) of thorny skate in spring 1971-2002 and fall 1981-2002. Not all areas were surveyed every year for both time series; the missing data are denoted by blank cells on biomass and abundance tables. The total area surveyed in 1996-2002 was 294 589 km^2 in 1994-96 was 283 321 km^2 and in 1986-93 was 255 542 km^2.

STRAP2 is a routine that calculates areal expansion of survey tracks to the total area within a series of predefined strata related in part to depth (Smith and Somerton, 1981). These strata estimates are 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 calculated as the sum of the strata estimates for each length group over the research vessel survey area. Due to the absence of length-weight data from DFO stratified random surveys in NAFO Div. 3LNOPs, sexed length-weight relationships of thorny skate generated by del Rio *et al*. (2002 from Spanish spring trawl surveys in 2001 for Div. 3NO) were utilized in STRAP1 calculations. These calculations assumed that weight at length remained constant throughout the entire survey period.

The fall series does not include data from Subdiv. 3Ps for any year, or from Div. 3N and 3O before 1990. Thus, they are not comparable to spring results which extend over the entire area and time period except for certain Divisions and years. 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 the fall, skates are concentrated on the shelf, whereas in the spring, part of the population has moved to the shelf edge, and a proportion apparently moves outside of the spring survey area (see discussion on migration below). As well, the spring survey reaches shallower depths (~750 m) than in the fall (~1 400 m in recent years) (Table 1). 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.

Size and age based conversion factors for amounts and sizes of fish caught in the survey sets 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, in terms of catchability of different sizes of fish. For many fish species, the Campelen trawl tends to catch a larger proportion of smaller fish when compared to Engels gear (Walsh, 1995). However, a comparison of skate frequency data before and after this gear change suggests that size composition of the two gears is very similar. Selectivity of the two trawl survey gears may not be significantly different. Thus, a simple weight based conversion applied against the entire catch may provide an appropriate conversion factor for the two survey gears.

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 entire period of the surveys. Where the time series has not been standardized to Campelen units, the change in gear is temporally delineated on various tables by a dashed line or space, and on figures by a vertical bar.

Changes in the proportion of three life stages of thorny skate were examined in this study: young of the year (YOY); immature; and mature individuals referred to as Spawning Stock Biomass (SSB). Research survey length frequency numbers at length were partitioned into recently hatched, immature and mature components The ogives of del Rio (2001) for 1997, 1999, and 2000 were used to estimate the proportion of mature males and females in Canadian spring survey catches, in order to derive an index of spawning stock biomass (SSB). The year 2000 ogive was applied to surveys in 2000-2002 the year 1999 ogive to 1998 and 1999 and the year 1997 ogive was applied to 1997, and all years earlier. If size at maturity varied in years prior to 1997, then the spawning stock index could be over or under-estimated for those years. Information from Templeman (1987b) suggests that this may be the case although the bias is not large. The remaining thorny skates were defined as immature, excluding the smallest mode, the young of the year (YOY) as described in the following section. Information on hatch size of thorny skate reported by Berestovskii (1994) was used to delineate YOY. The smallest mode ranging from 9-22 cm TL and averaging 15.5 cm was observed every year, spring and fall. Berestovskii (1994) determined that size at hatching from the egg case for thorny skate in the Barents Sea was approximately 10.4-11.4 cm. This hatching size compared closely to the starting size of the smallest. This mode was used to derive a recruitment index.

SPANS GIS (Anon., 2003) was used to investigate spatial distribution of thorny skate with research vessel survey data. Details of the potential mapping technique used to convert point data (catch weight and numbers for each survey set) to surfaces depicting distribution is described in Kulka (1998). The DFO survey trawl gear change (noted above) resulted in the scale of maps representing a different catch rate after fall 1995. In addition, extra sets that were not part of standard surveys have been added to some strata in 1985-1994 for a diurnal study in Div. 3LNO. Although these diurnal sets are a deviation from the proportional allocation of sets, they use the same sampling protocol as standard survey sets, and are included in the present mapping of thorny skate distributions. They provide for a greater sampling density without violating any statistical principles.

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 (1980-2003). All legends were devised using fifteen density strata. To smooth the surface transition from one density stratum to another, a linear decay function was applied to this potential mapping thereby giving points on the periphery of scanning circles less weight in the averaging function.

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

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

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

The Fisheries

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

Canadian landings were compiled using Canadian statistical records in the ZIF database available since 1985. Discards from Canadian fisheries were calculated by applying the proportion of skate catch to groundfish landings (kept fish, all species) in the Fishery Observer database to the reported groundfish landings in Canadian statistical files. In addition, skate catches (kept fish plus discards) of non-Canadian vessels in Canadian waters were extracted from Fishery Observer records. Canadian Fishery Observers have covered 100% of non-Canadian fishing effort since the inception of the Canadian Observer Program in 1978, and approximately 8% of Canadian effort since the skate-directed fishery began in 1994. Observers collected set-by-set information on catches, employing methods described in Kulka and Firth (1987; periodically updated in unpublished versions as the Fisheries Observer Program Training Manual (Science) – Newfoundland Region). Total lengths of thorny skate in commercial catches from various gears were measured only sporadically since 1994 with most of the sampling done in 2000-2003. 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 1999-2003 were used to examine spatial distribution of fishing grounds by gear type. The fishery along the southwest slope of the Grand Banks is a mixed fishery for monkfish (American angler, *Lophius americanus*), white hake (*Urophycis tenuis*), Atlantic halibut (*Hippoglossus hippoglossus*), and thorny skate. Thus, data used to map the fishing grounds included sets that were designated as directed for all of these 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 1999-2003. 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.
Information on sizes of skate in the catches come from different sources, mainly from National Research Reports for non-Canadian countries (usually based on data from scientific observers) and from Canadian observers for Canadian catches (Table 2).

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

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

Limit Reference Points

Several options were explored in producing Limit Reference Points from staged survey data and commercial catch information. Such analyses for this species are constrained by the lack of age-disaggregated data. However, data from the catch (relatively reliable from the mid-1980s following the start of the directed fishery, less reliable in the 1970s) and survey biomass (from the early-1970s) provide information that can be examined in the context of a production model. As well, stage based analyses, namely recruitment in relation to the spawning stock component were examined (see section on stages above for details).

To explore the feasibility of using a surplus production model for this stock, catch and biomass history were modeled using ASPIC (Prager, 1994). ASPIC provides estimates under a non-equilibrium Schaefer model. Data comprised series of catch and relative biomass from spring surveys, 1971-2003. Six different runs comprising different time periods and using the Engel and Campelen data as separate and combined (Engel converted to Campelen units) series were used to explore options in producing Limit Reference Points (LRPs) and projections using various levels of catch.

Results

Trends

Spring and fall research survey biomass and abundance indices derived using STRAP2 (non-length based areal expansion) are presented in Table 3 and Fig. 2 (spring and fall biomass and abundance for Engel and Campelen time series, by NAFO Division). A comparison of spring and fall biomass estimates (a ratio of estimates in NAFO Div. 3LNO, the only three Divisions surveyed during both seasons) indicates that fall estimates are consistently higher (Fig. 3). Both seasons were surveyed consistently since 1990. However, limited data in Div. 3L suggests that, prior to 1990, the fall/spring ratio may have been lower. From 1990-1995, this ratio increased from approximately 50% to 80-90%, concurrent with the period of decline. The ratio declined to about 40% by the late-1990s, and has since remained relatively stable.

With the change in survey trawls to Campelen in fall 1995, most teleost species captured by that gear were observed to have a smaller average size compared to those caught by Engel gear. Thus, a size based Engel to Campelen conversion is required to standardize the two series for those species. However for thorny skate, comparing the last year when Engel gear was used to the first year of Campelen usage, average weight (biomass/abundance) is very similar over all Divisions (Fig. 4). 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 Engel, and 2.4 times more skates than the latter trawl.

To confirm that the size composition captured in the two survey gears was similar, proportion of three stages, young of the year (YOY), immature and mature fish by sex was examined over time. If there was size selection differences between the two gears, one would expect a greater proportion of the YOY and immature fish in the Campelen gear. This analysis showed no change in the proportion of the three stages between the periods when the different survey gears were used (Fig. 5).

Thus a weight based conversion factor was derived using the ratio of the average of the first two years of Campelen biomass and abundance to the last two years of Engel biomass and abundance. This yielded a conversion factor of

2.8 for biomass and 2.4 for abundance. As well, data (weights and numbers) from the comparative survey was examined corroborated these results. Average weight of skates from the Campelen sets were 2.4 times higher than for the Engel sets and count was 2.2 times higher. A conversion factor of 2.8 was applied to the Engel biomass estimates and 2.4 was applied to the Engel abundance estimates to standardize the two series. Henceforth, this paper presents standardized (converted) estimates of biomass and abundance.

The spring index of biomass (Fig. 6a, upper panel) indicates that the trends in relative biomass in NAFO Div. 3LNO were very similar to the 3LNOPs trend. The 1971 estimate is missing data from NAFO Div. 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 are likely anomalously high. Only Subdiv. 3Ps was surveyed in 1983, and some other areas were only partially surveyed resulting in an artificially low estimate in that year.

Given the missed survey areas and the anomalous year, the biomass index increased from 1971-1985, before declining rapidly to its lowest level in 1993-1995. Relative biomass in 1993-1995 was $1/5^{thy}$ of that observed in the early-1970s. Most of this decline occurred in Div. 3L on the northern part of the Grand Banks, and to a lesser extent in Div. 3O. Biomass in Div. 3O and Subdiv. 3Ps appeared to fluctuate without pattern, possibly 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 (see discussion on distributional changes). The index increased moderately between 1996 and 1999, but has since been flat or slightly increasing. Biomass in 2003 is only slightly higher than in 1993-1995, when it was at its lowest.

The relative spring abundance trends mirrored the biomass indices, both spatially and temporally (Fig. 6a, lower panel). The index increased between the early-1970s and mid-1980s, then declined rapidly in 1990-1995 mostly in Div. 3L and 3O. Skate abundance increased from 1996-1999, then declined afterwards. These changes appear to be relatively small. Most of the thorny skate were found in Div. 3N, 3O, and Subdivision 3Ps, approximately 60% in the 1970s, and 90% following its decline in the early-1990s. A scaled comparison of the Canadian Campelen survey trend from 1995-2003 in NAFO Div. 3NO to the Spanish survey for the same period and area is very similar (Fig. 6b).

For comparable years and areas (1981-2003 in NAFO Div. 3L, 1990 in NAFO Div. 3LNO), spring and fall survey estimates of biomass showed similar trends. However, fall estimates were more variable, and consistently higher within each NAFO Division. The decline observed in the spring series during the early-1990s also appeared in the fall series. After 1995, the fall index fluctuated without pattern but 85-90% of the skate biomass in Div. 3LNO was found in 3NO.

The trend in proportion of biomass between the northern part of the Grand Banks and the southern portion (the NAFO Div. 3LN in the northeast vs. 3NOPs in the southwest) is illustrated in Fig. 7 (Upper panel). Division of the Grand Banks in this manner clearly illustrates that the biomass and abundance in the southwest was fluctuating but stable over the entire time series whereas thorny skate biomass in the northeast declined by nearly 95% between the 1970s and the mid-1990s. Biomass has increased slightly since. Abundance in the two areas showed similar trends although the degree of decline was not as great (Fig. 7, middle panel). The ratio of 3LN/3LNOPs biomass and abundance was stable during the 1970s but then declined steadily during the 1980s to the late-1990s, stable since (Fig. 7, Lower panel).

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

Since 1995, this decline in mean weight of skates in research survey catches has reversed. From 1995 (fall) or 1996 (spring) to 2003, the trend in average size has consistently increased in all Divisions (Table 2 and Fig. 4). 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 annual weight was in Div. 3N in 2003 at close to 2 kg, only slightly below what was observed in the 1970s. During the period of decline in size, the largest (mature) skates were found on the southwestern Grand Banks and southern St. Pierre Bank (Div. 3O and Subdiv. 3Ps). At other times, mean weight was generally similar among all areas.

Size

Length composition of thorny skate in research surveys by year (1986-2003) and by NAFO Division is presented in Figure 9a (spring) and Figure 9b (fall). By Division, the shapes of frequencies were generally similar between spring and fall. A large range of lengths were present (11-101 cm TL), and this range varied slightly from year to year. There was some inter-annual variation in the mix of sizes. In addition, observed peaks usually matched among areas within a given year suggesting similar size compositions between Divisions. For most areas and years, a peak of smallest skates was between 10-20 cm, and averaged 15 cm. The next largest peak of (immature) skates occurred between 20-30 cm; sometimes merging with the 10-20 cm mode. The 20-30 cm mode was much reduced after the mid-1990s. A peak of large (mature) skates of approximately 65-83 cm is apparent, particularly from 1986-1989. This peak re-appeared during 1997-1999 especially in the fall. Until 1990, large skates were also found on the northern part of the Grand Banks (Div. 3L).In Div. 3L, these large fish are nearly absent in 1992-94 then increased in number after 1994 in the fall, and after 1998 in the spring.

Skate taken in the surveys on the northern Grand Banks (NAFO Div. 3L), the mode of young skates averaging about 25 cm (ranging from 10-35 cm, probably year-class 1 fish) dominated both spring and fall survey catches until 1994 or 1995 (Fig. 9). This suggests that recruitment was occurring there on a yearly basis, or that young skates were consistently moving into that area. Since 1995, these young skates have been largely absent or low in number in 3L. That small mode was apparent in 2001-2003 (fall), but it appears that recruitment in this area has remained low following the decline in biomass there. For the southern Grand Banks (Div. 3N and 3O), this mode of young fish was also small or largely absent after 1995 in spring and fall. However, a mode of 10-35 cm skates was present since 1996 although narrower in range (10-20 cm). This suggests that, after 1995, recruitment (presence of substantial numbers of small fish) occurred mostly on the St. Pierre Bank (Subdiv. 3Ps).

Stages

Abundance and biomass was also calculated using STRAP1, a size based calculation of biomass and abundance. Numbers of thorny skate at length were partitioned into young of the year (YOY), immature and mature (SSB) components (Fig. 10). Partitioning thorny skate life stages was based on results of other maturity studies (see Methods). These partitioned frequencies were then used to examine trends in young of the year (YOY) and mature (SSB) components of the thorny skate population.

Figure 11 compares the estimates of biomass produced by STRAP1 and STRAP2 indicating close agreement between the two particularly in later years. Greater differences between estimates prior to 1990 may be a result of changes in average weight at length. Average length of the three size components tended to be fairly consistent over time, 1980-2003 (Fig. 12). YOY (both males and females) showed little variation (15-17 cm). Immature Male varied around 30 cm until 1997 then increased to 37 cm while immature females fluctuated around 35 cm reaching a low of 31 cm in 1993. Size of mature males fluctuated between 60 and 68 cm without trend but mature females decreased from ~ 71 cm to 67-68 cm after 1997.
The ratio of males to females in the sampled population over time has been relatively consistent, with some fluctuations over time for the three population components (Fig. 13). YOY averaged close to 1 (1:1 males to females) while the ratio of immature males to females was lower averaging about 0.75 and SSB averaged 1.5. Why there are proportionately fewer immature males in the sampled population than mature males and YOY males is

unclear. This pattern suggests changes in the catchability perhaps due to differential migration in and out of the sampled area.

Abundance of thorny skate stage and sex underwent similar changes over time (Fig. 14a, upper panels). The indices for each stage increased between the early-1970s and mid-1980s, then declined rapidly in 1990-1995.All three stages have been stable at al low level since the mid-1990s. During the period of decline (late-1980s to mid-1990s) the proportion of mature fish in the population declined while the immature component increased (Fig. 14a lower panels, Fig 14b, upper panel). This trend has reversed since the 1990s. While proportion of abundance was changing, proportion of biomass of each stage remained stable over the entire period.

The relationship between female spawning stock biomass (SSB) and recently hatched skate (YOY) is illustrated in Fig. 15. The upper panel shows that the ratio of YOY/SSB was low between 1980 and 1986, increased between 1989 and 1995 then declined, stabilizing at levels previously observed in the mid to early-1980s. This increase in YOY relative to SSB is concurrent with the period of decline of the stock. Figure 16 further illustrates that the female SSA (spawning stock abundance) and YOY followed a similar trend with and without YOY offset by one year plus suggesting a relationship between stock and recruitment. The average of the highest three years in the series was 24 444 tons, the lowest three years of female relative SSB averaged 6 906 tons and the last three years of female relative SSB averaged 13 121 tons.

Figure 17a (abundance) and b (biomass) shows that there is a linear relationship between female spawning stock and YOY. The relationship is slightly stronger for biomass offsetting YOY (+ 1 year) produced a slightly higher r^2. The estimate of SSB following the decline of the stock (post-1992) was less than 40 000 tons. SSB during years prior to the decline averaged about 80 000 tons.

Distribution

Within NAFO Div. 3LNO and Subdivision 3Ps, the distribution of thorny skate has undergone significant changes since the early-1980s (Fig. 18 spring, Fig. 19, fall). In 1980-1982, skates were widely distributed over the entire Grand Banks in moderate to high concentrations. Only a very small area along the western extent of Div. 3L (around the southern extent of the 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. 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 2001-2003. The greatest changes were observed on the northern Grand Banks by 2001-2003, where a large portion was devoid of skates and dense concentrations were largely absent. Remaining concentrations stretched from the Tail of the Banks onto St. Pierre Bank and along the edge of the Laurentian Channel.

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

Comparing Fig. 18 with Fig. 19 indicates that thorny skates were distributed differently in the spring than in the fall and these differences were consistent over the years. Differences were less pronounced in earlier years, when thorny skates were more widespread during spring and fall. In spring, skates were distributed deeper, with moderate to high concentrations forming a nearly continuous band along the periphery of the Banks (outer limits of the surveyed area). This concentration extended from the Nose and Tail of the Grand Banks, across the outer Haddock Channel, Green Bank, Halibut Channel, along the edge of the Laurentian Channel, and ending in the Hermitage Channel. The band of thorny skates was most dense and wider along the southwestern slope of the Grand Banks and up into the

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

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

Between 1980 and 2003, the proportion of the surveyed area containing no skates increased from about 3% in 1980-1988 to 25% in 2001-2003 (Fig. 20, left panels). At the same time, the biomass became increasingly more concentrated. During 1980-1988, about 57% of the biomass was located within 20% of the survey area and the concentrations of skate located over the southern Grand Banks (see Fig. 18 and 19). By 2001-2003, 83% of the biomass was concentrated into 20% of the surveyed area, primarily along the southwest slope of the Grand Bank. At the same time, the catch rate, both in terms of number and kg has increased where skates were concentrated within each year since 1992; more so within the area where skate concentrated in 2001-2003. This indicates that the skate are becoming progressively concentrated or hyper-aggregated within a small portion (20%) of the available area on the Grand Banks. Plotting relative biomass against percent of biomass in 20% of the area (x-axis) shows a trajectory sharply to the right on the x-axis starting in 1992 fallowing the decline in biomass (Fig. 21).

Various life stages of the thorny skate stock distribute in a different manner, and these population components have varied over time somewhat differently compared to the total population. Young of the year (YOY) were observed to distribute around the periphery of the Bank (Fig. 22a and c), and a similar distribution pattern was apparent in both spring and fall research surveys except that they were distributed more onto the Bank in the fall. The extent of this distribution (total area occupied by YOY) was similar over time. Area occupied by YOY in spring was 142 100 km^2 in 1980-1981, and 132 500 km^2 in 2001-2003. However, some of the occupied area had shifted from the north and east to the south and west. The greatest change in thorny skate distribution was observed in the reduction of area containing dense concentrations. In the 1980s and early-1990s, relatively dense concentrations of YOY were found along the entire periphery, the Laurentian Channel to the northern Grand Banks. In 2001-2003, although low numbers of YOY persisted over the entire periphery, dense concentrations of thorny skate were seen only in the western part of its stock area. Areas where YOY abundance was highest (exceeding 5.2 skates per tow) diminished from 5 960 km^2 in 1980-1981 to less than 1 700 km^2 in 2001-2003. The large majority of YOY abundance/biomass is now located in the most western part of the stock area along the Laurentian Channel in NAFO Subdiv. 3Ps. Refer also to Fig. 9 showing the near absence of a YOY mode in NAFO Div. 3LNO frequencies.

Mature thorny skates (males and females) were more widely distributed across the shelf, particularly in early years (Fig. 22b and d). In 1980-1981, mature thorny skates occupied most of the stock area, covering 320 350 km^2. By the mid-1990s, most mature skates (and immature fish) were absent from the northern part of the Bank except for small concentrations along the shelf edge (occupying 229 000 km^2, a 29% reduction in area occupied by the SSB).

The Fisheries

Thorny skate are caught in a wide variety of fisheries over an area extending well beyond the managed 3LNOPs stock area. Figure 23 illustrates skate catch per set from all commercial fishing activity observed in 1992-2003 (DFO-NL Region: Fisheries Observer Program). This period was subsequent to the collapse of some demersal fish stocks entailed a corresponding reduction in groundfish fishing effort, and increases in shrimp and crab fishing and occurred after non-Canadian fleets stopped fishing within Canada's 200-mile-limit. Thorny skate are taken as by-catch as far north as the Davis Strait. North of Lat. 52^o, skate catch rates were generally lower, but skates were reported as a relatively common by-catch as far north as Lat. 70^{o}N in NAFO Subarea 0A. Directed fisheries in this area were primarily targeting shrimp (*Pandalus* sp.), crab (*Chionocetes opilio*), and Greenland halibut. Shrimp trawls are equipped with Nordmore grates, which exclude larger fish thereby decreasing by-catch of larger skates.

Most by-catch in the Greenland halibut fishery is discarded, but survival rates of discarded fish are unknown. South of Lat. 52^{o}, higher skate catch rates were observed as far south as Lat. 48^{o}, on the northern section of the Grand Banks. Between Lat. 46^{o} and 48^{o}, a large area was not fished, or skate by-catch was low to nonexistent except along the shelf edge, where Greenland halibut is targeted. Highest skate catch rates occurred on the southern Grand Banks (in the vicinity of the Canadian directed fishery (compare Fig. 14 and 15 to Fig.20), and also on the northern part of St. Pierre Bank.

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

In terms of areas fished, skate catches in Canadian waters occurred primarily in NAFO Div. 3L and Subdiv. 3Ps prior to 1992 (as by-catch), but have shifted to 3O in addition to 3Ps in recent years after the non-Canadian (3O) and Canadian (3OPs) skate-directed fishery began in 1985 and 1994 respectively. Figure 24 (upper panel) shows that directed sets for skate occurred mainly along the shelf edge in 1999-2003 from the Laurentian Channel in NAFO Subdiv. 3Ps to Canada's 200-mile-limit in NAFO Div. 3N. Fishing effort distribution was similar among years, clustering in southern 3Ps, and in two locations in 3O. Most of the effort occurred in depths of 100-300 m for otter trawls and gillnets, and 50-150 m for longlines (Fig. 24, lower panel). However, catch rates (catch per set) tended to be similar across a wider range of depths: 50-800 m.

Locations of the Canadian gillnet (Fig. 25 upper panel), longline (middle panel), and otter trawl (lower panel) skate/monkfish/white hake/Atlantic halibut mixed fisheries in 2002-2003 were similar. The same areas were fished consistently between years and fishing patterns in 199-2001 are similar to 2002-2003. Fishing effort was concentrated on the southwest slope of the Grand Banks, and extended onto the slope of St. Pierre Bank (along the Laurentian Channel). Skate catch rates with all gears were higher on the inner extent of these grounds (in primarily 50-200 m), where sets targeting thorny skate occurred. However, skate by-catch was also substantial at greater depths where the fleet was targeting other species.

A spatial representation of non-Canadian effort outside of Canada's 200-mile-limit is presented in Figure 26 1995-1999. These data were recorded from Spanish and Portuguese fishing logbooks by Canadian Fishery Officers during vessel inspections at sea. On the Tail of the Grand Banks, fishing effort encompassed most of the available shallow Bank where the most dense skate concentrations straddle the NAFO line in fall. For 1995-1997 and 1998-1999, catch rates were substantially higher on the portion of the Bank less than 200 m deep, than along the shelf break (Fig. 24a). Average catch of skate within the 200 m contour, corresponding to the "skate directed fishery", was 534 kg per hour (10.7 tons per day) in 1995-1997, and 669 kg per hour (13.4 tons per day) in 1998-1999 (Fig. 26, circled area). These shallow sets comprised primarily a skate-directed fishery. This on-shelf effort occurred mainly in June-December when thorny skates were aggregated on the shallow section of the Bank, which extends outside the 200-mile-limit. Both time periods reflected very similar spatial patterns except that in 1998-1999, the area fished extended slightly further west, and on-shelf catch rates were higher. Fishing effort along the shelf edge yielded significant skate by-catch in a fishery mainly targeting Greenland halibut.

Locations fished in 2000-2003 were similar to previous years (Fig. 27). However, spatial patterns of skate catch rates did not resemble previous years. Skate catch rates on the Tail of the Grand Banks (circled area) was 157 kg per hour (3.2 tons per day), only 24% of that recorded in the previous time period. In addition, average skate by-catch rate in the Greenland halibut fishery was considerably higher than that in previous years: 113 kg per hour, as compared to 40 kg per hour in 1995-1999. This suggests a problem with the log information since 2000.

Catches as reported in NAFO STATLANT-21A of non-Canadian countries is listed in Table 4 and catches of countries combined are listed in Table 5. The latter table provides estimates derived from Canadian Fisheries and Oceans Conservation and Protection (C&P) estimates for non-Canadian countries as well as figures agreed to by STACFIS (NAFO). The 2003 estimate agreed to by STACFIS was 17 394 tons and 18 127 based on ZIF for Canada, and Canadian Surveillance for other countries. Catches of skates for all countries since 1985 are illustrated in Fig. 28 and 29. The majority of the catch is attributable to non-Canadian fleets fishing in NAFO Div. 3NO. Percent of catch by non-Canadian fleets in Div. 3LNO (those Divisions straddling the 200 mile limit) fluctuated between 40-80% (Fig. 29). The non-Canadian share increased during that period.

Figure 30 (lower panel, all countries, upper panel non-Canadian) compare catch trajectories depending on information source, STACFIS or ZIF plus Canadian C&P. Estimated since 1998, the STACFIS estimates are higher than C&P except in 2003. The Canadian portion of skate catches during 1985-1993 was 30%, but 99% of that was discarded (prior to the start of the directed fishery). However, almost all non-Canadian skate catches were retained whether taken as by-catch or in a directed fishery (see Fig. 28).

Before 1985, about 50-80% of reported catches of skate were attributable to Spain, Portugal, and USSR. Approximately 90% of non-Canadian catches was reported by Spain, Portugal, and Russia (USSR) after 1985 (Fig. 31). From 1993-2001, almost 100% of non-Canadian skate catches was taken by those three countries. Estonia catches have amounted to about 10% in 2002-2003.

Commencing in 1994, Canada retained most of its skate catches in a new directed fishery (non-Canadian countries are thought to retain most of their skate catches) (Fig. 32a). Canadian catches are summarized by month by gear in Table 5. In the Canadian fishery, skate discards (common before its skate-directed fishery began in 1994) are presently negligible. Regulations dictate that all skates must be landed. Thorny skates were only discarded because of spoilage. In 1985-1993, all reported Canadian skate landings were by-catch, averaging 61 tons per year (Fig. 32a). Much of this by-catch came from mixed fisheries for Atlantic halibut/monkfish/white hake, and the redfish fishery. In 1994-2003, the skate-directed fishery accounted for 74% of the total skate landings for Canadian vessels, and average total catch was 2 800 tons. In 2003, the total skate catch was 2 348 tons, similar to the past 2 years.

Since the late-1980s, 100% of skate caught by non-Canadian countries has been from trawls, with 86% (1997-2003) taken in NAFO Div. 3N on the Tail of the Grand Banks (where the skate-directed fishery occurs; Fig. 28). Most of that directed fishery is prosecuted in August-December. The remaining non-Canadian skate catches were by-catch in the Greenland halibut fishery, which occurs throughout the year. In contrast, 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. 32b).

In 1994, the first year of the directed Canadian skate fishery, most of the skate catch were taken in the fall (Fig. 33). 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 6). 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 May-August in 2001-2003. The activity was more spread out over spring, and skate catch rates were generally approximately 180-200 kg per 1000 hooks.

Although most of the reported Canadian catches were in spring (March-June as compared to non-Canadian fishing on the Tail of the Grand Banks primarily after August), trawl catch rates (750 kg per hour) recorded by Canadian Fishery Observers were approximately the same as that reported in the fall Spanish skate fishery. The best Canadian skate catches were taken at the mouth of Haddock Channel (Fig. 1) in fall. All gears were fished in a narrow range of depths averaging 140 m. However, skate by-catch in the mixed fishery occurred at greater depths although at lower catch rates. Both spring and fall research surveys indicated that skates along the southwestern edge of the Banks were more densely aggregated at depths greater than where they were fished by Canada (see Fig. 24 and Fig. 25).

Annual Canadian catches have remained fairly stable, being regulated by quota. In 1997-2003, the Canadian allocation was set at 45.8% for mobile gear (otter trawl), and 54.2% for fixed gear (gillnets and longlines). Canadian skate fishery policies and regulatory measures for 2003 are summarized in Table 7. In contrast, the skate fishery outside Canada’s 200-mile-limit is prosecuted by non-Canadian countries, and has been unregulated by quota limits. However, since July 2002, a minimum codend mesh size of 280 mm is required when directing for thorny skate in the NRA.

Size of thorny skate in the Canadian commercial catches varied considerably among gear types but less among years. Commercial skates are measured for total length by Canadian Fishery Observers at sea, because landed products of the Canadian fleet are in the form of wings (pectoral fins), body discarded. As a result of low observer coverage of the Canadian skate fishery, commercial length frequencies have been sparse (Table 1) and not all gears were sampled every year. Figure 34 provides a summary of 26 292 thorny skate total lengths from 1994-2003 collected by

Canadian Fishery Observers indicating that shape and range of commercial lengths varied with gear type. Gillnet and longline fisheries caught a similar size range of skates, 50-100 cm TL; averaging 74 cm in a single mode. Trawls captured a wider range of skates, 28-98 cm with approximately 25% less than 55 cm. In 3Ps, there was a smaller mode at 59 cm not observed in Div. 3O. Annual commercial length frequencies indicates that, where data were available, average length of commercial skates was similar over all years for each of the gear types (Fig. 35).

Figure 36 compares the sizes of thorny skate taken in Canadian, Spanish, and Portuguese trawl fisheries in years where there was comparable data. On average, Canadian trawls caught larger skates (approximately 25% were smaller than 55 cm consisting of immature fish) than in the Spanish trawl fishery. Skate sizes in Spanish commercial catches were between 30-85 cm TL, with a mode at 50 cm, and consisted of about 55% immature skates. Skate sizes in Russian catches ranged from 25-92 cm TL, with the majority between 32-60 cm (similar to Spanish skate sizes).

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

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. 37). 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 has tripled, from approximately 5% in the mid-1980s to an average of 15% in 1996-2003. The rate has increased from 7% in 1999 to 16% in 2003. The entire period of increased exploitation is concurrent with the period of thorny skate decline in NAFO Div. 3LNOPs.

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

Several options in producing Limit Reference Points from staged survey data and commercial catch information. Such analyses for this species are constrained by the lack of age-disaggregated data. However, data from the catch (relatively reliable from the mid-1980s following the start of the directed fishery) and survey biomass (from the early-1970s) provide information that can be examined in the context of a production model and a segmented regression. As well, stage based analyses, namely recruitment in relation to the spawning stock component is possible. The following possibilities were considered.

A temporal trajectory of Relative F to Relative (total) Biomass (Fig. 38) may provide some indication of an appropriate or maximum level of exploitation for thorny skate. The point of inflection (where the trajectory starts to increase on the x-axis) may provide some insight into an appropriate limit for exploitation and a corresponding level of biomass. This turn to the right occurs where Rel F ~ 0.1 and relative (total) biomass is ~110 000 tons.

Figure 39 shows the relationship between catch and exploitation index to relative biomass. The exploitation index was highest when the biomass was lowest. This reflects a relatively stable level of catch during the period when the biomass declined; rather than an increase in catch. The reason for this is that fleets have been able to sustain good catch rates as biomass was reduced because the remaining biomass has become increasingly concentrated.

Surplus Production

Estimates of B relative to B_{MSY} and F relative to F_{MSY} are shown in Fig. 40-44. Six runs If F_{MSY} is the taken as the Limit Reference Point (LRP) in terms of fishing mortality rate, the stock is estimated to have been exploited in excess of its LRP since the late-1980s regardless of which input data were used. As a consequence, the stock biomass is estimated to have been below B_{MSY} since about that time.

The parameter constraints and estimates of 5 runs are illustrated in Table 9. The run that produced the best fit capturing the major features of the dynamics of this stock .used the observed index of relative abundance used catch and survey data from 1972-2003 treating the Campelen and Engel surveys as separate series (Run 4, Table 9, Fig. 44). This was also considered the preferred model because it treated the Engel and Campelen data as separate series. As yet, a quantitative conversion factor (Engel to Campelen) has not been derived for this species. It estimated an MSY of 13 310 tons and an F_{MSY} of 0.2198. These parameter estimates are however very similar to Run 5 (which uses a series of combined surveys): Engel adjusted to Campelen using a conversion factor of 2.8 (refer to Methods for a description of the derivation of this conversion factor).

Using Run 4 as the model, a 6 year series of projections was produced (Fig. 45). This analysis shoed that catches above 12 000 tons resulted in an increasing F. This model suggests a stable biomass at catches of about 12 000 tons and an increasing biomass below that level of fishing mortality. Using input from the ASPIC model, catch versus biomass index yielded an r^2 of 0.7012 (Fig. 46 upper panel). Since 1985, F has fluctuated ranging from 0.42 to 1.18 (Fig. 46 lower panel).

Discussion

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

Catchability of skate in survey gear is a consideration in the management of the fishery for several reasons. Kulka and Mowbray (1998) first noted that the fall estimate of biomass of thorny skate is about 40% higher than spring estimates, because skates have migrated to deeper water during the spring. Therefore, a portion of the skate population is not available to survey trawls at that time. However, the spring survey is used as a relative measure of changes in skate population size because it surveys the entire stock management area while the fall series does not. In addition, the relative difference between spring and fall estimates has changed over time because of changes in skate patterns of migration. An increase in the spring/fall ratio of survey indices during the early to mid-1990s indicates a change in the degree of migration (less onto the shelf in the fall, Kulka and Mowbray 1998). This increase in degree of migration was concurrent with the period of decline. Thus, the thorny skate decline in the late-1980s and early-1990s may not be as great as the spring index suggests, because the degree of migration was greater in those years. For this reason and those stated above, the spring research survey greatly underestimates actual thorny skate biomass especially during the period of decline. However, the relative trend reflected in the survey indices (a decline in the late-1980s and early-1990s), and stability at the thorny skate’s lowest historic level is valid.

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

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

Examining trends in relative biomass and abundance (the traditional method for investigating population trends) however, does not encompass all of the population dynamics of thorny skate. The analyses of spatial dynamics have revealed changes in the skate population that would otherwise be difficult or impossible to detect, using aggregated statistics from commercial or survey sources. In addition to changes in relative biomass, thorny skate has also undergone substantial changes in its distribution, starting in the 1980s (before the beginning of its decline in biomass). The analyses of spatial dynamics have revealed changes in the thorny skate population that would be difficult or impossible to detect with standard analytical (non-spatial) analyses. Hyper-aggregation (increasing density at the center of distribution, decreasing at the periphery) was observed after the mid-1990s, when the skate population size was stable at a low level. More than 50 years of data suggest that this is a relatively recent phenomenon. A continuation of this trend could result in a further reduction of the stock, given that thorny skates are mostly concentrated in the area that is commercially fished. Commercial catch rates have remained and will probably continue to remain steady or increase in the short term even if the thorny skate population declines further. 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. This increases the probability of further depleting the stock. Thus, examination of thorny skate distribution dynamics constitutes an important part of understanding the status of the stock. This approach would benefit any assessment where geo-referenced data were available.

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

Frisk *et al.* (2002) suggested that conservation measures should focus on juvenile and adult stages of elasmobranch species. The approach in our assessment is consistent with this strategy. Our stage based analyses show that the greatest variation, both spatially and in the population dynamics occurred in the young of the year and the mature components. We also demonstrated a stock recruitment relationship. Thus, it is these stages that are the focus in assessing of the status of this stock.

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

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

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

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

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

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

Conclusion

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. However, 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.

Whether the current level of exploitation of thorny skate is sustainable is uncertain. Biomass has remained stable for about 12 years, but thorny skate distribution dynamics suggest that the 3LNOPs stock may decline at the current rate of exploitation. The Index of Exploitation outside of Canada's 200-mile-limit (which is fished exclusively by non-Canadian fleets) averaged 6.5 times higher than in areas fished by Canada inside 200 miles. Regardless, spatial dynamics in the form of hyper-aggregation suggest that current exploitation rates may be too high to affect recovery of the stock. The results from the production modeling suggest that catches exceeding 12 000 t (which is the case in most years) would impair stock recovery. Further, this study identified a fairly strong relationship between size of SSB and recruitment (size of YOY) and thus rebuilding depends on an increasing of the SSB. Even if fishing mortality is sufficiently low to allow recovery, the k selected reproductive strategy likely means a protracted recovery process.

Deficiencies

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

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

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

In addition, much of the basic biology necessary for understanding the population dynamicas (food and feeding, stock structure, morphology, reproduction) has not been updated in recent years. Ageing and stock structure research would greatly enhance knowledge of the current status of thorny skate in 3LNOPs. Tagging studies concentrating on offshore aggregations of thorny skate would lead to a better understanding of the mechanism and timing of its migrations. Accurate records of catch and sampling of commercial skate catches at sea should be enhanced through the Fishery Observer Program and reported to NAFO in order to define removals of thorny skate by size and, preferably, by age and sex.

Prognosis

Thorny skate continues to be at or near a historic low population size. The biomass has been stable for 12 years. Thus current levels of exploitation may be sustainable but do not allow the stock to rebuild. The desired strategy must first be determined: to sustain current levels of catches (no recovery) or reduce catches to a point that would allow the stock to grow. The latter strategy would lead to higher sustainable harvest in the longer term but would result in lower allowable catches in the short term. The results of the production model suggest that a catch <12 000 tons would be required to allow rebuilding of the stock.

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

Outlook

Thorny skate underwent a decline in the late-1980s to early-1990s. Since then, abundance has remained relatively constant at the lowest historic level. With the exception of the western extent of thorny skate distribution on St. Pierre Bank (NAFO Subdiv. 3Ps), information on lengths of thorny skate from research surveys indicates that recruitment has been low in all areas since 1996, except perhaps 3Ps. Recruitment on the northern Grand Banks (NAFO Div. 3L) has been nearly 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. The rate of decline to the north has increased in recent years. As a result of decrease in biomass, the Index of Exploitation for thorny skate has increased steadily since the 1980s.

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

Management Considerations

A key consideration in formulating an appropriate level of exploitation for thorny skate, and elasmobranchs in general, is their low reproductive potential due to slow growth, 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), and are thought to have low resilience to fishing mortality (Hoenig and Gruber, 1990). Frisk *et al.* (2002) with their analyses for several northwest Atlantic skates supported the notion that long-lived, slower growing, late maturing species are vulnerable to exploitation. Thus, it is especially important for thorny skate and skate species in general to take a conservative approach to the management of a fishery.

Although producing only < 40 eggs per year, thorny skates may not have lower reproductive capacity than more fecund fish 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. This was the approach taken in this paper. Our analyses have shown that there is a fairly strong stock/recruit relationship, smaller SSB producing smaller year-classes (YOY). The key difference is that most teleosts have the potential to produce large year-classes from a small spawning stock whereas elasmobranchs do not. Thus, they are vulnerable to over-exploitation as evidenced by world declines in this group of species (Christensen *et al.*, 2003; Dulvy *et al.*, 2003; Roberts and Hawkins, 1999). A rebuilding strategy must include reduction in exploitation of the SSB to allow an increase in recruitment.

Thus, an important management consideration relates to the inability of this group of marine fish to recover relatively quickly from depleted levels, regardless of cause. Low reproductive potential suggests a recovery period of many years even if exploitation is limited. The population of thorny skate on the Grand Banks is presently near its lowest historic since 1994 having declined by 95%, 1978-1986 compared to 1994-1997. Thus, even if environmental conditions were favourable and commercial fishing pressure was low, recovery of Grand Banks thorny skate would likely take much longer than more fecund teleost species. This is a key issue that must be considered when formulating management options. A conservative approach in the provision of advice seems prudent.

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

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

Summary

- 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).
- Small thorny skates (10-30 cm TL) have been largely absent from the northern Grand Banks (NAFO Div. 3L) since 1996. The largest occurrence of small skates is presently found in NAFO Subdiv. 3Ps.
- Since the mid-1990s, 17% of thorny skate biomass distributes outside Canada's 200-mile-limit, while <70% of skate catches were taken outside 200 miles.
- Reported commercial catches increased substantially in 2000, as compared to the previous five years. This increase occurred outside 200 miles.
- The Exploitation Index (commercial catch/spring research survey biomass index) increased from approximately 5% in the mid-1980s to about 15% in 2000 and thereafter. This coincides with the period of decline of the population.

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Table 1a. Summary of sets in Campelen spring surveys in SA 2+3 in **1995 - 2003.** Number of successful sets, spring surveys 1996-2003 (Campelen time-series). All surveys conducted by RV Wilfred Templeman. Depth range is given in meters.

	3L	# of inshore sets included	3N	3O	Tot	earliest	latest
1996	188	0	82	86	356	7-May	27-Jun
1997	158	0	71	81	310	30-Apr	26-Jun
1998	163	8	88	93	352	12-May	30-Jun
1999	177	32	82	86	377	11-May	29-Jun
2000	134	0	81	83	298	11-May	29-Jun
2001	154	12	79	79	324	29-Apr	24-Jun
2002	146	4	79	79	308	27-Apr	22-Jun
2003	155	14	79	79	327	8-May	26-Jun
mean	*159.4*		*80.1*	*83.3*	322.8		

Depth range (m), Campelen spring surveys 1996-2003.

	3L		3N		3O	
	min	**max**	**min**	**max**	**min**	**max**
1996	66	664	42	665	65	685
1997	60	681	35	689	62	669
1998	53	721	38	682	64	657
1999	41	692	40	659	62	679
2000	61	681	45	664	61	694
2001	34	695	40	650	74	699
2002	42	710	40	641	63	628
2003	62	698	39	681	63	726

Table 1b. Summary of sets in Campelen fall surveys in SA 2+3 in **1995-2003**. Depth range is given in meters, numbers of sets appear in parentheses.

Year	Div	Ship			
		Teleost	*W.Templeman*	*A.Needler*	***Total***
1995	2G	Not surveyed in 1995			
	2H				
	2J	145-948 (84)			84
	3K	166-1444 (31)	162-494 (100)		131
	3L	733-1210 (5)	63-640 (161)		166
	3M	Not surveyed in 1995			
	3N		40-650 (90)		90
	3O		63-730 (81)		81
					552
1996	2G	127 - 1436 (47)			47
	2H	122 - 1415 (77)			77
	2J	26 - 1410 (117)			117
	3K	11 - 1368 (115	126 - 472 (60)		175
	3L	305 - 1433 (31	51 - 671 (180)		211
	3M	784 - 1400 (18	127 - 707 (68)		86
	3N	390 - 1147 (13)		37 - 309 (54)	67
	3O	68 - 690 (24)	65 - 139 (19)	63 - 304 (15)	58
					838
1997	2G	201-1209 (69)			69
	2H	220-1382 (71)			71
	2J	123-1488 (117)			117
	3K	143-1431 (155	117-421 (20)		175
	3L	161-1436 (71)	35-714 (134)		205
	3M	799-1379 (26)			26
	3N		41-769 (74)		74
	3O		62-611 (73)		73
					810
1998	2G	143-1488 (34)			34
	2H	98-1473 (83)			83
	2J	126-1398 (118)			118
	3K	122-1415 (154	121-346 (17)		171
	3L	691-1437 (32)	34-675 (172)		204
	3M	768-1436 (26)			26
	3N	834-1447 (12)	37-1079 (78)		90
	3O		82-1076 (87)		87
					813

Year	Division	Ship			
		Teleost	*V.Templeman*	*A.Needler*	***Total***
1999	2G	142-1415(69)			69
	2H	104-1454(81)			81
	2J	109-1375(115)			115
	3K	146-1477(154)			154
	3L	1366(1)	63-1407 (169)		170
	3M	853-1403(12)			12
	3N		39-664(68)		68
	3O		58-692(75)		75
					744
2000	2G	Not surveyed in 2000			
	2H				
	2J	127-1400 (117)			117
	3K	113-1379 (159)			159
	3L	152-1430 (74)	42-447 (102)		176
	3M	764-1401 (26)			26
	3N	747-1419 (24)	46-642 (70)		94
	3O	752-1424 (24)	62-654 (76)		100
					672
2001	2G	Not surveyed in 2001			
	2H	999-1466 (8)		117-655 (49)	57
	2J	120-1389 (49)		105-574 (71)	120
	3K	146-1479 (106	128-439 (55)	170-252 (4)	165
	3L	146-1457 (34)	38-702 (169)	187-203 (2)	205
	3M	763-1407 (26)			26
	3N	739-1410 (24)	45-660 (70)		94
	3O	803-1391 (22)	67-703 (75)		97
					764
2002	2G	Not surveyed in 2002			
	2H				
	2J	102-1372 (98)	136-572 (19)		117
	3K	156-1395 (64)	121-481 (111)		175
	3L	763-1431 (30)	35-670 (176)		206
	3M	818-1403 (26)			26
	3N	811-1429 (24)	44-675 (70)		94
	3O	775-1504 (24)	65-696 (75)		99
					717
2003	2G	Not surveyed in 2003			
	2H				
	2J	123-1404 (116)			116
	3K	151-1474 (118	115-489 (50)		168
	3L	753-1446 (30)	32-702 (175)		205
	3M	795-1455 (26)			26
	3N		43-727 (70)		70
	3O		63-650 (75)		75
					660

1995 fall survey extended into January 1996 (66 sets - included above)
1996 survey of Div 3M covered all strata
2002 fall survey extended into January 2003 (128 sets - included above)
2003 fall survey extended into January 2004 (210 sets - included above)
2003 excludes 8 sets done in Div. 3O > 731 m

Table 1c. Monthly summary of effort in the Canadian spring (3LNOPs) and fall (3LNO) surveys using Campelen trawl gear, **1995-2003**.

Year	Month	# Sets	Min Depth (m)	Max Depth (m)
Spring				
1996	4	139	42	613
	5	184	42	685
	6	191	66	664
1996 Total		**514**	**42**	**685**
1997	4	162	34	637
	5	121	35	689
	6	189	43	681
1997 Total		**472**	**34**	**689**
1998	4	177	40	670
	5	161	51	657
	6	202	38	721
1998 Total		**540**	**38**	**721**
1999	4	124	41	484
	5	181	42	650
	6	239	40	692
1999 Total		**544**	**40**	**692**
2000	4	121	41	485
	5	188	39	694
	6	171	51	681
2000 Total		**480**	**39**	**694**
2001	4	184	38	609
	5	154	40	699
	6	158	34	695
2001 Total		**496**	**34**	**699**
2002	4	200	37	625
	5	157	40	641
	6	132	42	710
2002 Total		489	37	710
2003	4	153	40	675
	5	161	39	726
	6	181	51	698
2003 Total		**495**	**39**	**726**
Fall				
1995	1	17	54	1,210
	9	42	40	80
	10	166	53	730
	11	135	63	640
	12	4	71	159
1995 Total		**364**	**40**	**1,210**
1996	9	1	854	854
	10	118	51	671
	11	134	37	1,414
	12	105	47	1,433
1996 Total		**358**	**37**	**1,433**
1997	9	19	65	124
	10	126	44	679
	11	151	35	1,436
	12	90	65	1,406
1997 Total		**386**	**35**	**1,436**
1998	10	165	37	1,118
	11	179	59	1,374
	12	79	34	1,447
1998 Total		**423**	**34**	**1,447**
1999	10	67	65	692
	11	165	39	679
	12	81	98	1,407
1999 Total		**313**	**39**	**1,407**
2000	10	170	51	1,430
	11	79	42	641
	12	121	61	676
2000 Total		**370**	**42**	**1,430**
2001	9	27	739	1,392
	10	195	45	1,457
	11	131	38	1,398
	12	43	104	626
2001 Total		**396**	**38**	**1,457**
2002	10	233	44	1,504
	11	154	35	1,396
	12	12	148	1,431
2002 Total		**399**	**35**	**1,504**
2003	9	8	761	1,382
	10	128	43	650
	11	107	32	727
	12	85	65	700
2003 Total		**328**	**32**	**1,382**

Table 2. Number of thorny skates measured for total length in commercial catches, **1994-2003**. Data are from Canadian Fisheries 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	75	73		148
	Gillnet	1649	2873		4522
	All	1724	2946		4670
2003	Otter trawl	68	76		144
	Gillnet	708	781		1489
	Longline	13	64		77
	All	789	921		1710
Total		**10612**	**15287**	**393**	**26292**

Table 3a. Unconverted biomass, abundance, and mean weight of thorny skate from spring research surveys, **1971-2003**. Surveys were conducted with an Engels trawl during 1971-spring 1995, and Campelen trawl during fall 1995-2003.

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
2003	8,411	18,216	49,707	37,072	113,406

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
2003	6,737	9,645	34,735	24,615	75,732

Mean weight (kg)

Year	Div. 3L	Div. 3N	Div. 3O	Div. 3Ps
1971	3.04	2.88		
1972	2.12	2.31		2.92
1973	1.49	2.47	1.82	1.97
1974	1.51	1.88		2.01
1975	1.26	2.61	2.08	3.46
1976	1.42	1.84	2.81	1.54
1977	2.52	2.69	2.61	1.39
1978	1.73	1.62	2.35	0.67
1979	1.90	1.72	2.64	1.21
1980	2.15	1.65	1.28	1.73
1981	1.66	1.78	2.08	0.94
1982	1.77	1.28	2.07	2.07
1983				1.12
1984	2.17	2.18	2.36	2.06
1985	1.55	1.82	2.10	0.64
1986	1.30	1.97	2.10	1.26
1987	2.00	1.72	1.43	1.38
1988	1.91	1.79	1.94	1.50
1989	1.73	1.56	2.17	1.63
1990	0.98	0.63	1.47	1.08
1991	0.61	0.62	2.68	1.17
1992	0.30	1.06	1.55	1.71
1993	0.29	1.04	2.23	0.83
1994	0.23	0.55	1.44	0.82
1995	0.29	0.38	1.15	1.22
1996	0.48	1.04	1.56	0.85
1997	0.58	0.72	1.10	1.13
1998	0.75	1.30	1.24	1.26
1999	0.88	1.64	1.50	1.59
2000	1.12	1.74	1.43	1.21
2001	1.22	1.79	1.77	1.40
2002	1.45	1.65	1.16	1.26
2003	1.25	1.89	1.43	1.51

Table 3b. Converted biomass, abundance, and mean weight of thorny skate from **spring** research surveys, **1971-2003**. Conversion factors, Engel to Campelen: 2.4 for biomass, 2.8 for abundance based on ratios of 1996-97/1994-95 biomass and abundance.

	Biomass Index					Abundance Index				
Year	Div. 3L	Div. 3N	Div. 3O	Div. 3Ps	All Divisions	Div. 3L	Div. 3N	Div. 3O	Div. 3Ps	All Divisions
1971	99,100	31,927	0	0	131,026	27,753	9,435	0	0	37,188
1972	66,041	101,881	0	46,365	214,287	26,559	37,621	0	13,512	77,692
1973	50,801	76,911	65,750	37,881	231,343	29,151	26,549	30,874	16,416	102,990
1974	113,646	61,614	0	63,322	238,582	64,060	27,979	0	26,797	118,836
1975	88,063	60,925	71,510	16,147	236,645	59,587	19,908	29,317	3,980	112,791
1976	113,618	111,285	226,532	83,306	534,741	68,086	51,544	68,810	46,005	234,445
1977	179,571	124,488	55,428	34,800	394,287	60,736	39,405	18,091	21,273	139,505
1978	107,128	46,286	50,265	21,384	225,064	52,650	24,344	18,237	27,119	122,350
1979	125,292	67,412	55,960	28,498	277,162	56,237	33,350	18,037	19,996	127,620
1980	116,454	73,805	60,669	59,712	310,641	46,217	38,135	40,398	29,358	154,107
1981	156,060	48,825	34,757	32,328	271,970	79,948	23,328	14,226	29,345	146,846
1982	106,633	85,155	64,566	20,789	277,143	51,475	56,846	26,602	8,572	143,496
1983				38,691	38,691				29,474	29,474
1984	19,195	64,159	67,834	22,585	173,773	7,532	25,084	24,476	9,364	66,455
1985	113,769	96,081	122,630	41,076	373,556	62,726	45,023	49,841	54,903	212,493
1986	77,659	122,633	51,837	53,051	305,180	50,943	53,094	21,015	35,949	161,001
1987	91,189	67,289	56,696	45,236	260,410	38,930	33,350	33,848	27,955	134,083
1988	77,970	55,228	97,124	33,338	263,659	34,832	26,326	42,749	18,936	122,843
1989	81,468	54,624	44,654	49,211	229,957	40,121	29,861	17,579	25,717	113,277
1990	50,366	52,777	68,856	26,972	198,971	43,690	71,253	39,893	21,224	176,060
1991	24,673	32,152	110,049	68,399	235,273	34,584	44,299	34,996	49,971	163,850
1992	13,052	25,619	64,392	43,011	146,075	36,678	20,529	35,366	21,390	113,963
1993	9,501	20,619	39,030	15,461	84,610	27,608	16,972	14,941	15,911	75,432
1994	4,356	11,330	32,096	18,386	66,168	15,909	17,465	18,998	19,114	71,486
1995	3,111	3,140	35,930	27,703	69,884	9,267	6,978	26,631	19,383	62,260
1996	4,992	11,010	35,529	21,851	73,382	10,416	10,636	22,731	25,591	69,374
1997	3,969	9,703	28,293	20,705	62,670	6,804	13,554	25,635	18,379	64,372
1998	5,807	13,186	42,351	28,629	89,973	7,764	10,141	34,130	22,781	74,816
1999	7,278	26,254	54,045	32,062	119,639	8,273	15,967	36,042	20,212	80,494
2000	14,011	27,861	40,917	22,528	105,317	12,512	16,027	28,525	18,574	75,638
2001	10,383	29,197	59,078	24,566	123,224	8,521	16,276	33,321	17,606	75,724
2002	8,580	13,987	38,025	22,127	82,719	5,920	8,469	32,902	17,560	64,851
2003	8,411	18,216	49,707	37,072	113,406	6,737	9,645	34,735	24,615	75,732

Table 3c. Biomass, abundance, and mean weight of thorny skate from **fall** research surveys, **1981-2003**. Surveys were conducted with an Engels trawl during 1981-spring 1995, and Campelen trawl during fall 1995-2003. **Some deep strata were not sampled in 2003.

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
2003**	9,072	36,829	46,123	92,024

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
2003**	5,828	19,203	34,556	59,587

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
2003	1.56	1.92	1.33	1.54

Table 3d. Percent difference between **spring and fall** estimates of biomass, abundance, and mean size, by NAFO Division and year, 1981-2003. 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%			
1982	42.16%			
1983				
1984	88.41%			
1985	27.44%			
1986				
1987	6.61%			
1988	35.00%			
1989	-7.98%			
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%
2003	7.29%	50.54%	-7.77%	59.71%
Average:	39.79%	56.92%	8.51%	40.58%
1996-2003: (Campelen)	35.47%	51.69%	3.00%	33.70%

Abundance (thousands)

Year	Div. 3L	Div. 3N	Div. 3O	All Divisions
1981	0.89%			
1982	40.95%			
1983				
1984	89.33%			
1985	26.71%			
1986				
1987	51.59%			
1988	59.57%			
1989	47.46%			
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%
2003	-15.60%	49.77%	-0.52%	14.21%
Average:	41.53%	42.67%	15.17%	36.54%
1996-2003: (Campelen)	22.19%	49.04%	10.65%	27.68%

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%
2003	19.80%	1.52%	-7.22%	53.04%
Average:	-4.07%	23.18%	-13.82%	5.03%
1996-2003: (Campelen)	15.75%	8.05%	-16.14%	6.40%

Table 4. Skate catch history for non-Canadian fleets, **1970-2003** (from NAFO STATLANT-21A). Catch statistics are preliminary for 2003; 2001-2002 are incomplete. All data for 2003 are from NAFO letter of Provisional Catches for December 2003. Estimates for EU in 2003 are not differentiated by country.

Year	Cuba	Estonia	EU	Faroes	F.R.G.	France (main)	France (SPM)	G.D.R.	Japan	Lithuania	Norway	Poland	Portugal	Spain	South Korea	Russia	U.S.A.	U.S.S.R.	U.K.	All
1970	0	0		0	0	0	341	0	0		0	0	0	0	0		0	427	0	**768**
1971	0	0		0	0	0	289	0	0		0	0	0	0	0		0	1	0	**290**
1972	0	0		0	5	0	282	0	0		0	0	0	0	0		0	370	14	**671**
1973	0	0		0	3	0	172	20	0		14	0	0	0	0		0	401	34	**644**
1974	0	0		0	0	71	165	0	0		245	0	0	0	0		0	1,763	87	**2,331**
1975	0	0		0	0	326	156	0	0		70	0	472	0	0		0	2.001	0	**3.025**
1976	0	0		0	0	230	72	0	0		90	0	401	0	0		0	443	0	**1,236**
1977	0	0		0	0	384	109	0	0		0	0	300	57	0		0	776	0	**1,626**
1978	0	0		0	1	159	136	6	0		59	0	0	4	0		0	875	31	**1,271**
1979	0	0		0	0	86	67	0	0		9	2	17	23	0		0	574	0	**778**
1980	0	0		14	0	403	281	8	0		0	0	56	19	0		0	855	0	**1.636**
1981	0	0		0	0	197	365	15	18		0	0	13	222	0		0	1,157	0	**1,987**
1982	0	0		0	0	0	418	0	29		0	0	1	44	108		0	551	0	**1,151**
1983	6	0		0	0	45	573	50	0		0	0	0	611	65		0	443	0	**1,793**
1984	0	0		0	0	619	134	154	0		0	2	6	1,056	0		0	644	0	**2,615**
1985	26	0		0	44	774	170	31	0		0	0	0	8.108	0		0	2.181	0	**11.334**
1986	0	0		0	0	641	972	21	0		0	0	742	10,646	147		0	2,684	0	**15,853**
1987	0	0		0	0	663	158	18	0		0	0	3.079	12.428	888		1	1.853	0	**19,088**
1988	0	0		0	3	134	653	54	0		0	0	1,029	9,367	1,659		0	6,557	0	**19,456**
1989	0	0		0	0	0	1,773	69	0		0	0	444	12,762	490		6	369	0	**15,913**
1990	0	0		2	0	0	576	0	0		0	0	10.476	3.347	744		1	129	0	**15.275**
1991	0	0		0	0	0	641	0	0		0	0	21,097	6,462	762		0	66	1	**29,029**
1992	0	0		0	0	0	46	0	0		0	0	3.822	128	1.044	62	0		3	**5,105**
1993	0	0		0	0	0	11	0	0		0	0	3,987	1,994	5	6	0		0	**6,003**
1994	0	0		0	0	0	3	0	0		0	0	1,398	5,203	0	0	0		0	**6,604**
1995	0	0		0	0	0	4	0	0		0	0	626	4.281	0	5	0		0	**4.916**
1996	0	0		0	0	0	2	0	0		0	0	744	4,060	0	0	0		0	**4,806**
1997	0	0		0	0	0	3	0	0		0	0	856	9.047	0	0	0		0	**9,906**
1998	0	0		0	0	0	9	0	0		0	0	993	7,503	0	2	0		0	**8,507**
1999	0	0		2	0	0	4	0	0		0	0	1,980	8,727	0	155	0		0	**10,868**
2000	0	240		0	0	0	21	0	0		0	0	648	13.324	0	3.567	0		0	**17.800**
2001	0	1,015		1	0	0	38	0	0		0	2	793	4,472	0	2,570	0		0	**8,891**
2002	0	328		0	0	0	238	0	33		0	0	1.325	5.806	0	3.157	0		0	**10,887**
2003	*0*	*881*	*10.054*						*63*	*406*	*0*					*3.221*				***14.625***

Table 5. Landings of skate in Canadian and non-Canadian waters of NAFO Divisions 3LNOPs, 1985-2003. Catches inside 200 miles were calculated from ZIF files (landings) and Observer data (Canadian discards and non-Canadian catches). Catches in non-Canadian waters were estimated from Conservation & Protection (Fisheries and Oceans, Canada) boardings prior to 2003. 2003 non-Canadian are from NAFO Letters and pro-rated by Division based on an average from past 3 years (2000-2002), due to lack of NAFO data by Div. The table includes estimates from various sources including numbers “ agreed” to by STACFIS (Scientific Council of NAFO).

	3L		3N		3O		3Ps		Canadian & Non-Canadian					3LNOPs		STATLANT		3LNOPs		3LNO	3LNO (C&P)			
Year	Can.	Non-Can.	Can.	Non-Can.	Can.	Non-Can.	Can.	Non-Can.	3L	3N	3O	3PS	3LNOPs	Can.	non-Can	non-Can.	Surv-STATLANT	STACFis	Use	STATLANT 21A	Can 3LNO	non-Can 3LNO	All 3LNO	3LNO STACFis
1985	1,676	1,850	870	13,000	1,126	900	1,299	944	3,526	13,870	2,026	2,243	21,666	4,972	16,694	11,334	5,360		21,666	10,390	3,673	15,750	19,423	19,423
1986	1,830	1,500	1,315	10,500	1,596	700	1,106	1,576	3,330	11,815	2,296	2,682	20,123	5,847	14,276	15,853	-1,577		20,123	14,277	4,742	12,700	17,442	17,442
1987	2,307	1,200	1,708	8,500	935	600	4,999	787	3,507	10,208	1,535	5,786	21,036	9,949	11,087	19,088	-8,001		21,036	18,301	4,950	10,300	15,250	15,250
1988	9,785	950	1,431	6,500	1,567	400	2,006	781	10,735	7,931	1,967	2,787	23,420	14,789	8,631	19,456	-10,825		23,420	18,675	12,784	7,850	20,634	20,634
1989	1,367	1,000	1,910	7,400	1,324	500	2,424	1,685	2,367	9,310	1,824	4,109	17,610	7,025	10,585	15,913	-5,328		17,610	14,228	4,601	8,900	13,501	13,501
1990	2,033	1,800	485	12,400	953	900	3,396	549	3,833	12,885	1,853	3,945	22,515	6,866	15,649	15,275	374		22,515	14,726	3,470	15,100	18,570	18,570
1991	1,710	1,550	549	10,500	771	700	4,023	639	3,260	11,049	1,471	4,662	20,442	7,053	13,389	29,029	-15,640		20,442	28,390	3,030	12,750	15,780	15,780
1992	436	600	343	5,800	1,953	200	2,385	46	1,036	6,143	2,153	2,431	11,763	5,117	6,646	5,105	1,541		11,763	5,059	2,732	6,600	9,332	9,332
1993	303	1,100	853	4,600	3,417	150	711	11	1,403	5,453	3,567	722	11,146	5,285	5,861	6,003	-142		11,146	5,992	4,573	5,850	10,423	10,423
1994	269	650	63	6,700	1,219	150	1,238	3	919	6,763	1,369	1,241	10,293	2,790	7,503	6,604	899		10,293	6,601	1,551	7,500	9,051	9,051
1995	182	250	3	2,600	2,603	50	1,959	4	432	2,603	2,653	1,963	7,651	4,747	2,904	4,916	-2,012		7,651	4,912	2,787	2,900	5,687	5,687
1996	71	1,200	8	3,000	2,151	200	995	2	1,271	3,008	2,351	997	7,626	3,224	4,402	4,806	-404		7,626	4,804	2,229	4,400	6,629	6,629
1997	45	650	148	7,950	3,557	275	1,491	3	695	8,098	3,832	1,494	14,119	5,241	8,878	9,906	-1,028		14,119	9,903	3,750	8,875	12,625	12,625
1998	79	250	61	7,200	1,040	300	1,517	6	329	7,261	1,340	1,523	10,453	2,697	7,756	8,507	-751	11,196	11,196	8,501	1,181	7,750	8,931	**8,825**
1999	74	634	85	4,166	1,166	482	1,284	4	708	4,251	1,648	1,288	7,895	2,609	5,286	10,868	-5,582	12,144	12,144	10,864	1,325	5,282	6,607	**9,535**
2000	139	346	156	5,859	620	485	1,054	21	485	6,015	1,104	1,075	8,680	1,969	6,711	17,800	-11,089	15,631	15,631	17,779	915	6,690	7,604	**13,662**
2001	273	905	269	6,955	646	380	2,008	38	1,178	7,225	1,026	2,046	11,475	3,196	8,278	8,891	-613	13,180	13,180	8,853	1,188	8,240	9,429	**10,366**
2002	246	575	385	4,755	1,348	558	1,544	238	821	3,475	1,907	1,782	7,985	3,523	6,127	10,887	-4,760	13,201	13,201	9,695	1,980	5,889	7,869	**9,678**
2003	67	1,375	404	12,431	1,032	819	1,999	0	1,442	12,835	1,851	1,999	18,127	3,502	14,625	14,625	0	17,394	17,394	14,625	1,503	14,625	16,128	**13,416**

Table 6. Canadian landings of thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps by gear type and month, 1985-2003.

Gear	Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	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	33	348	331	310	47	8	2	4	4
	2003	6	22	6	0	29	336	252	142	49	28	23	5	46
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	32	52	62	31	18	17	6	3
	2002	0	8	41	69	127	54	103	89	33	18	11	3	0
	2003	1	3	38	223	62	6	23	19	46	18	6	4	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	2,120	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	1,499	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	572	8	3	1	2	4	3	0	0
	2002	0	0	18	584	107	2	6	93	22	3	2	0	0
	2003	0	3	1	761	120	4	5	43	16	3	2	0	0

Table 7. Fishery regulations and quota allocations for thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps in 2002 and 2003.

Gear Type	Vessel Size	Sector	Season	Gear Restrictions	Adjustments /reason	TAC
Fixed Gear	<35'	Inshore	**3LNO** May 15, 2003-July 10, 2003 3Ps <12miles from shore July 7/03-December 19, 2003 (vessels <35' only) >12miles from shore June 2, 2003 – August 23, 2003 (vessels 35'-65')	**3LNO – Gillnets** (200 nets, min mesh size 12",) OR hook and line. **3Ps – Gillnets only** <12 miles from shore: 40 nets, min mesh size 10½") >12 miles 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/ 03 – Mar.31/04	GN min mesh size 12"		3LN-50 3O-150 3Ps-100
Mobile Gear	<65'	Inshore	**3LNO** **April 1, 2003-March 31, 2004** **3Ps** April 11, 2003-May 5, 2003	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.1/03 – Dec.31/03	Min mesh size 300mm for codend 250 for rest of trawl		
Mobile Gear	>100'	Offshore	Jan.1/03 – Dec.31/03	Min mesh size 300mm for codend 250 for rest of trawl		

Table 8. Size of thorny skate, proportion mature in the commercial trawl catches in NAFO Div. 3NO, and size of codend mesh used.

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

Table 9. Parameter constraints and estimates for five non-equilibrium production model runs (refer to Prager et *al*. 1994).

	Run 1	Run 2	Run 3	Run 4	Run 5
Input	1996-2003 Campelen series only (8 yr)	1985-2003 Campelen Engel, 2 series Unadjusted	1985-2003 Campelen Engel, single series Adjusted to Campelen	**1972-2003 Campelen Engel, 2 separate series Unadjusted**	1972-2003 Campelen Engel, single series Adjusted to Campelen
Parameter Constraints					
MSY	15,000 (5,000- 50,000)	15,000 (5,000- 50,000)	15,000 (5,000- 50,000)	**15,000 (5,000- 50,000)**	15,000 (5,000- 50,000)
K	600,000 (100,000- 900,000)	600,000 (100,000- 900,000)	600,000 (100,000- 900,000)	**600,000 (100,000- 900,000)**	600,000 (100,000- 900,000)
q	1	1	1.2	**1**	1
Parameter Estimates (percent bias in parentheses)					
MSY	22,760 (na)	26,070 (-17.3)	18,970 (-2.1)	**13,310 (-1.3)**	13,980 (-5.1)
K (in Campelen	124,600 (na)	796,311 (-1.4)	591,605 (22.0)	**326,998 (8.6)**	411,060 (15.9)
q (campelen)	1.246 (na)	5.596 (-27.5)	6.675 (-16.4)	**2.698 (-1.6)**	3.9 (-12.3)
q (Engel)		2.724 (-16.8)		**1.263 (-3.8)**	
B_{MSY} (in Campelen	62,300 (na)	398,155 (-1.4)	295,836 (22.04)	**163,472 (8.6)**	205,569 (15.9)
F_{MSY}	0.4552 (na)	0.3664 (-7.8)	0.4281 (-15.4)	**0.2198 (-4.3)**	0.265 (15.5)
B1/K	0.4518 (na)	0.269 (95.2)	0.6938 (7.3)	**0.477 (9.2)**	0.5046
Objective Function	0.2009	1.5271	1.167	**2.919**	2.6894
R^2 in CPUE	0.508	-0.233 ,0.751	0.854	**0.082, 0.364**	0.596
MSE	0.05023	0.1091	0.0778	**0.1081**	0.09605
RMSE	0.2241	0.3303	0.2789	**0.3288**	0.3099

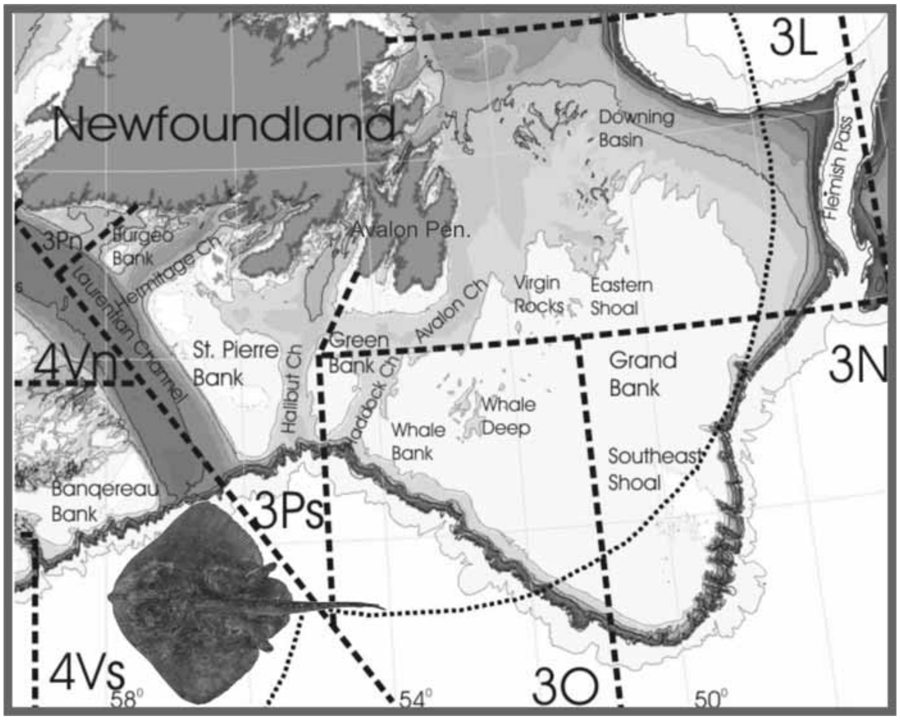


Fig. 1. The Grand Banks, showing locations referenced in the text, bathymetry, Canada's 200-mile-limit, and NAFO Divi. 3L, 3N, 3O, and Subdiv. 3Ps (image of thorny skate on lower left).

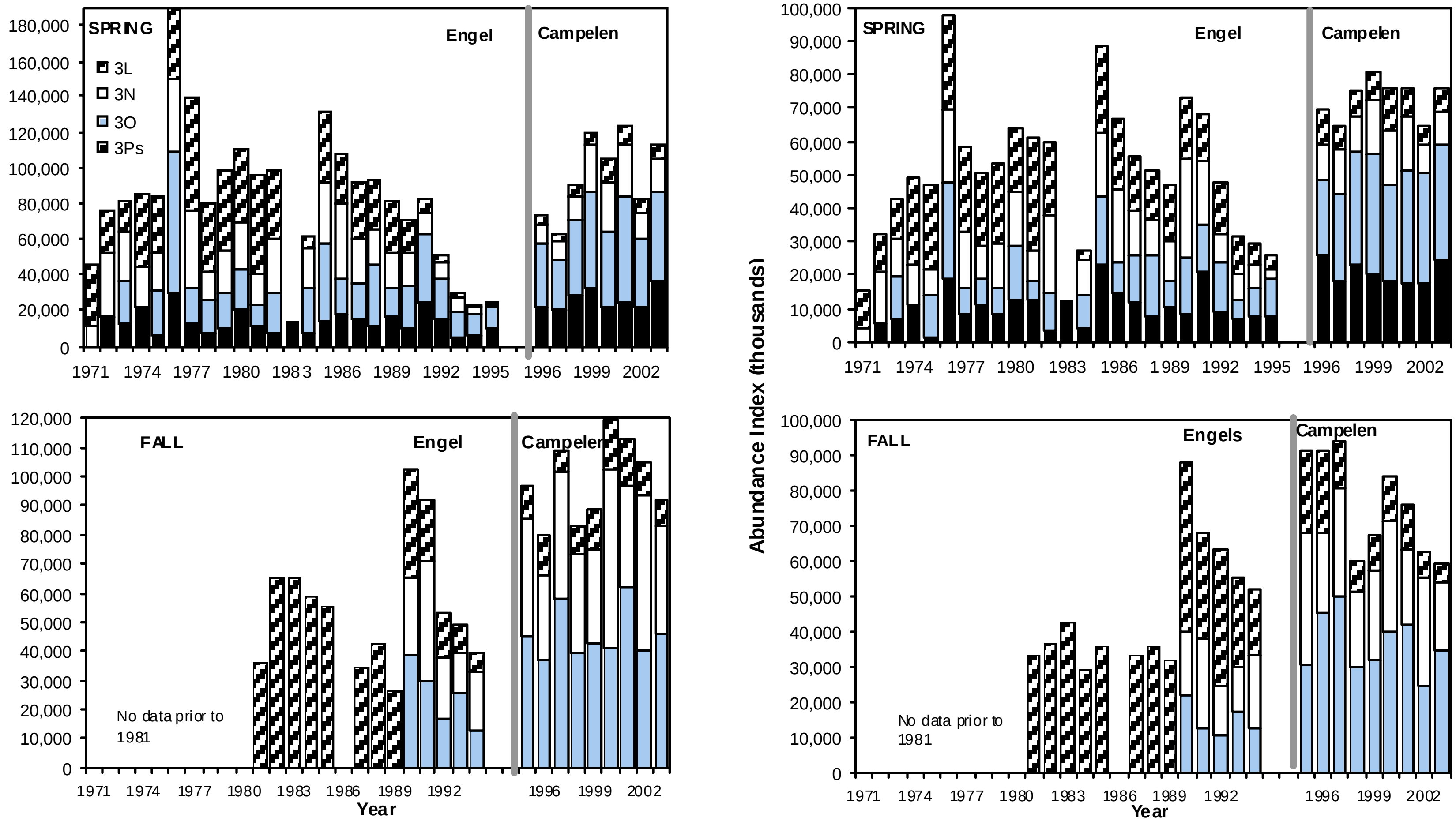


Fig. 2. Spring and fall survey biomass and abundance indices for thorny skate in NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps, **1971-2003.** Indices are not adjusted for the change in survey gear.

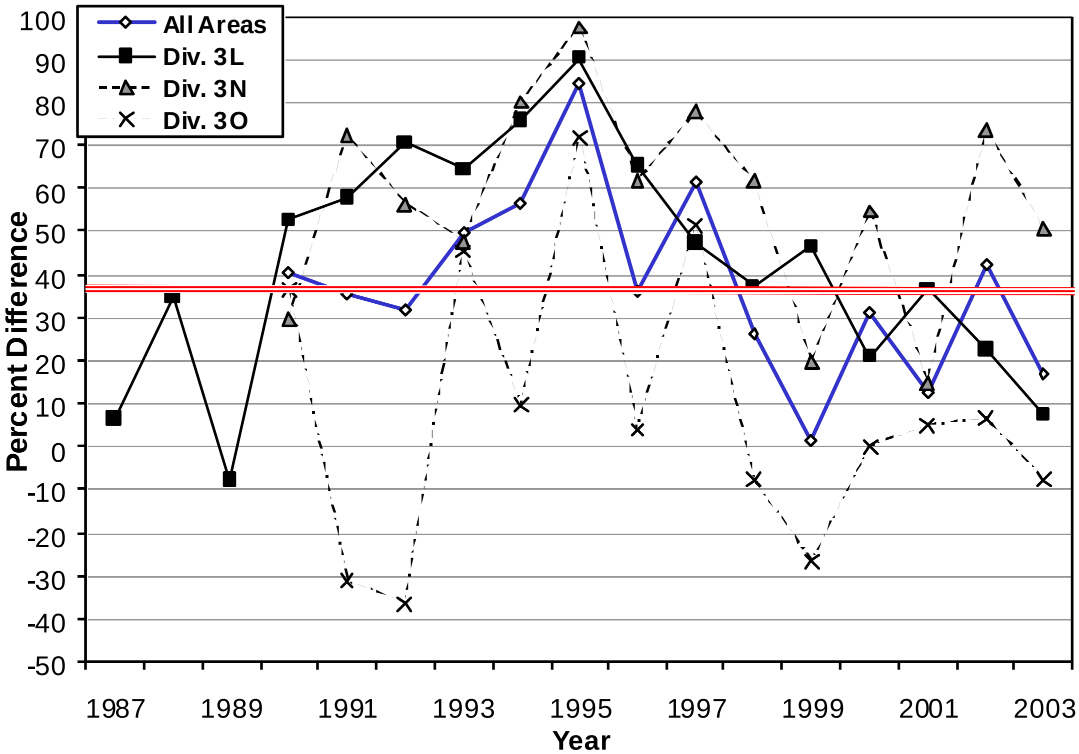


Fig. 3. Percent difference between spring and fall survey biomass estimates for thorny skate in NAFO Divisions 3LNO, 1987-2003.

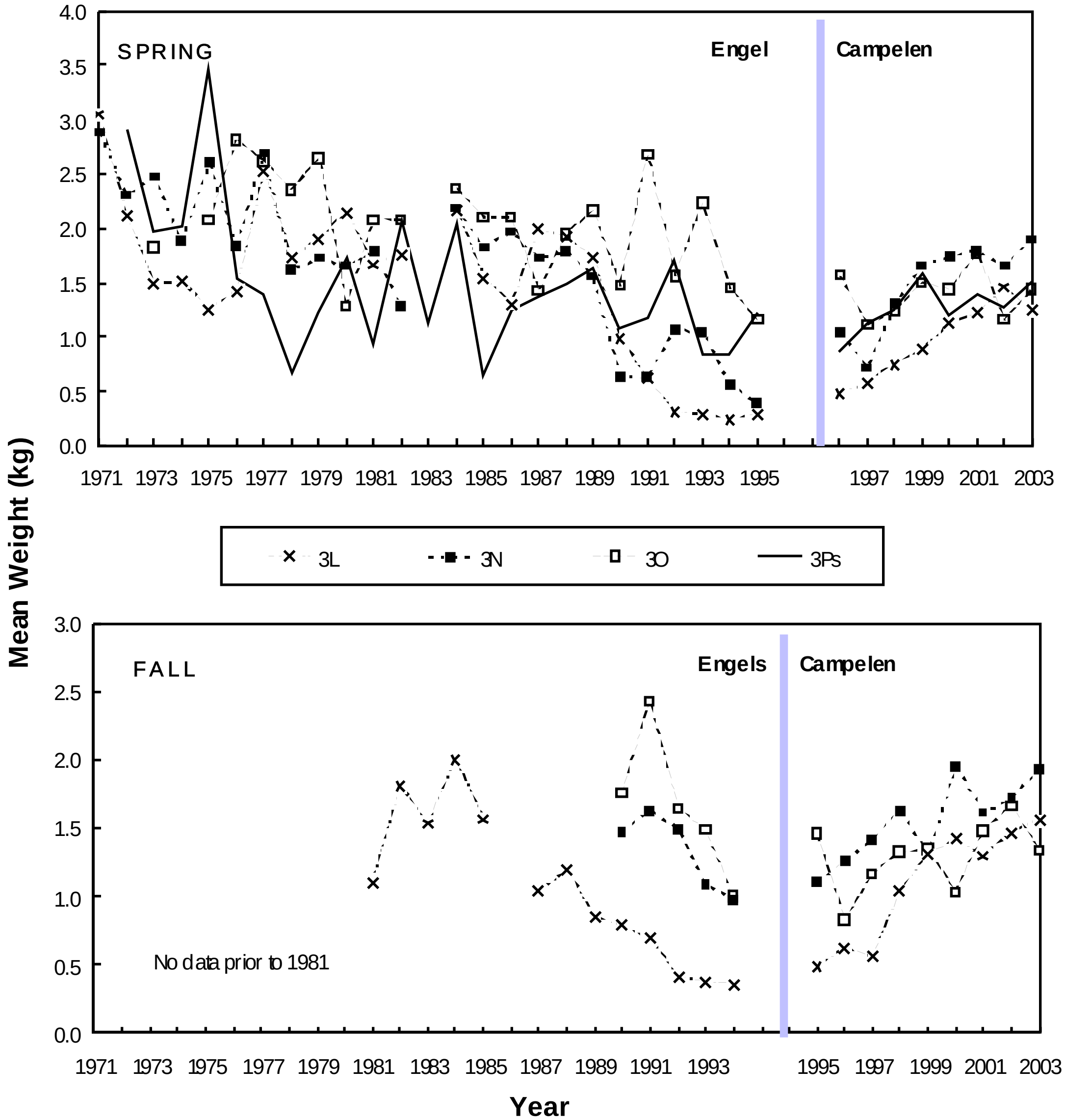


Fig. 4. Mean weight of thorny skate in spring (1971-2003) and fall (1981-2003) surveys in NAFO Divisions 3LNO and Subdivision 3Ps.

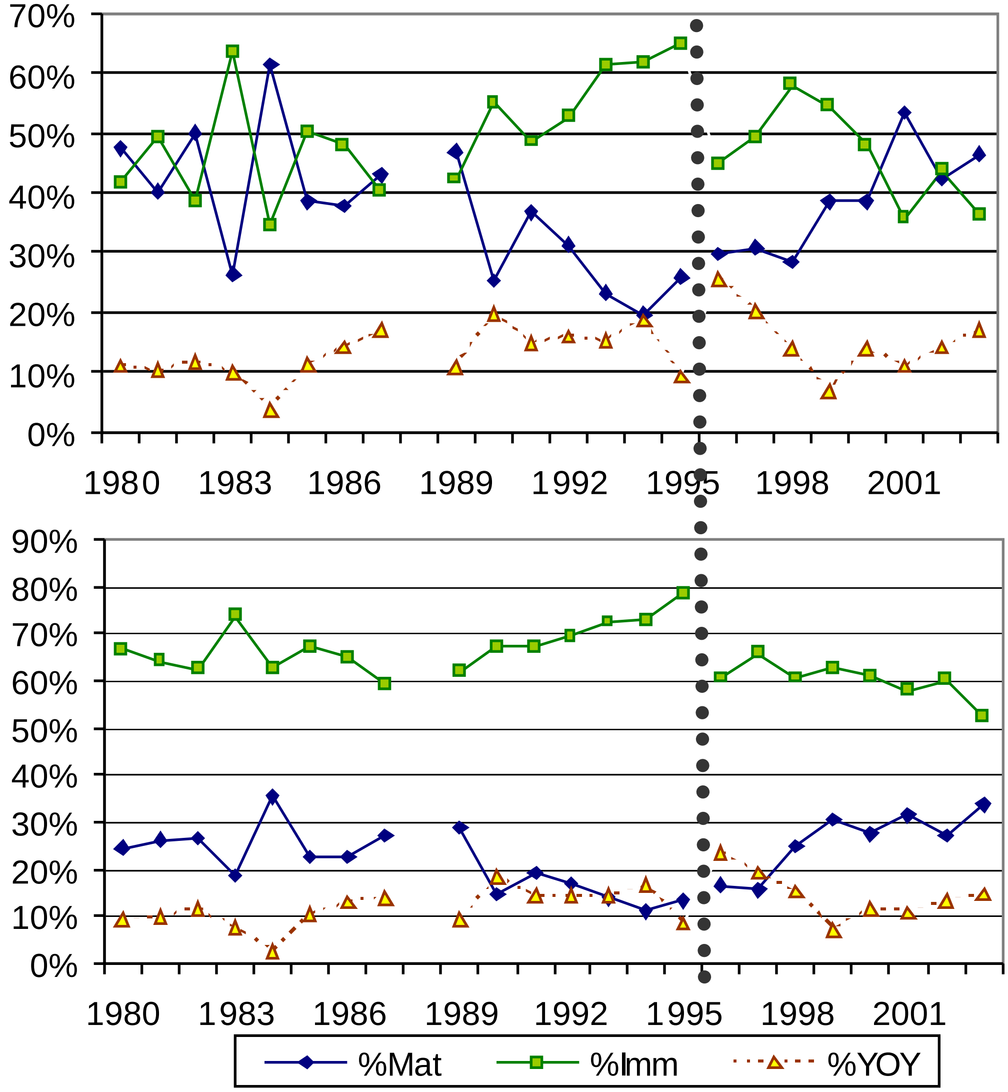


Fig. 5. Mature, immature and YOY (young of the year) stage as a percent of total abundance, 1980-2003.

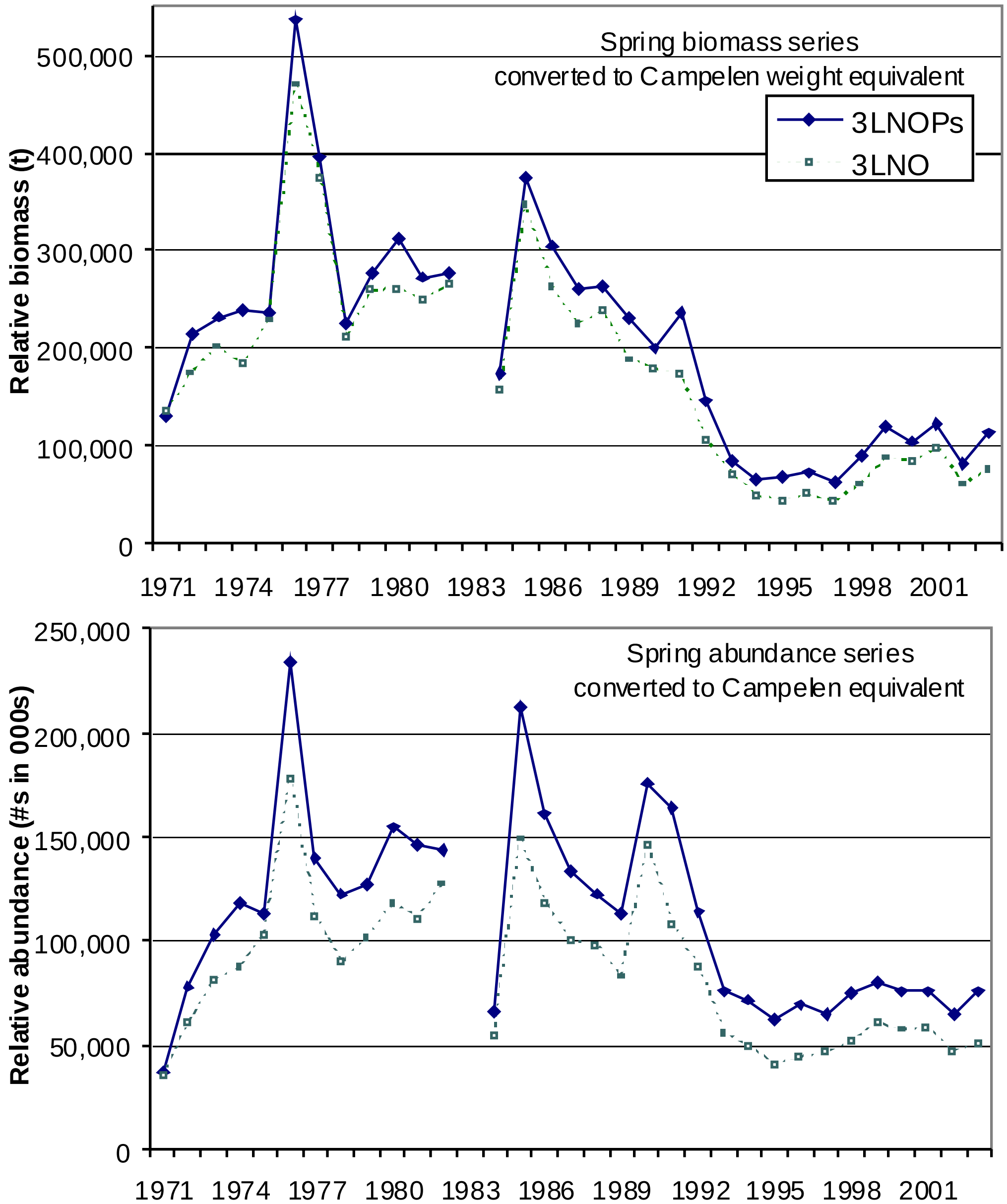


Fig. 6a. Relative biomass of thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps, with Engl estimates converted to Campelen equivalents. Some Divisions were not sampled in 1971, 1972, 1974, and 1983.

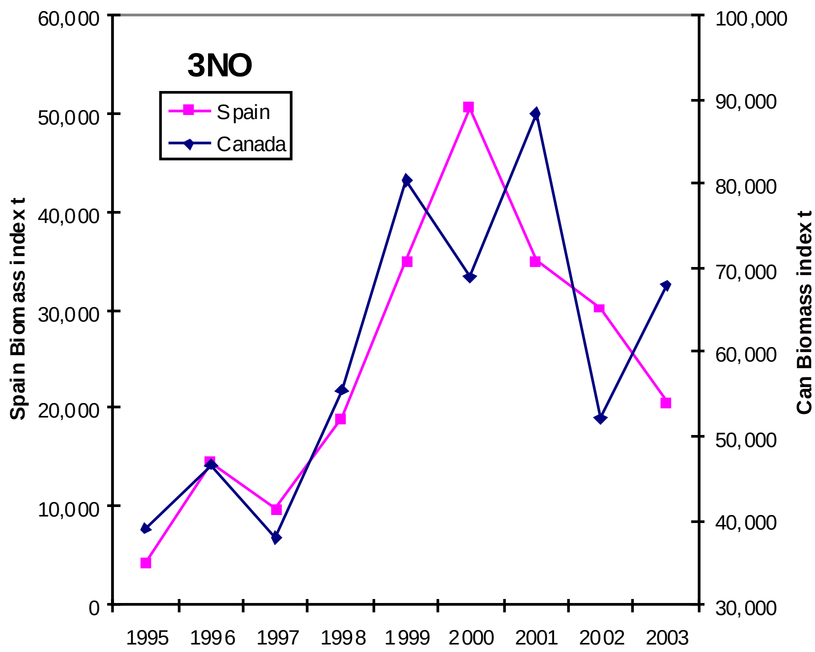


Fig. 6b. Scaled comparison of the Canadian Campelen survey trend from 1995-2003 in NAFO Div. 3NO with the Spanish survey for the same period and area.

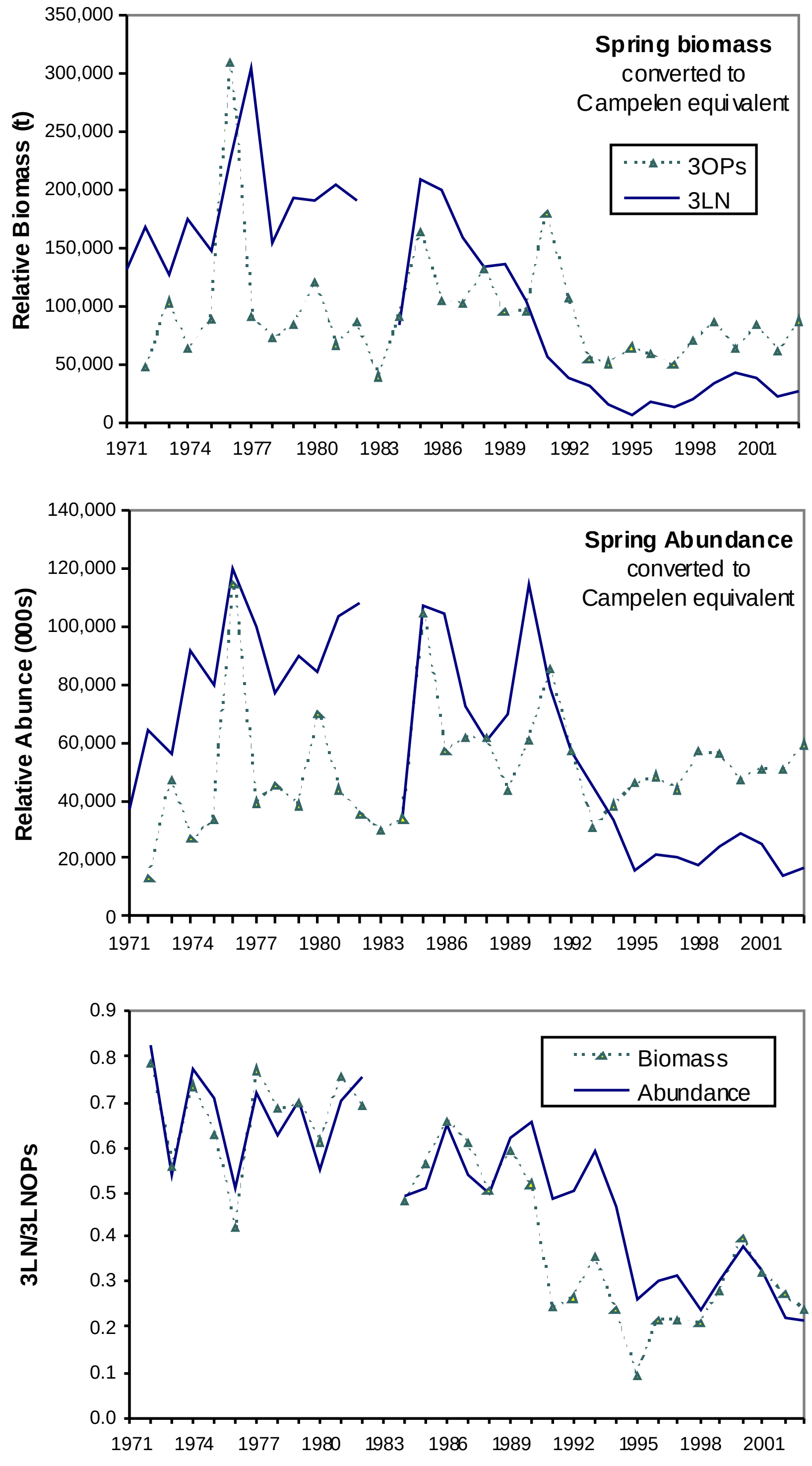
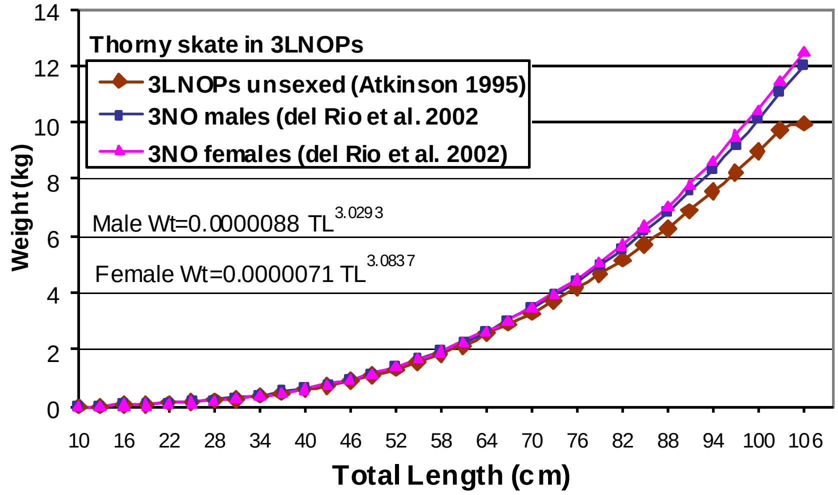
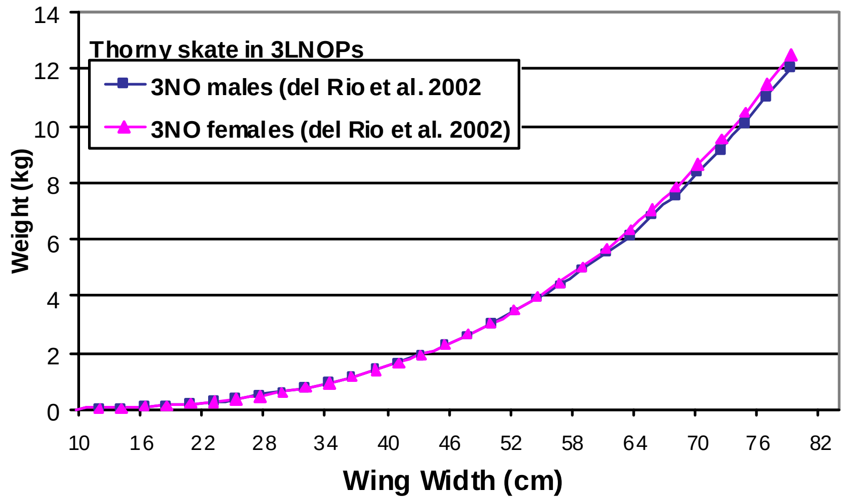


Fig. 7. Relative biomass of thorny skate in 3LN vs. 3OPs, with Engl estimates converted to Campelen equivalents. Some Divisions were not sampled in 1971, 1972, 1974, and 1983.





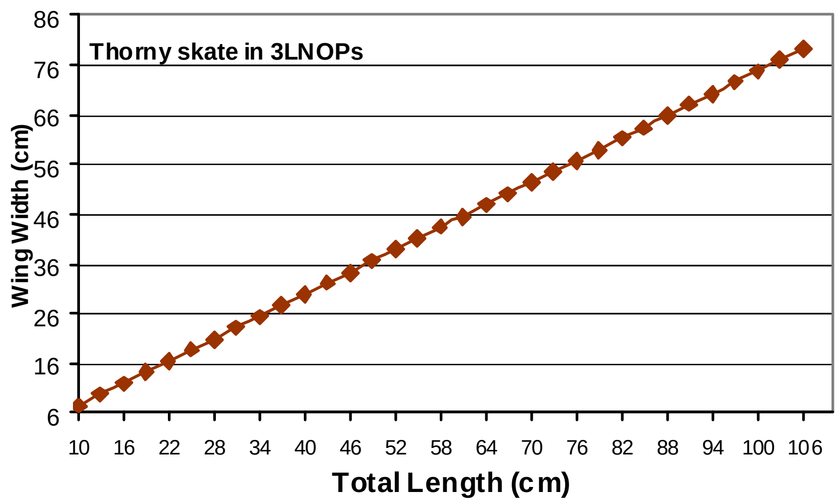


Fig. 8. Total length, average weight, and wing width relationships for thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps (after Atkinson 1995, and del Río *et al*. 2002).

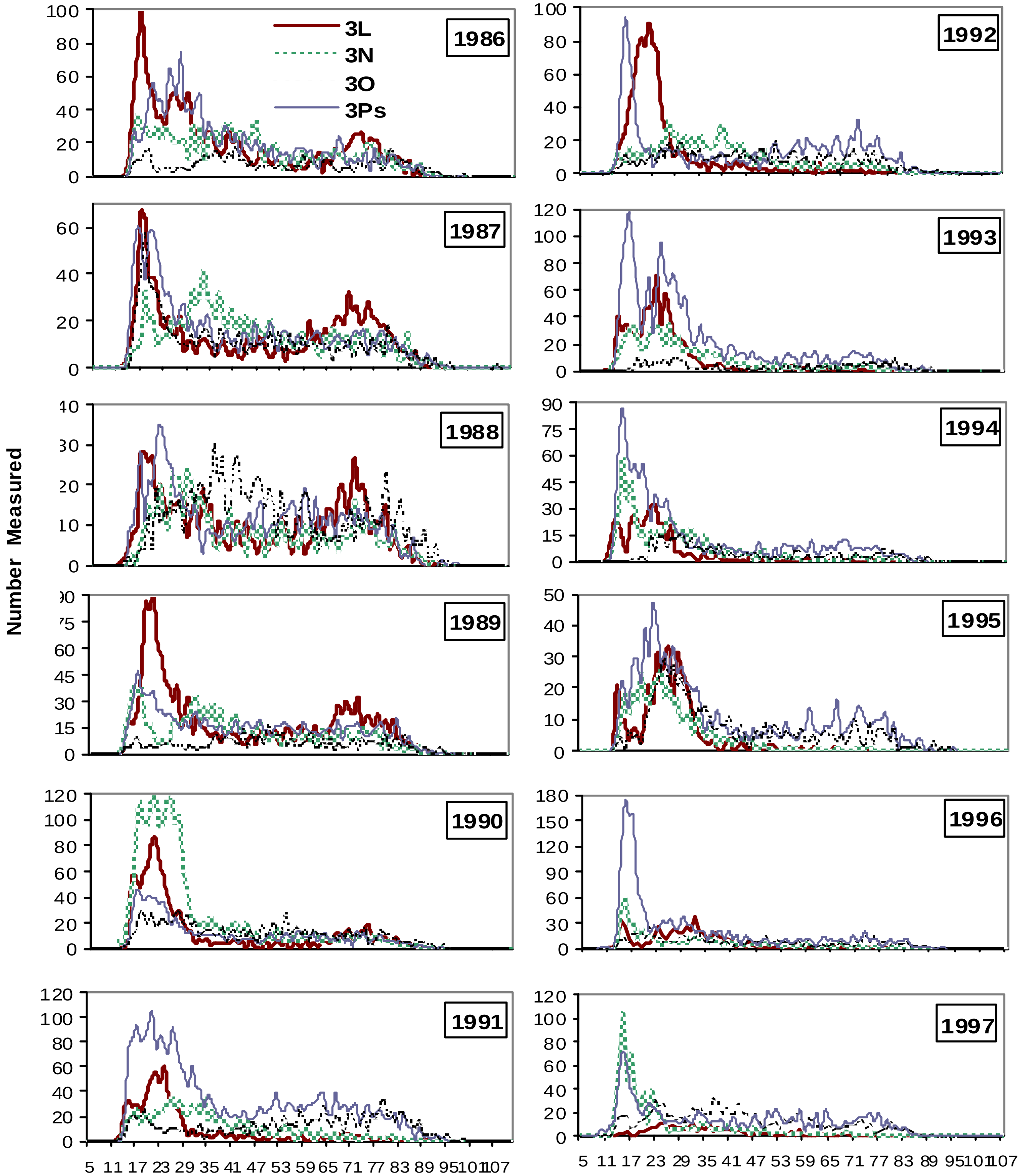


Fig. 9a. Length frequencies of thorny skate caught by spring research vessel surveys in NAFO Divisions 3LNOPs, 1986-2003. X-axis represents the lengths of skate in centimeters.

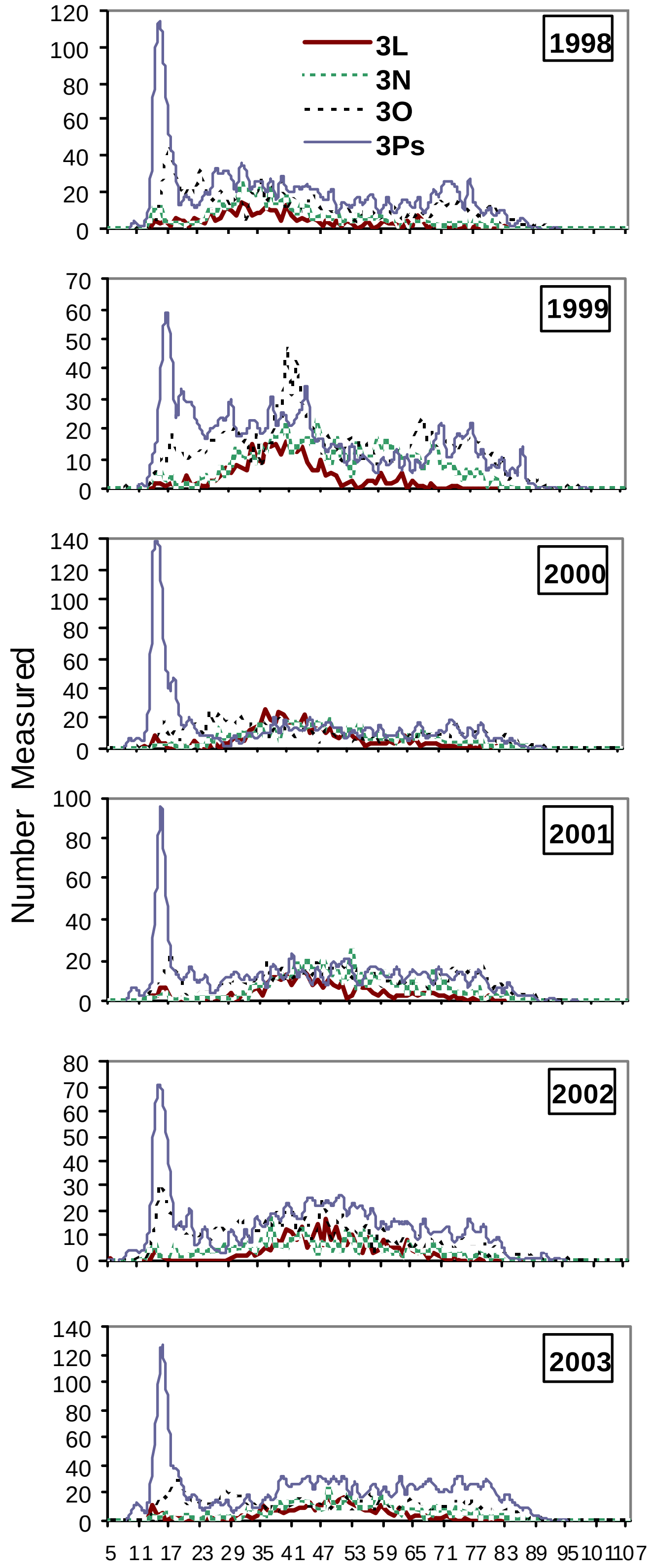


Fig. 9a – continued (1998-2003).

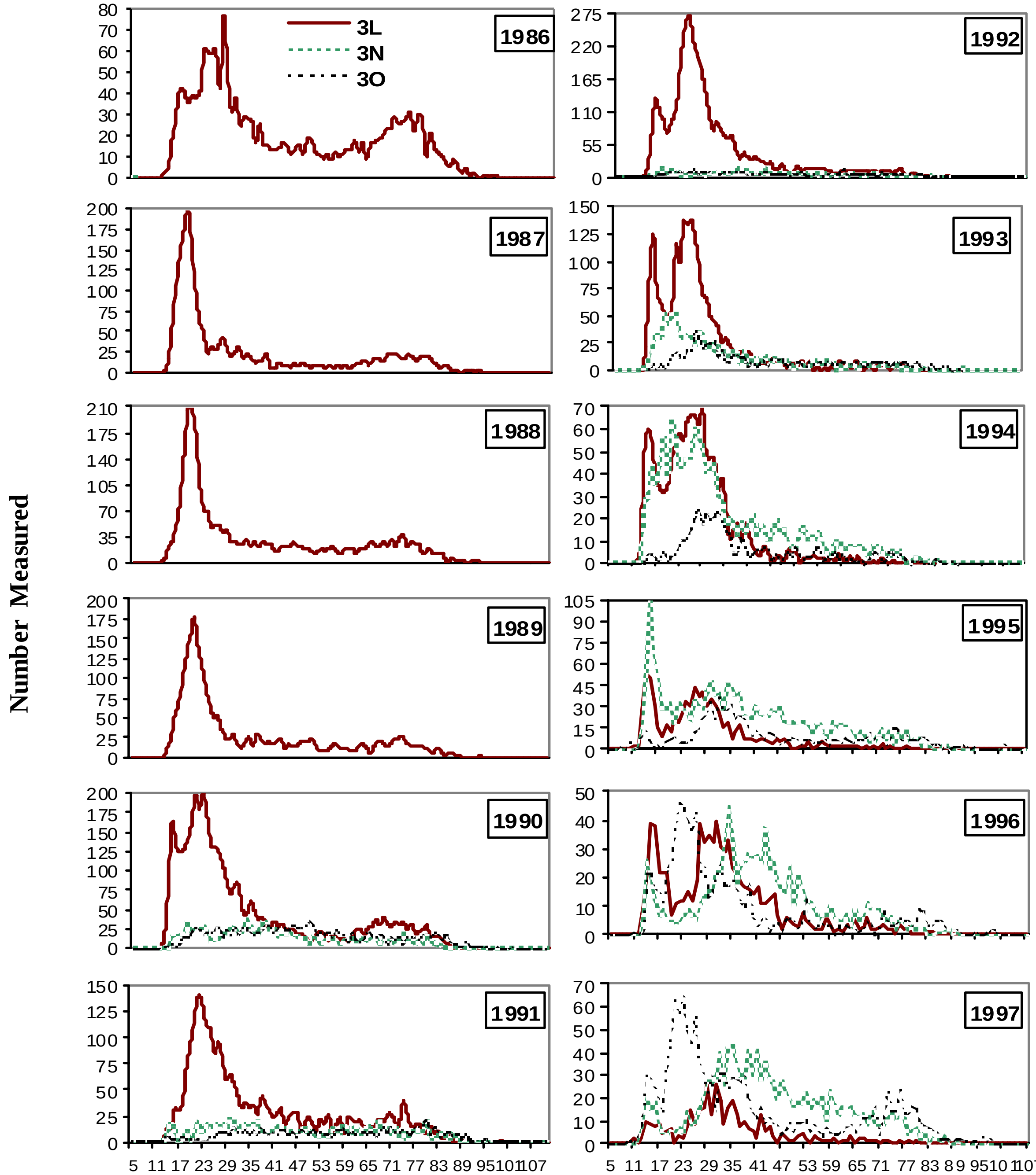


Fig. 9b. Length frequencies of thorny skate caught by fall research vessel surveys in NAFO Divisions 3LNO, 1986-2003. X-axis represents the lengths of skate in centimeters.

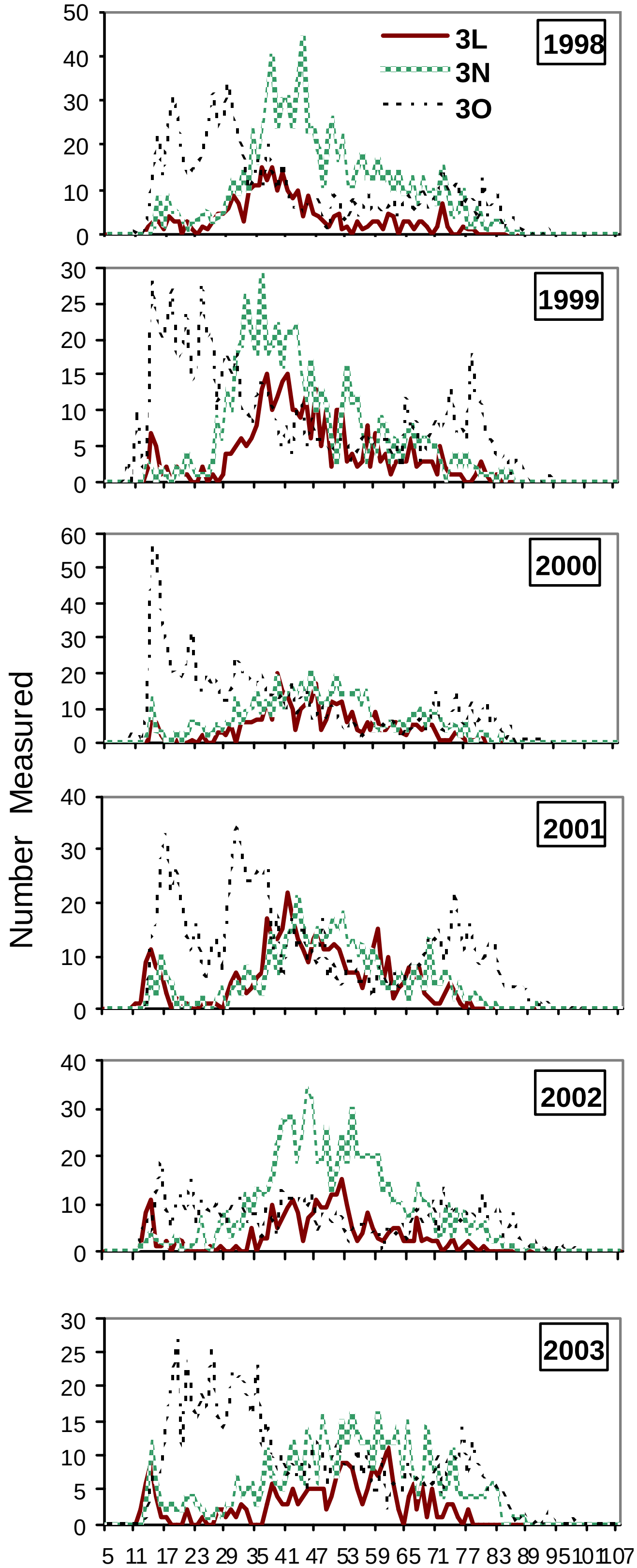


Fig. 9b – continued (1998-2003).

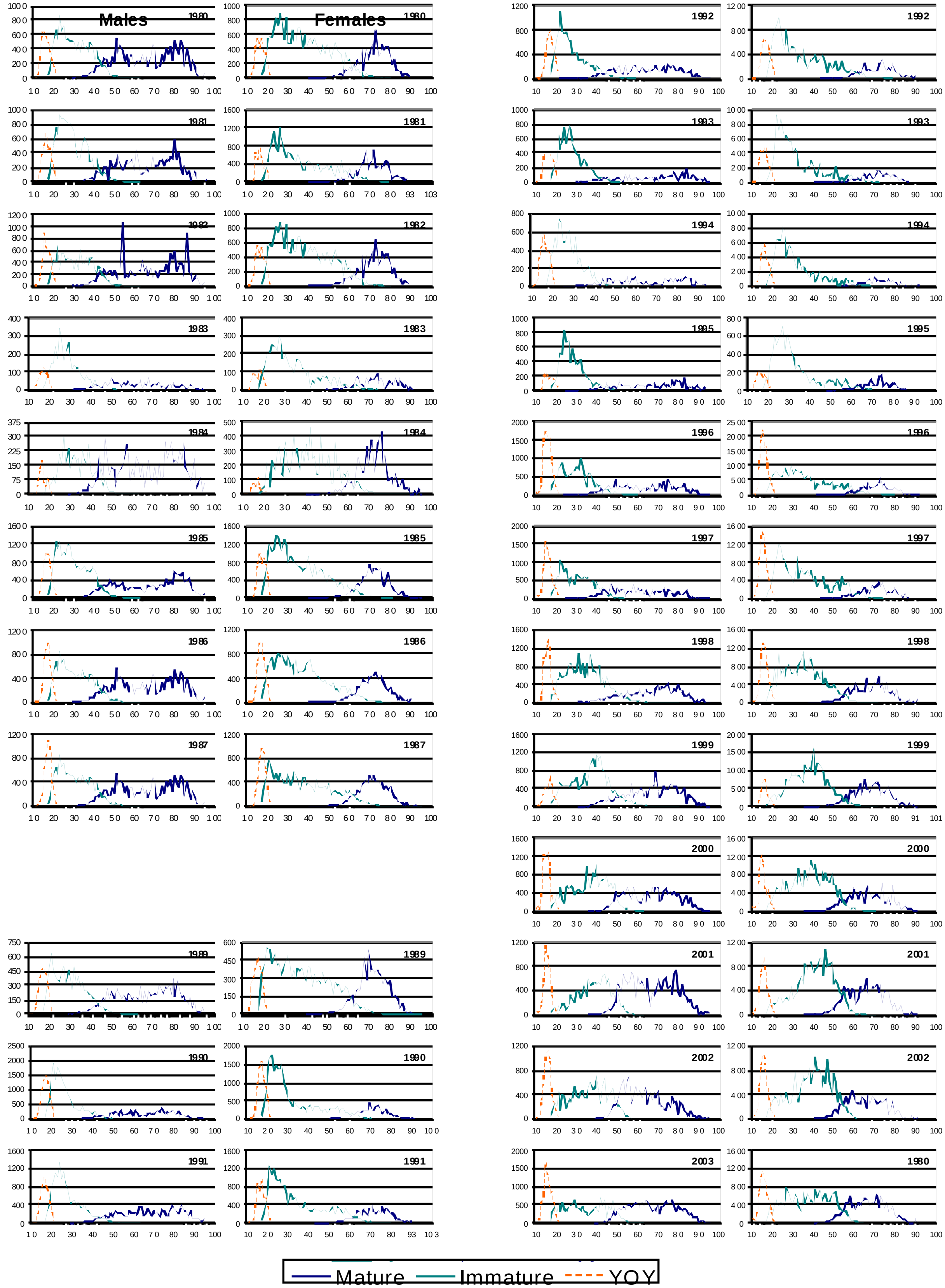


Fig. 10. Numbers at length partitioned into Young of the Year (YOY), Immature, and Mature in 1980-2003 (size at maturity based on del Río 2002 ogives).

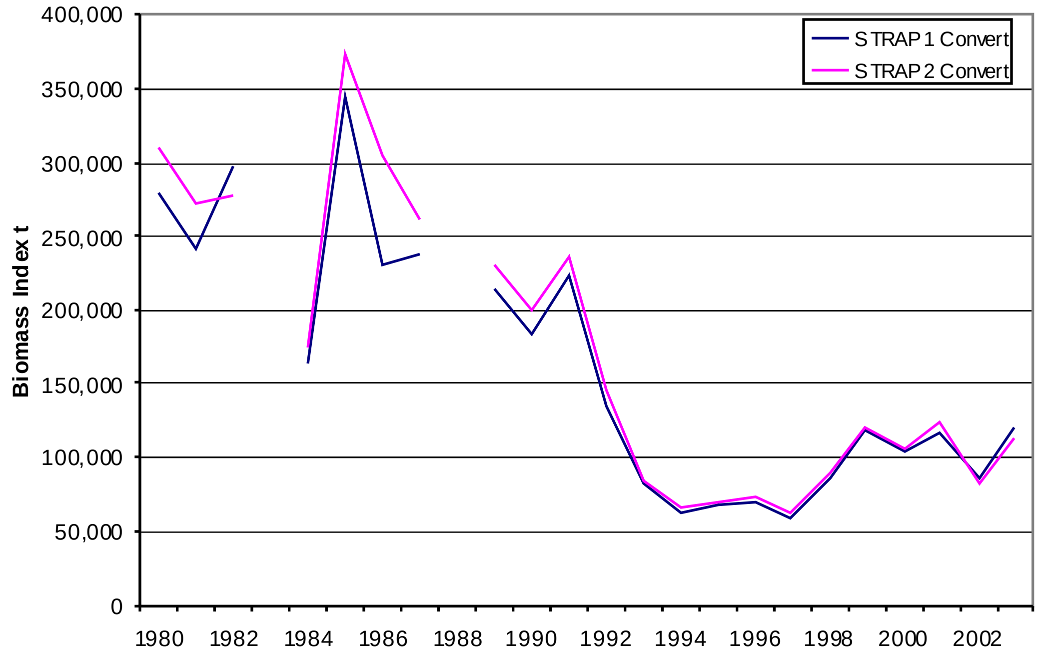


Fig. 11. Comparison of STRAP1 (length based calculation) and STRAP2 (weight based) biomass results.

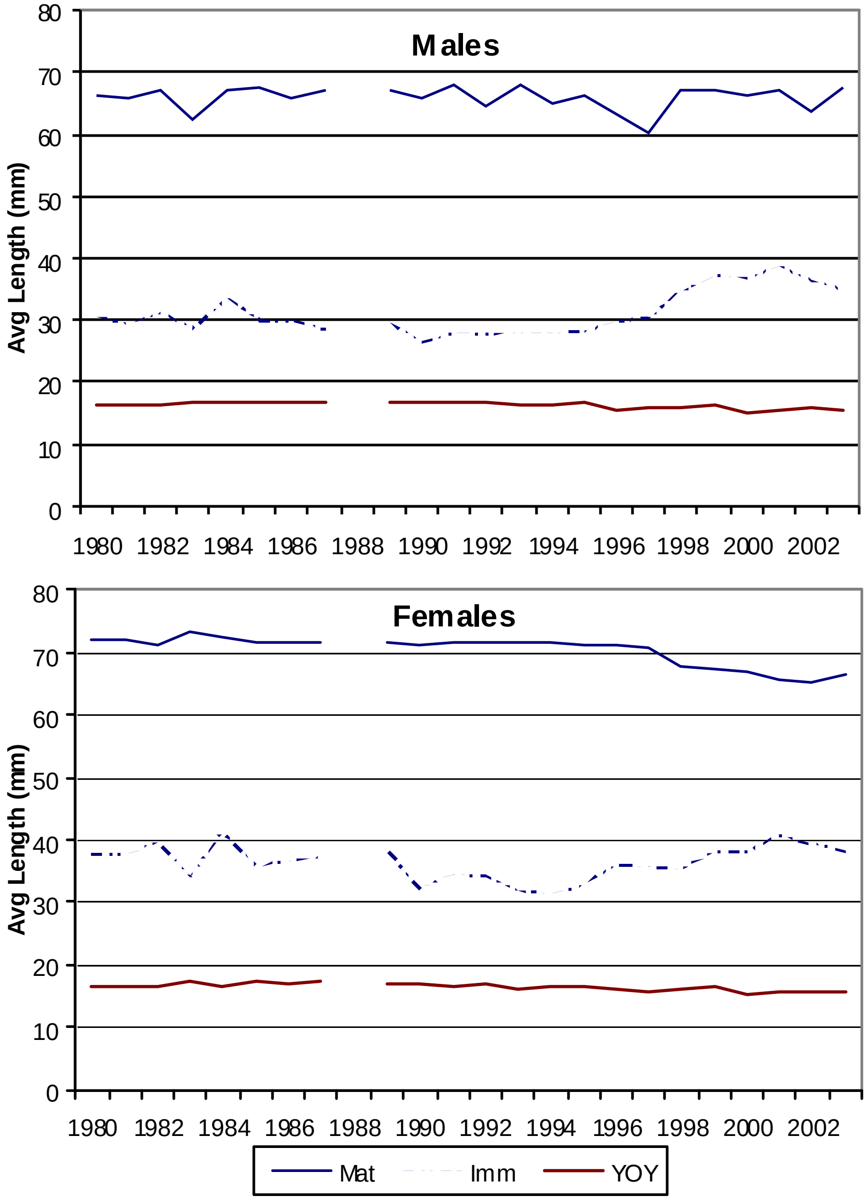


Fig. 12. Average length of Young of the Year (YOY), Immature, and Mature in 1980-2003 (size at maturity based on del Río 2002 ogives).

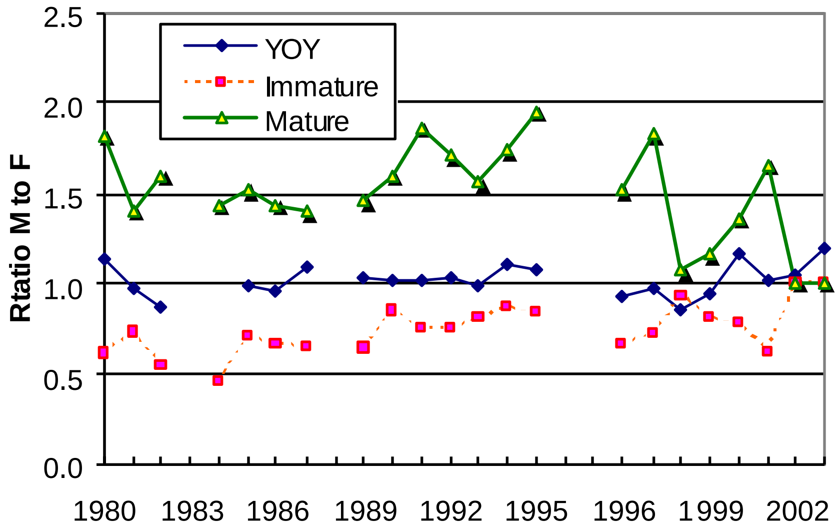


Fig. 13. Ratio of males to females for YOY (young of the year), immature, and mature thorny skates, 1980-2003.

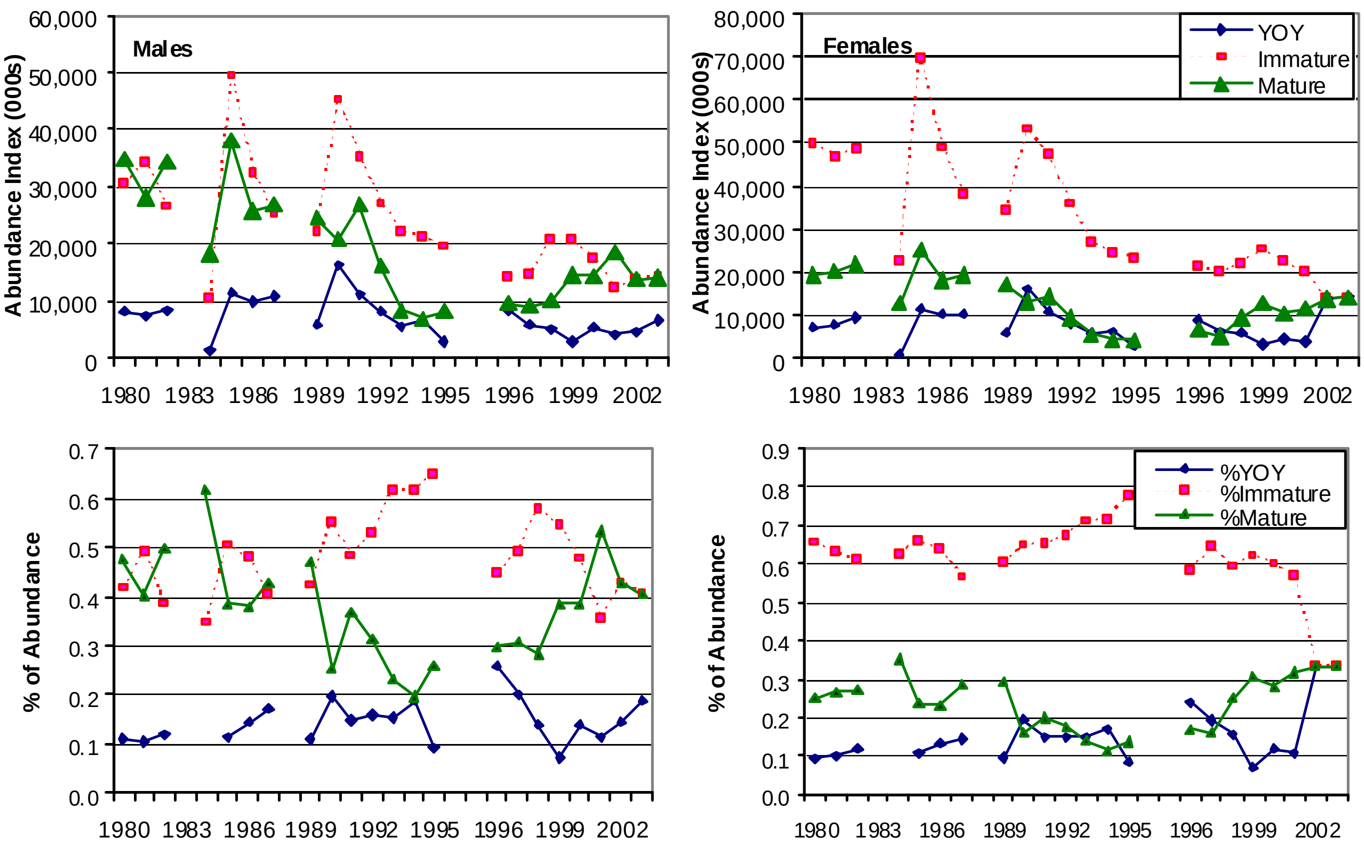


Fig. 14a. Trends in abundance by stage and percent of total abundance that is young of the year (YOY), immature, and mature, depicted separately by sex, 1980-2003.

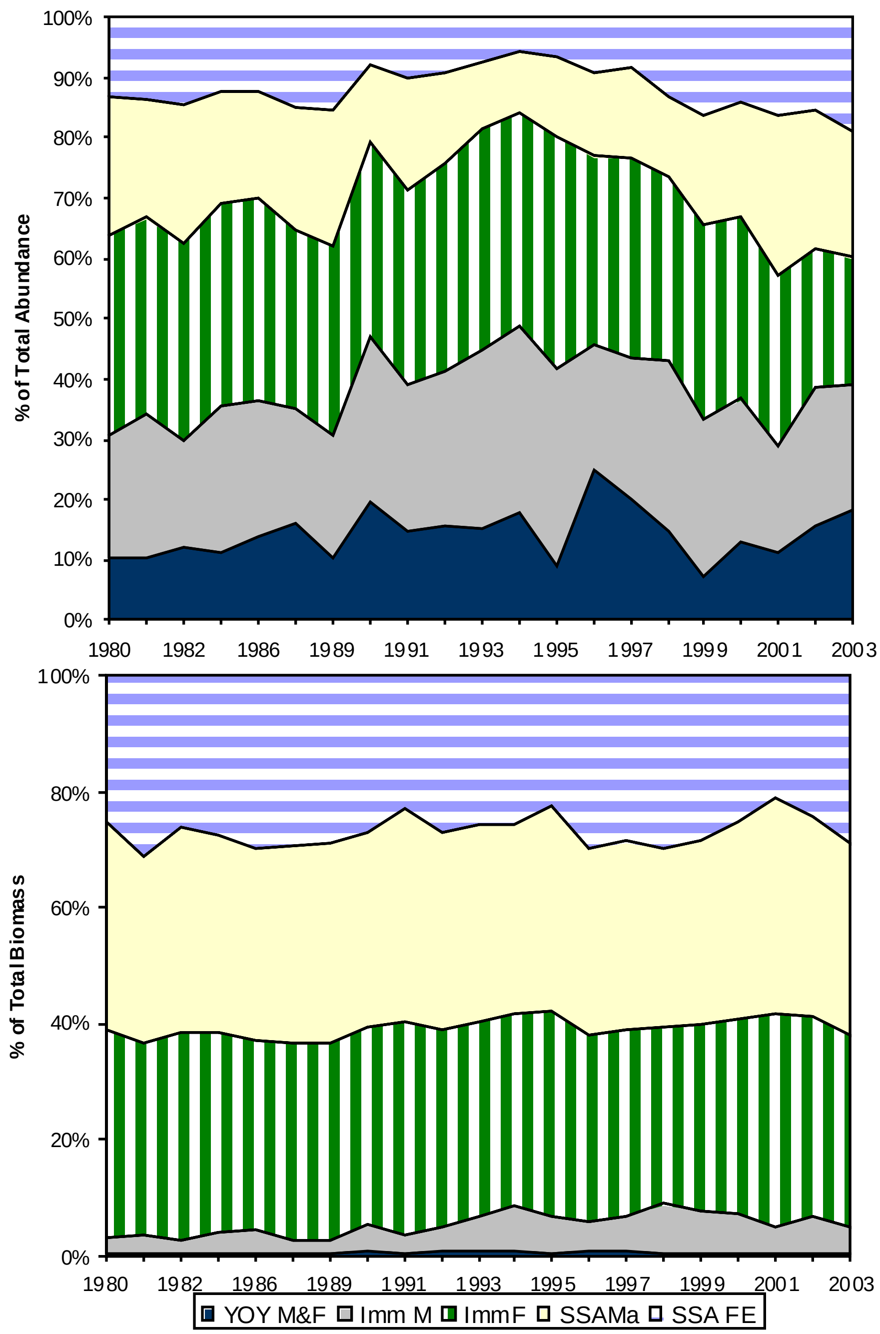


Fig. 14b. Proportion of biomass and abundance by stage, 1980-2003.

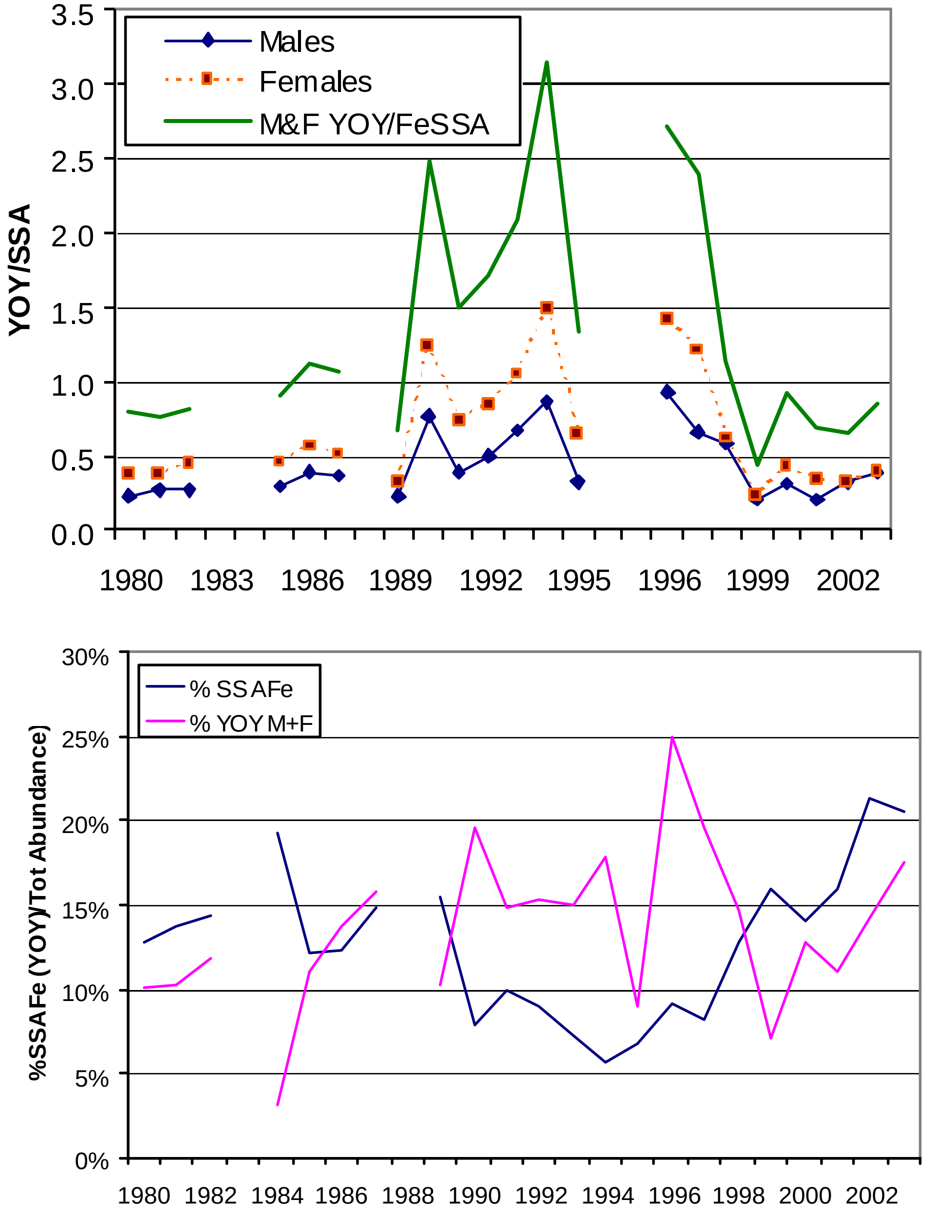


Fig. 15. Relationship between male and female thorny skate young of the year (YOY) and female spawning stock abundance (SSA).
Upper Panel: Ratio of YOY (young of the year) to SSA (spawning stock abundance; consisting of mature females), 1980-2003.
Lower Panel: relationship of YOY and SSA to total abundance derived from spring research surveys.

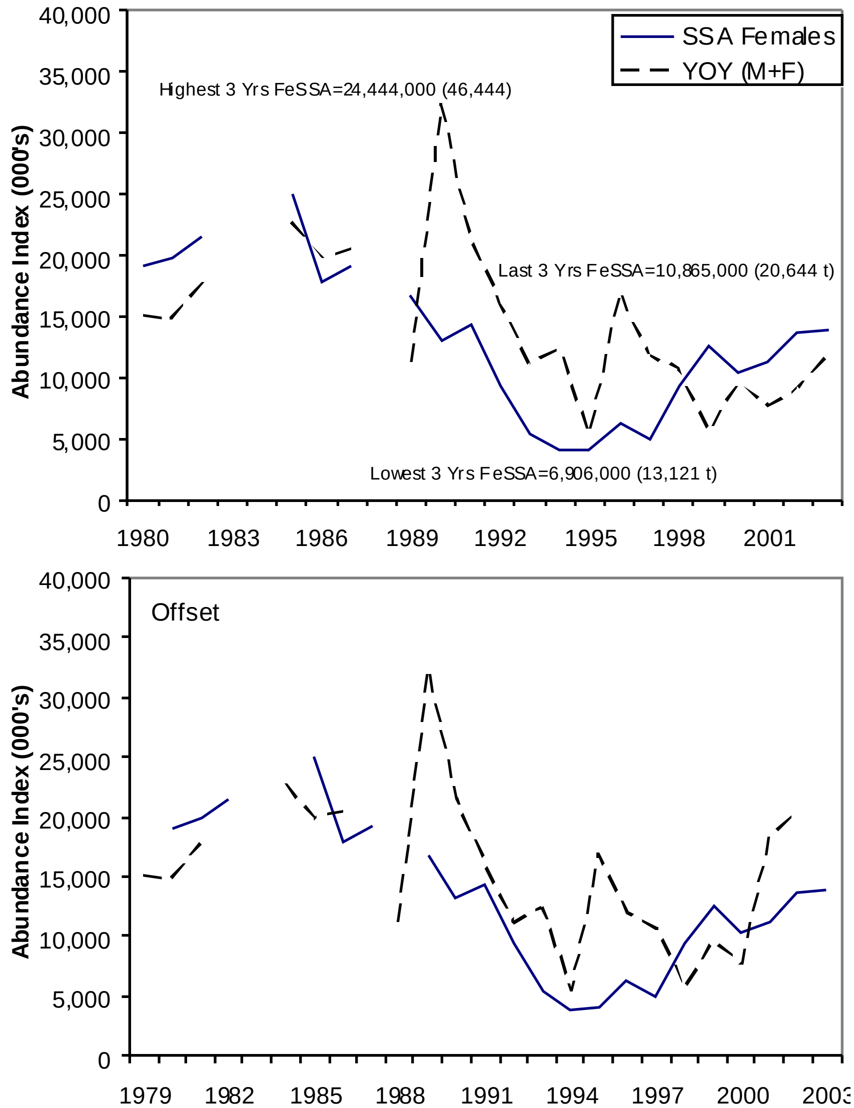


Fig. 16. Recruitment Index (male plus female) and Spawning Stock Abundance (SSA female) Index for thorny skates, 1980-2003. Lower graph shows the YOY offset by one year.

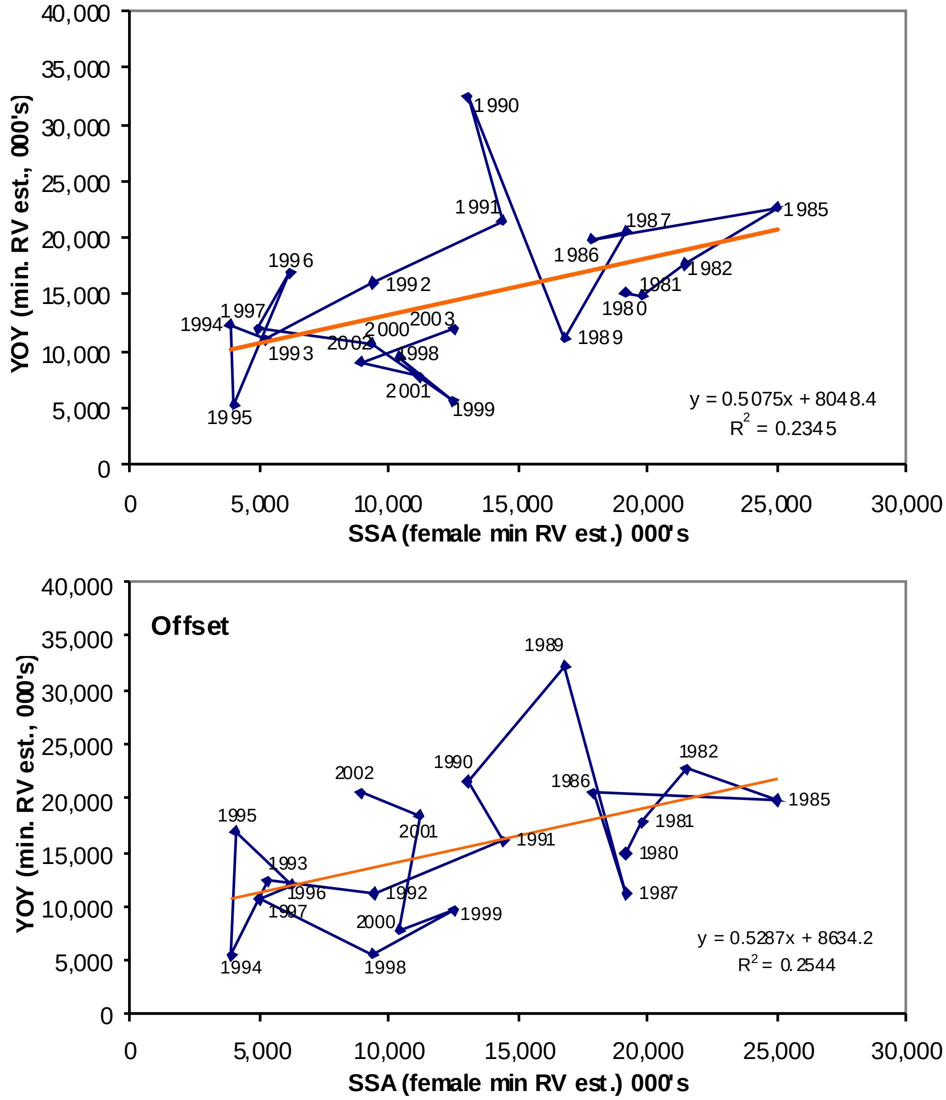


Fig. 17a. Spawning Stock (Female abundance) versus Recruit (male plus female) Indices for thorny skates, 1980-2003. Lower graph shows the YOY offset by one year.

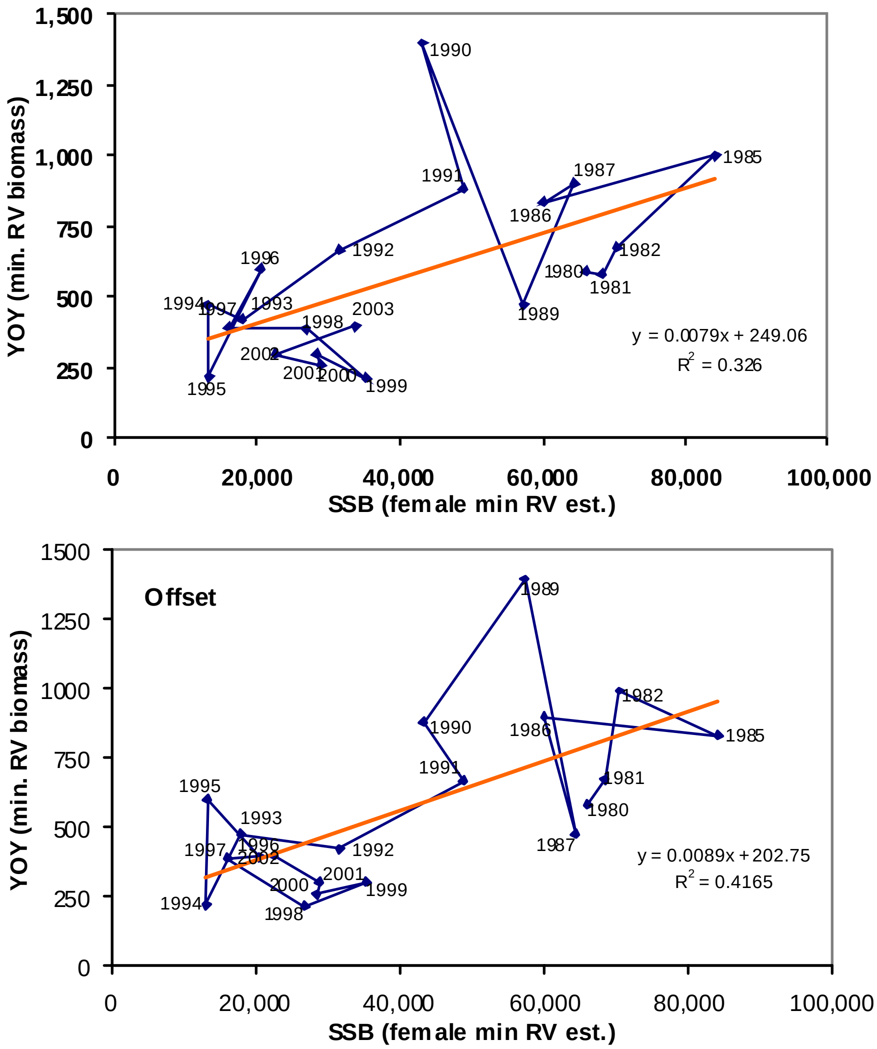


Fig. 17b. Spawning Stock (Female biomass) versus Recruit (male plus female YOY biomass) Indices for thorny skates, 1980-2003. Lower graph shows the YOY offset by one year.

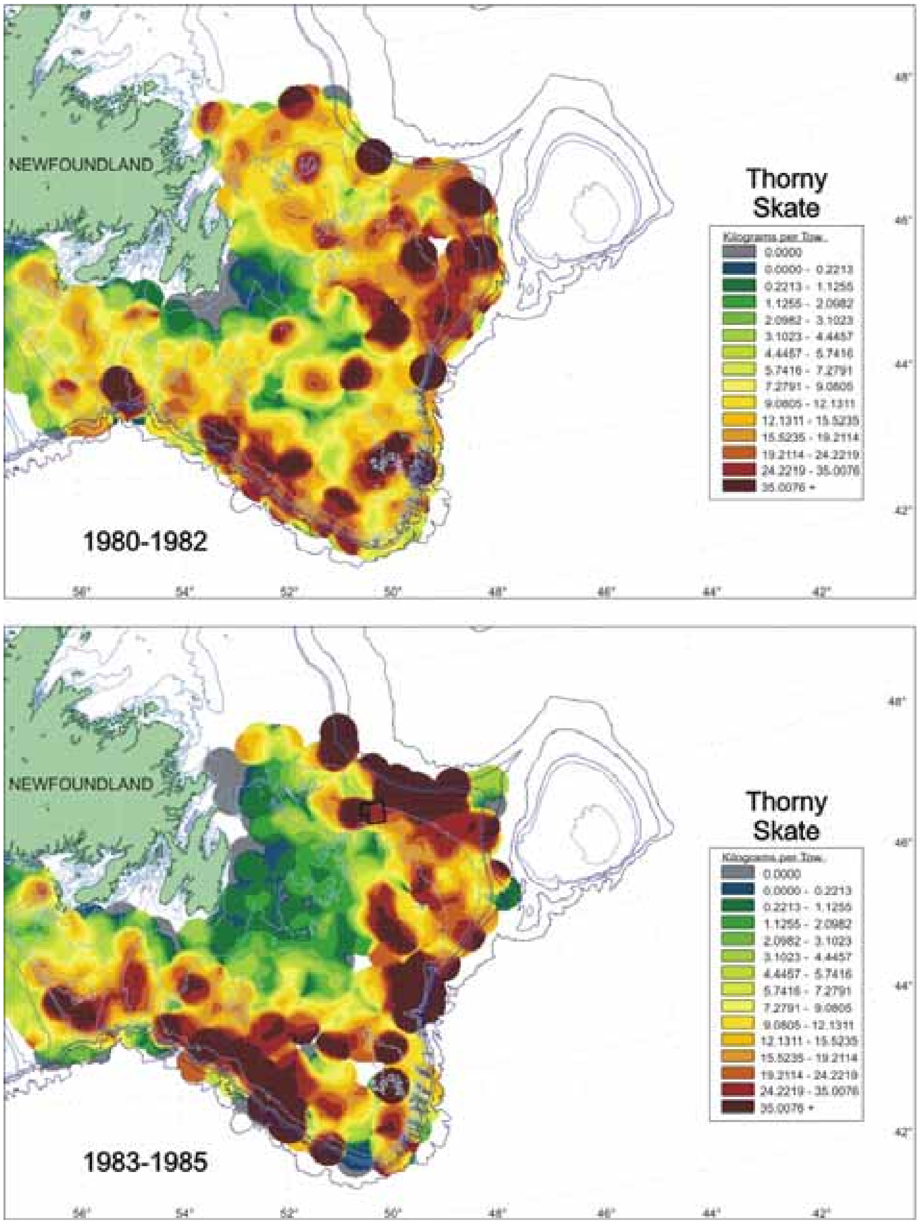
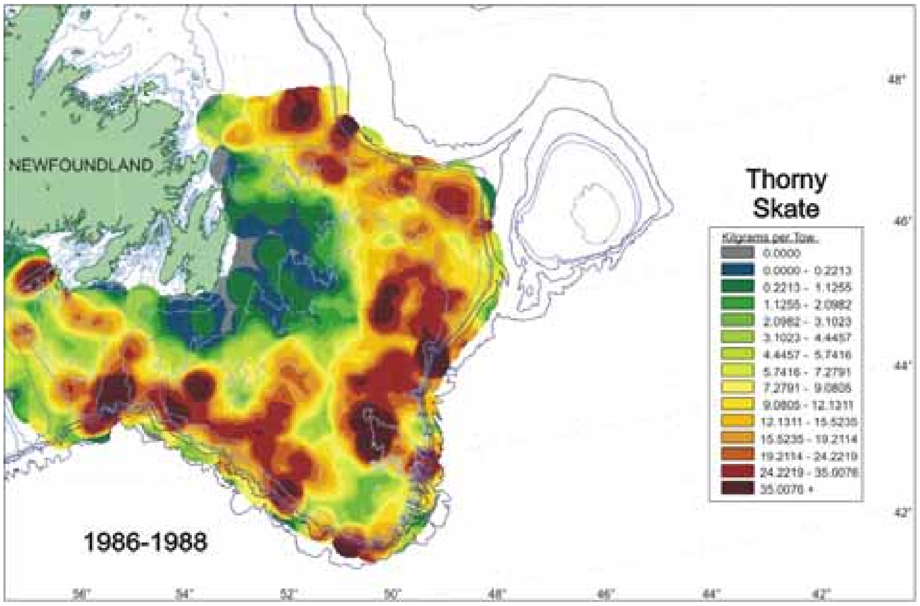


Fig. 18a. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **spring** surveys in 1980-1982 and 1983-1985 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.



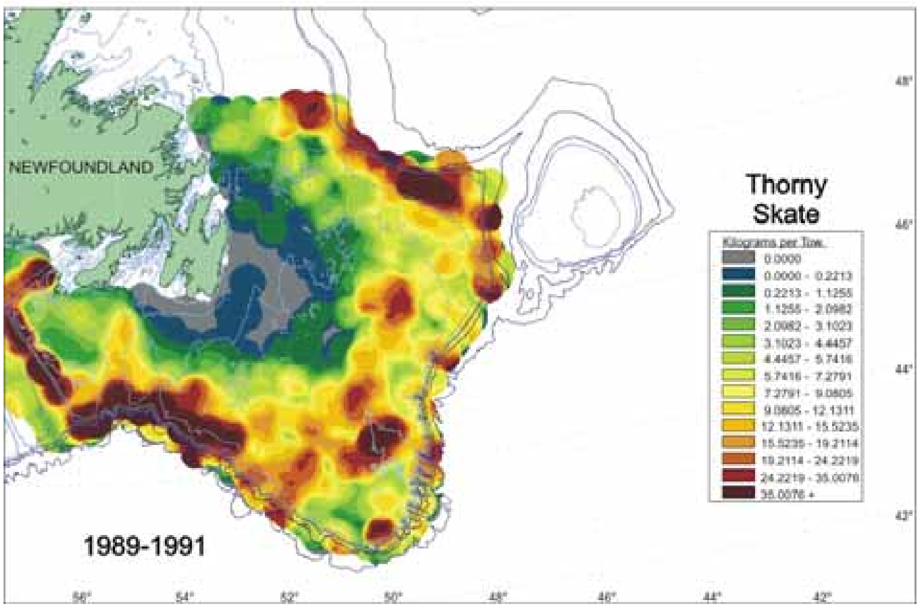


Fig. 18b. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **spring** surveys in 1986-1988 and 1989-1991 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

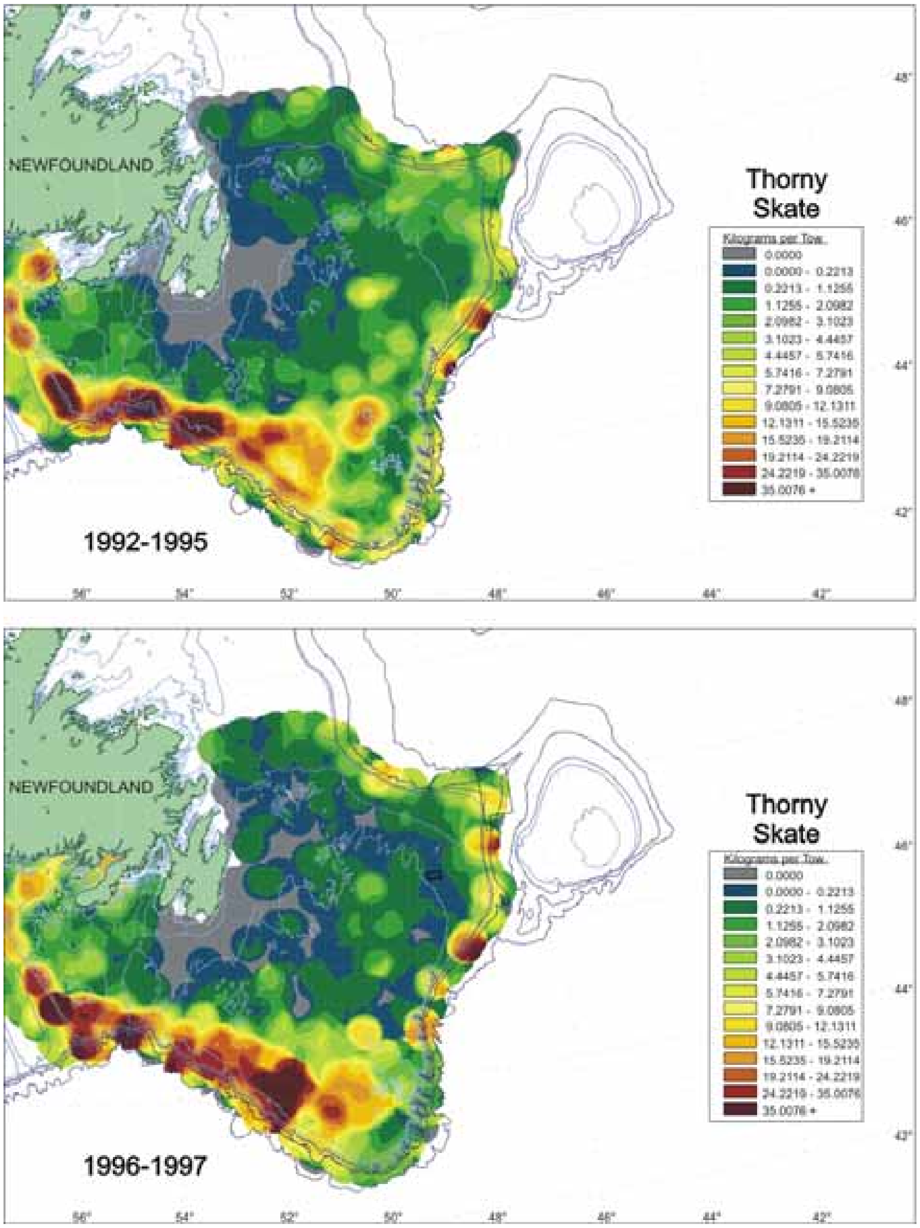


Fig. 18c. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **spring** surveys in 1992-1995 and 1996-1997 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

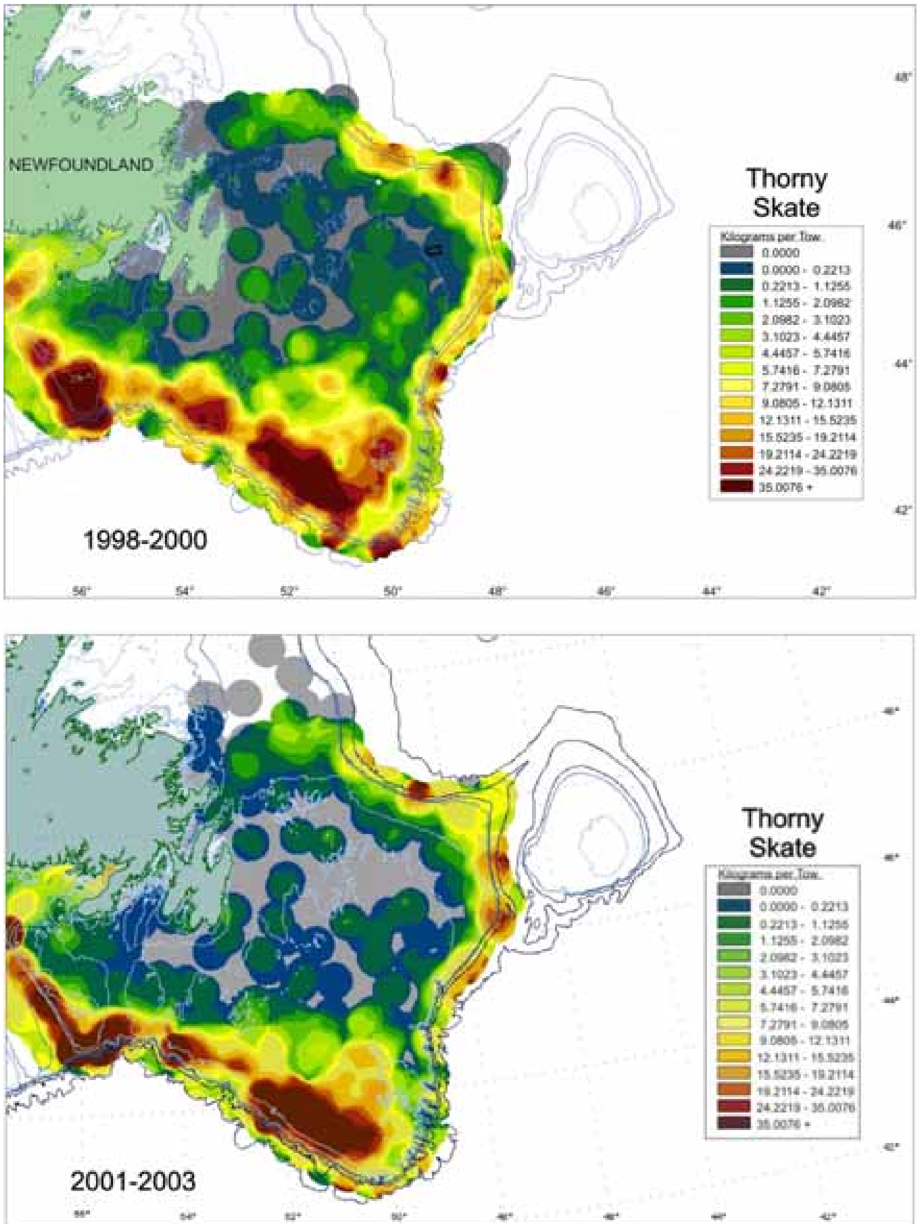


Fig. 18d. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **spring** surveys in 1998-2000 and 2001-2003 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

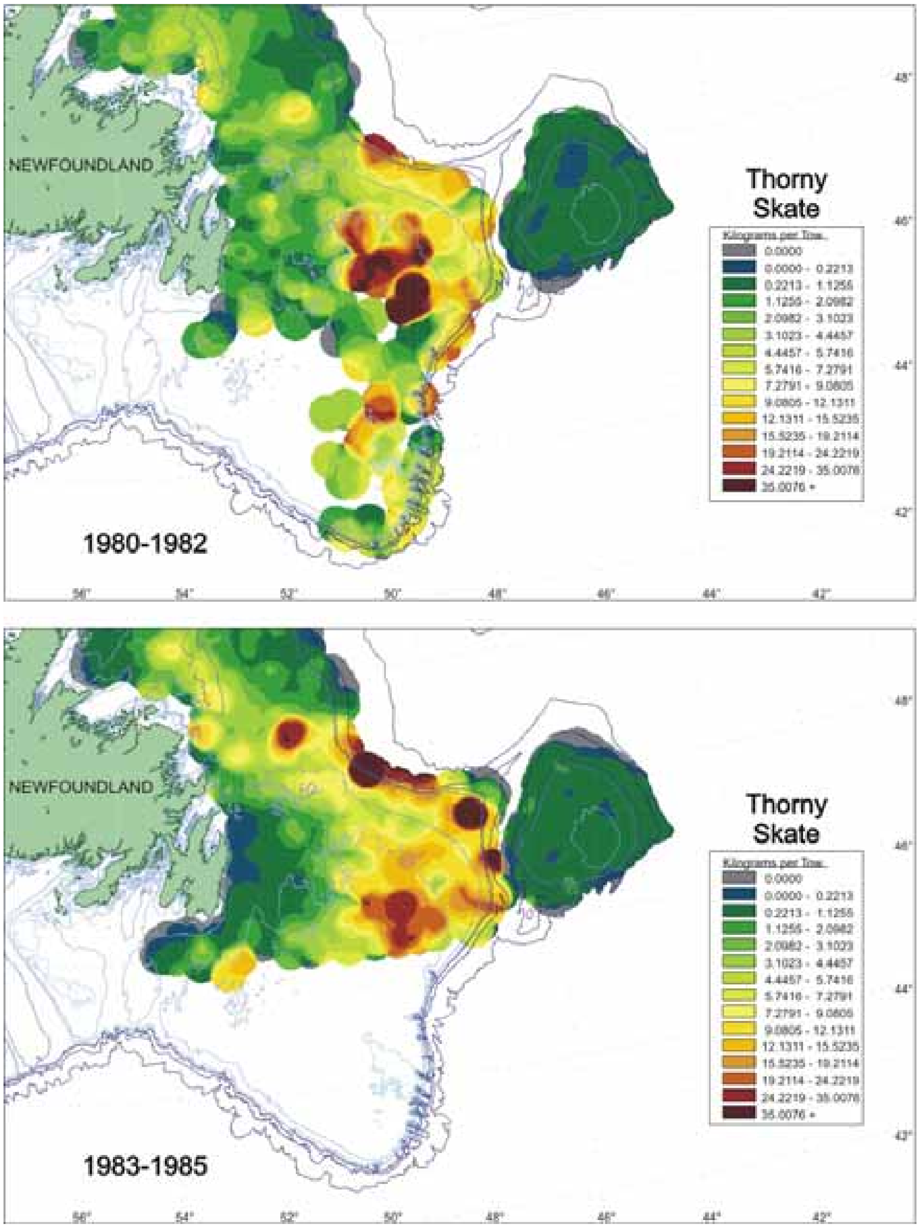


Fig. 19a. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **fall** surveys in 1981-1982 and 1983-1985 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

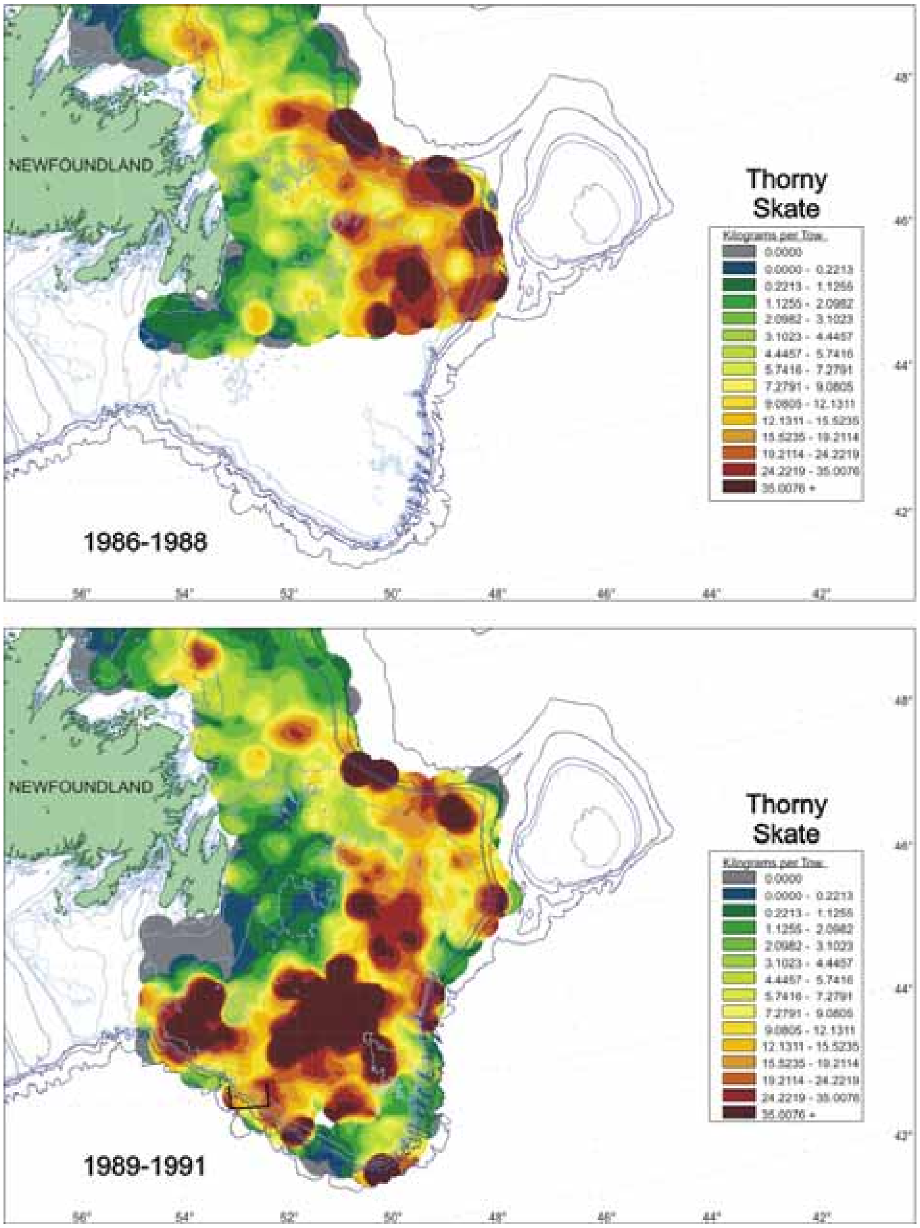


Fig. 19b. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **fall** surveys in 1986-1988 and 1989-1991 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

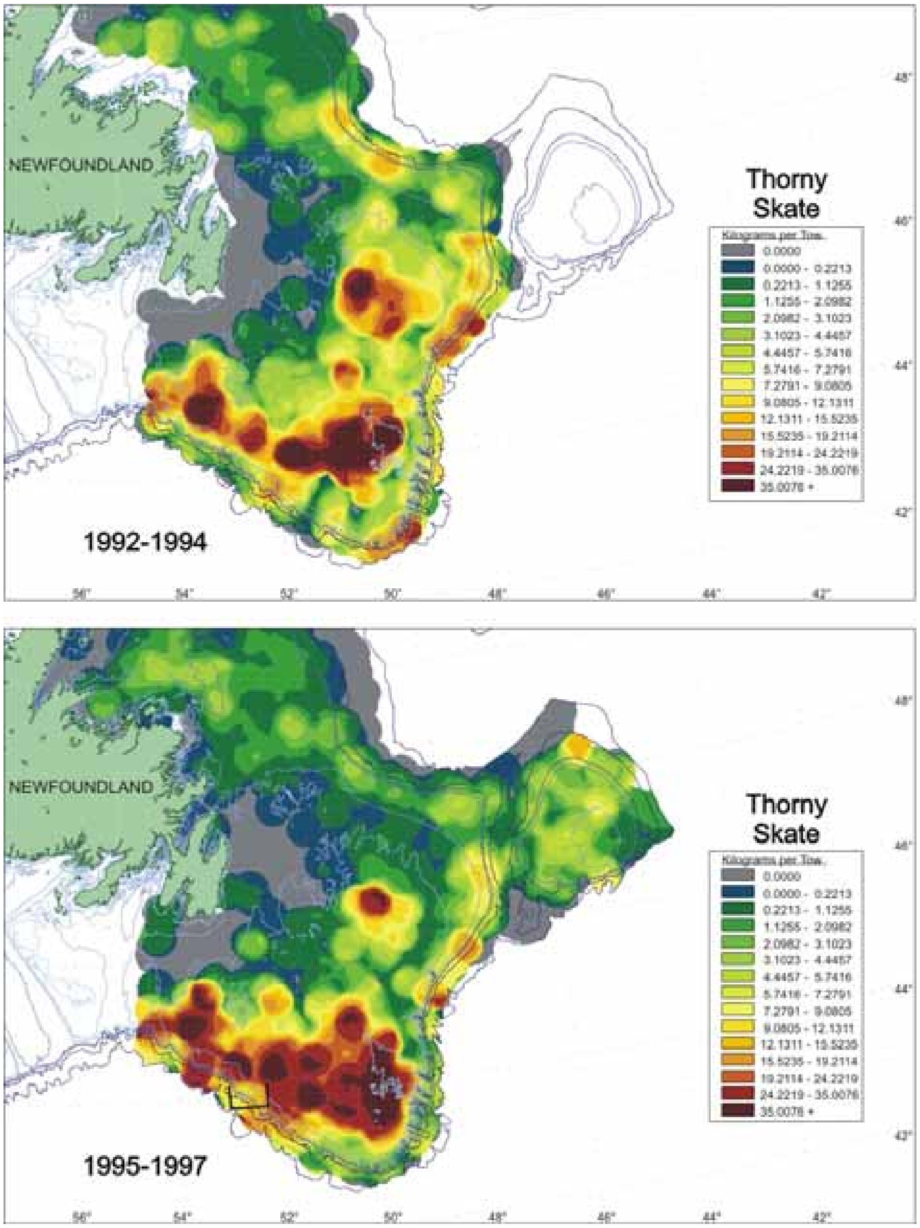


Fig. 19c. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **fall** surveys in 1992-1994 and 1995-1997 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

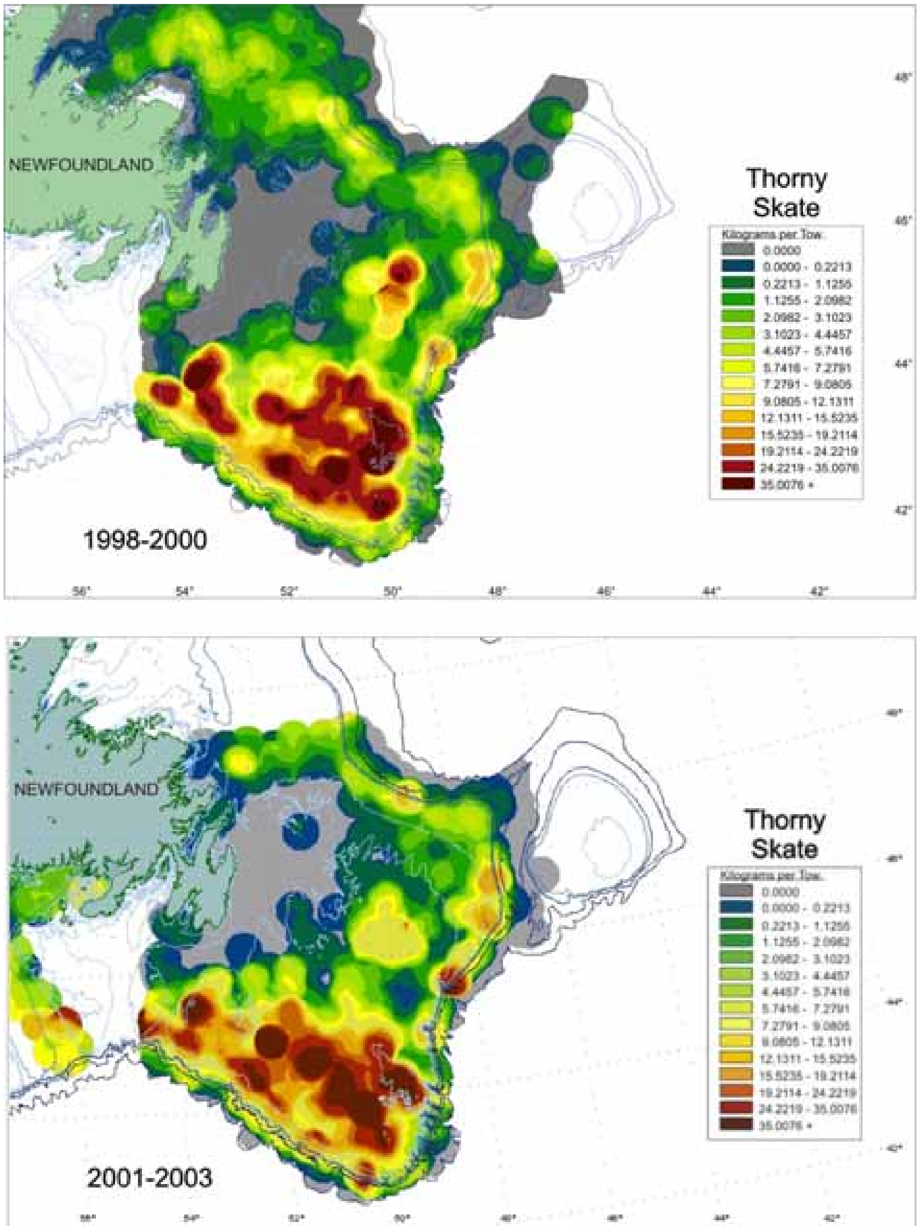
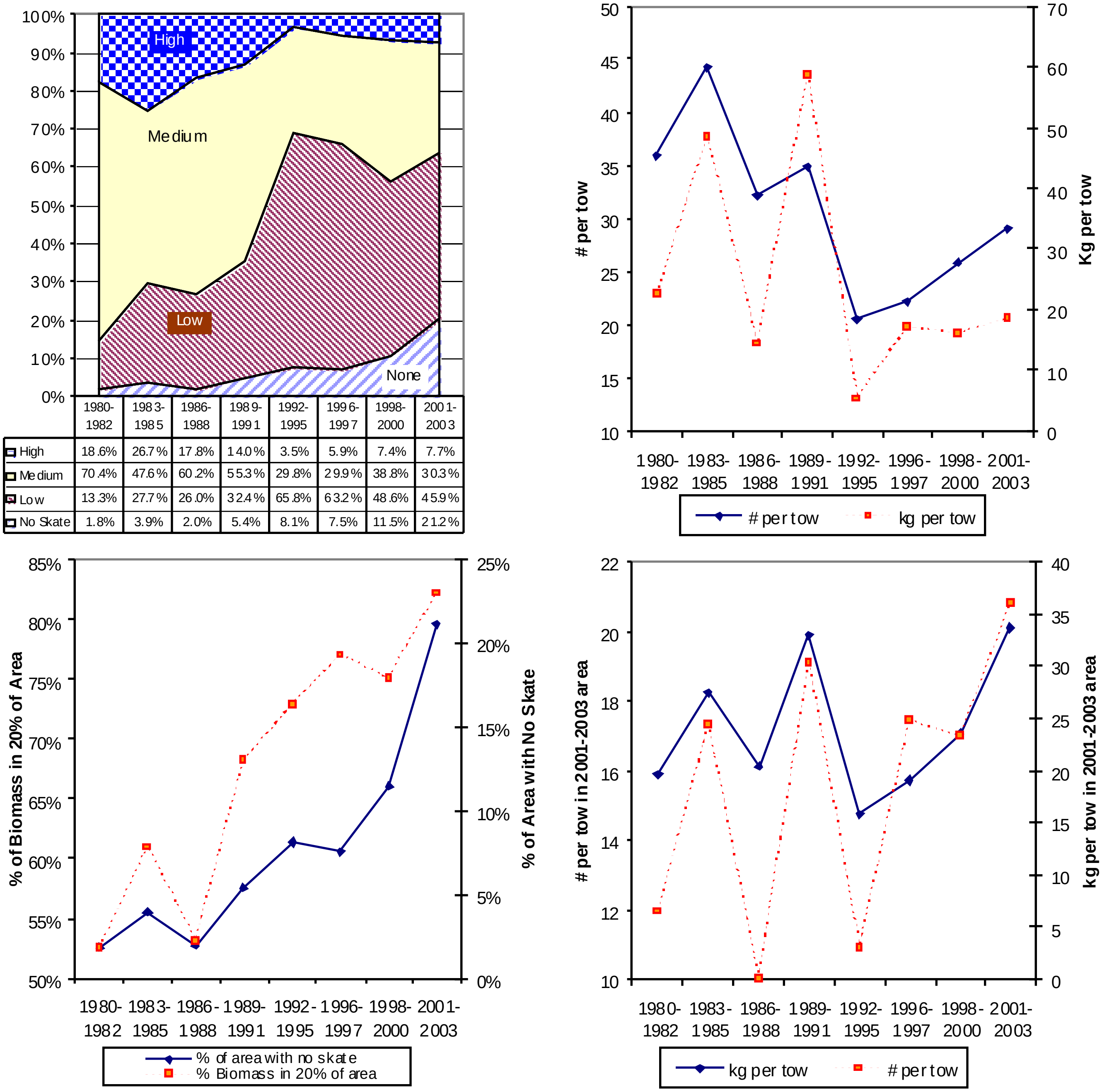
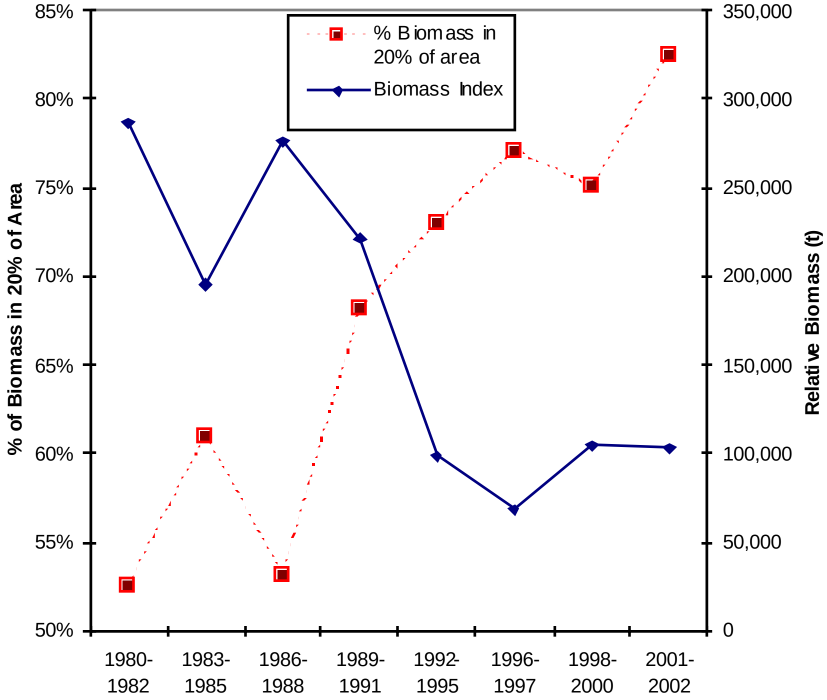


Fig. 19d. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **fall** surveys in 1998-2000 and 2001-2003 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.



	1980-1982	1983-1985	1986-1988	1989-1991	1992-1995	1996-1997	1998-2000	2001-2003
High	18.6%	26.7%	17.8%	14.0%	3.5%	5.9%	7.4%	7.7%
Medium	70.4%	47.6%	60.2%	55.3%	29.8%	29.9%	38.8%	30.3%
Low	13.3%	27.7%	26.0%	32.4%	65.8%	63.2%	48.6%	45.9%
No Skate	1.8%	3.9%	2.0%	5.4%	8.1%	7.5%	11.5%	21.2%

Fig. 20. Changes in area of occupancy, based on **spring** survey data, 1980-2003: Upper Left – percent of the area (3LNOPs) with none, low, medium, and high densities of thorny skate; Lower Left - percent of the area (3LNOPs) without thorny skate (solid line), and percent of biomass contained within 20% of the total area (dotted line); Upper Right – density (number and weight per tow) of skate in 20% of the area for those years; Lower Right – density (number and weight per tow) of skate in 20% of the 2001-2003 high density area.



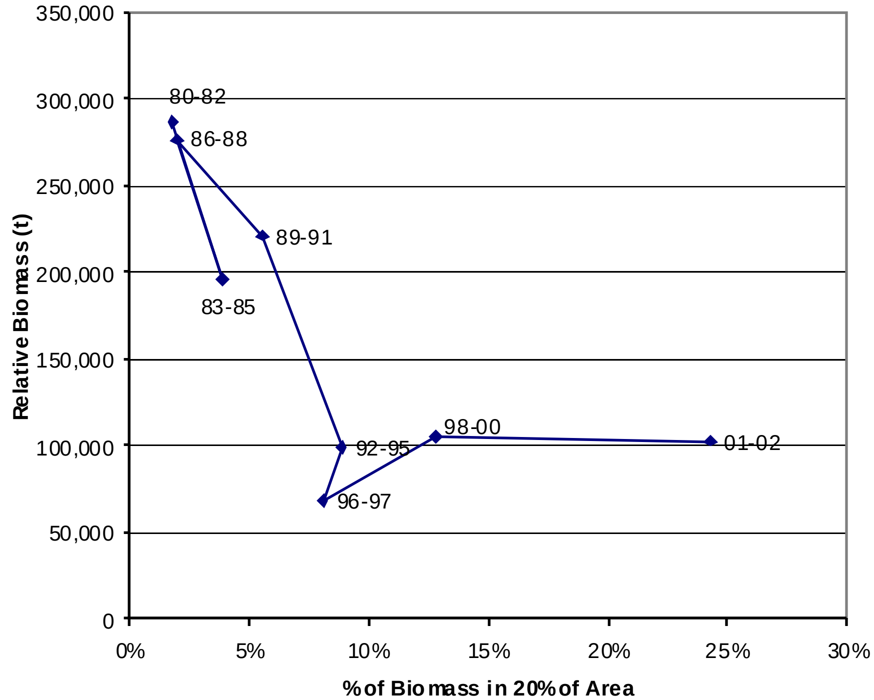


Fig. 21. Changes in area of occupancy, based on **spring** survey data, 1980-2003: Left – percent of biomass contained within 20% of the total area (dotted line) compared to the survey biomass trajectory; Right – Relative biomass in relation to biomass concentration as a time line.

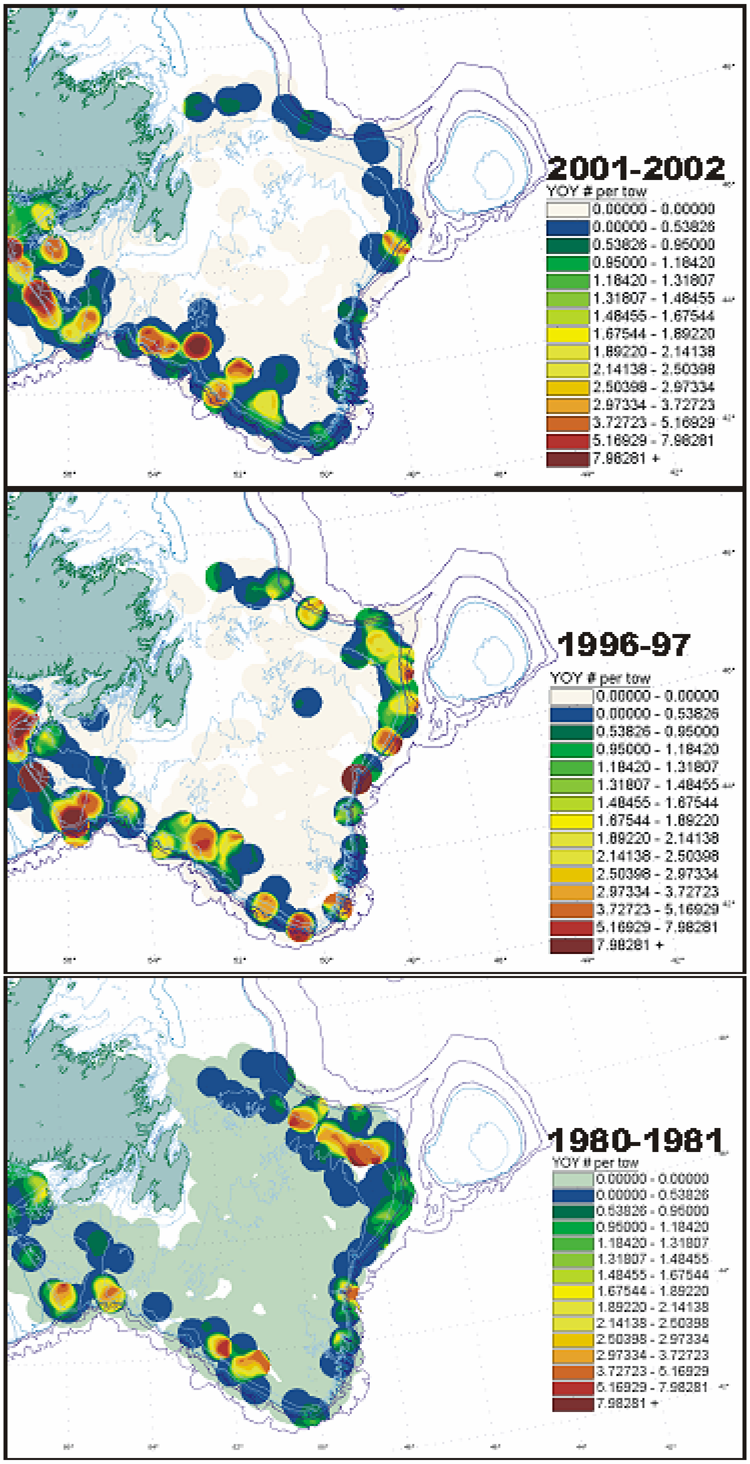


Fig. 22a. Distribution of thorny skate young of the year (YOY) during spring research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

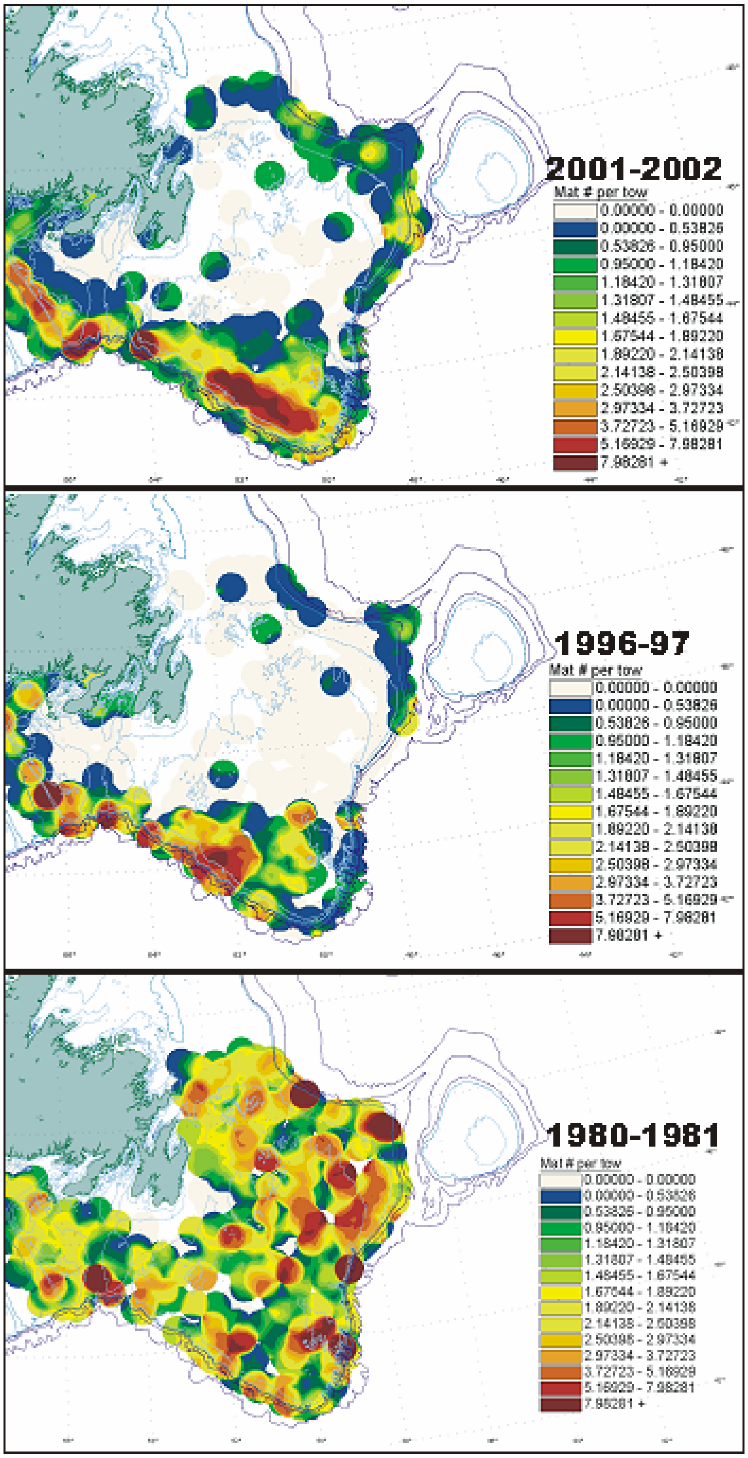


Fig. 22b. Distribution of mature male and female thorny skates during spring research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

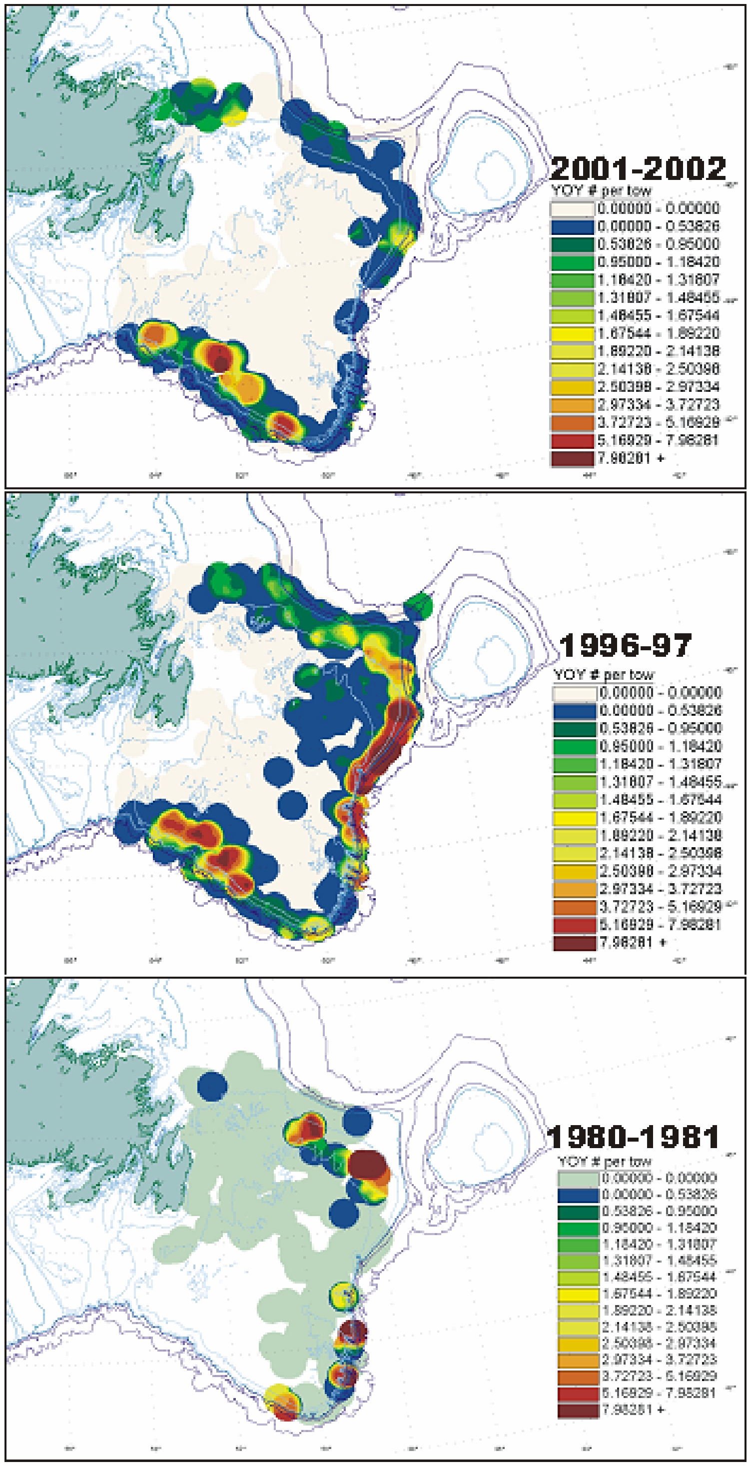


Fig. 22c. Distribution of thorny skate young of the year (YOY) during fall research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

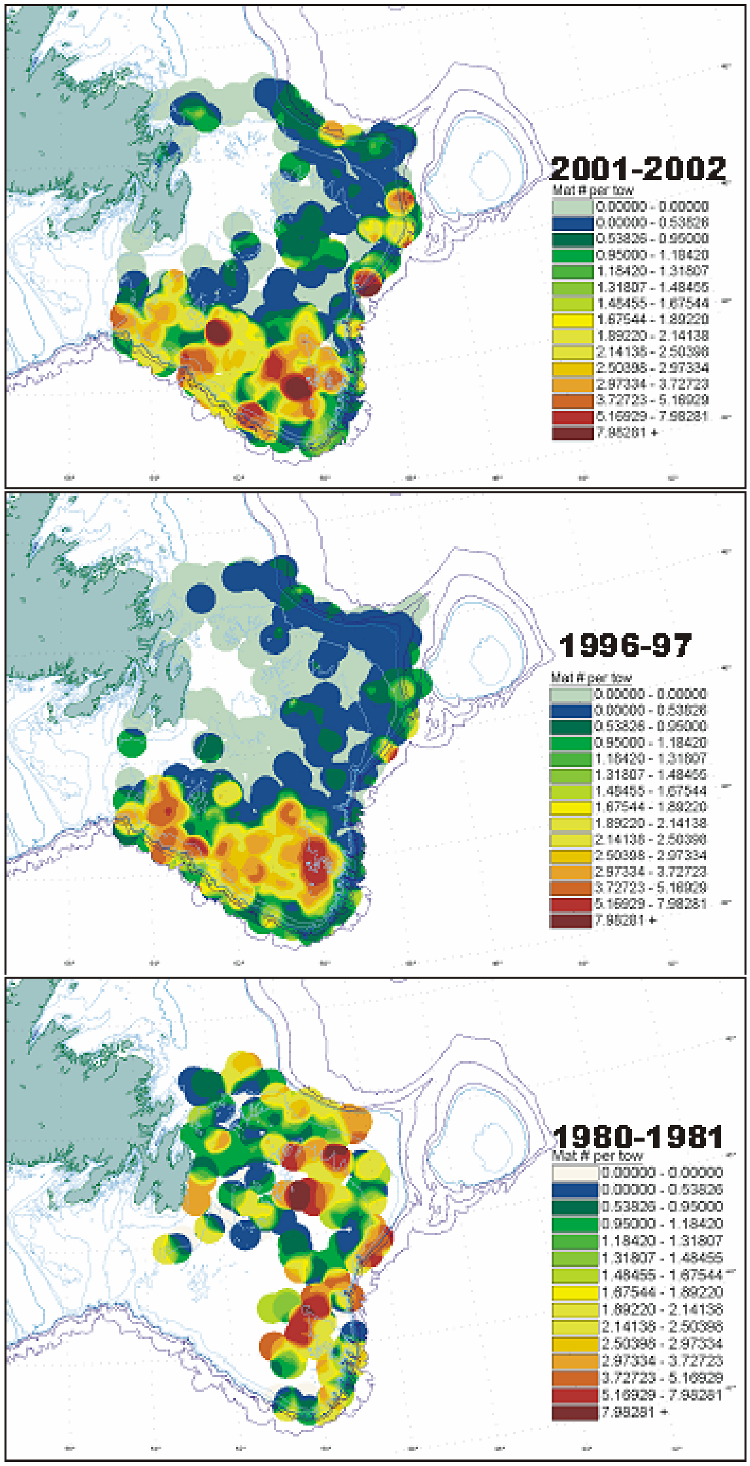


Fig. 22d. Distribution of mature male and female thorny skates during fall research surveys in three time periods: 1980-1981, 1996-1997, and 2001-2002.

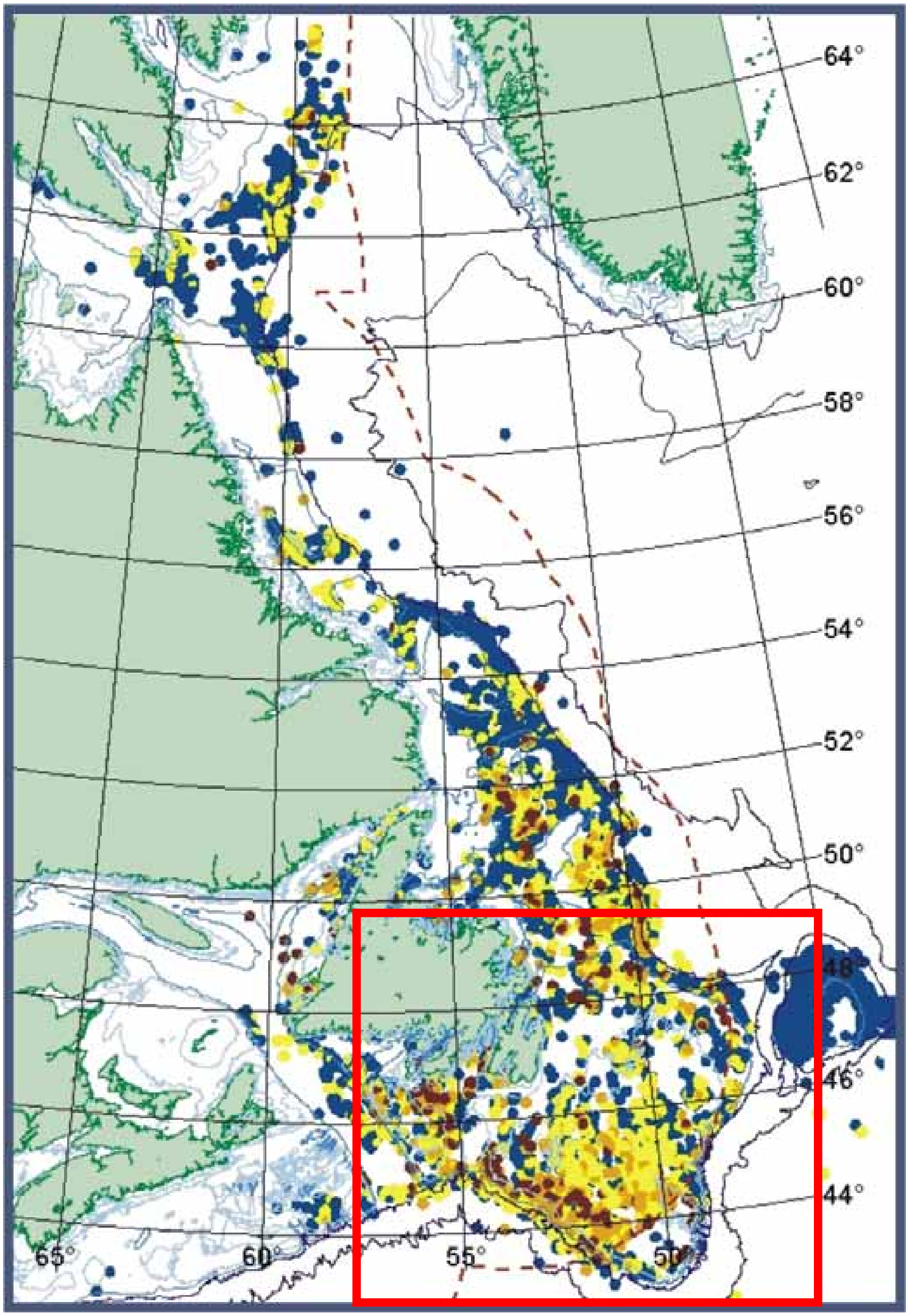


Fig. 23. Distribution of thorny skate catches in all commercial fisheries north of the Laurentian Channel, 1992-2002. Data are from Canadian Fisheries Observers.

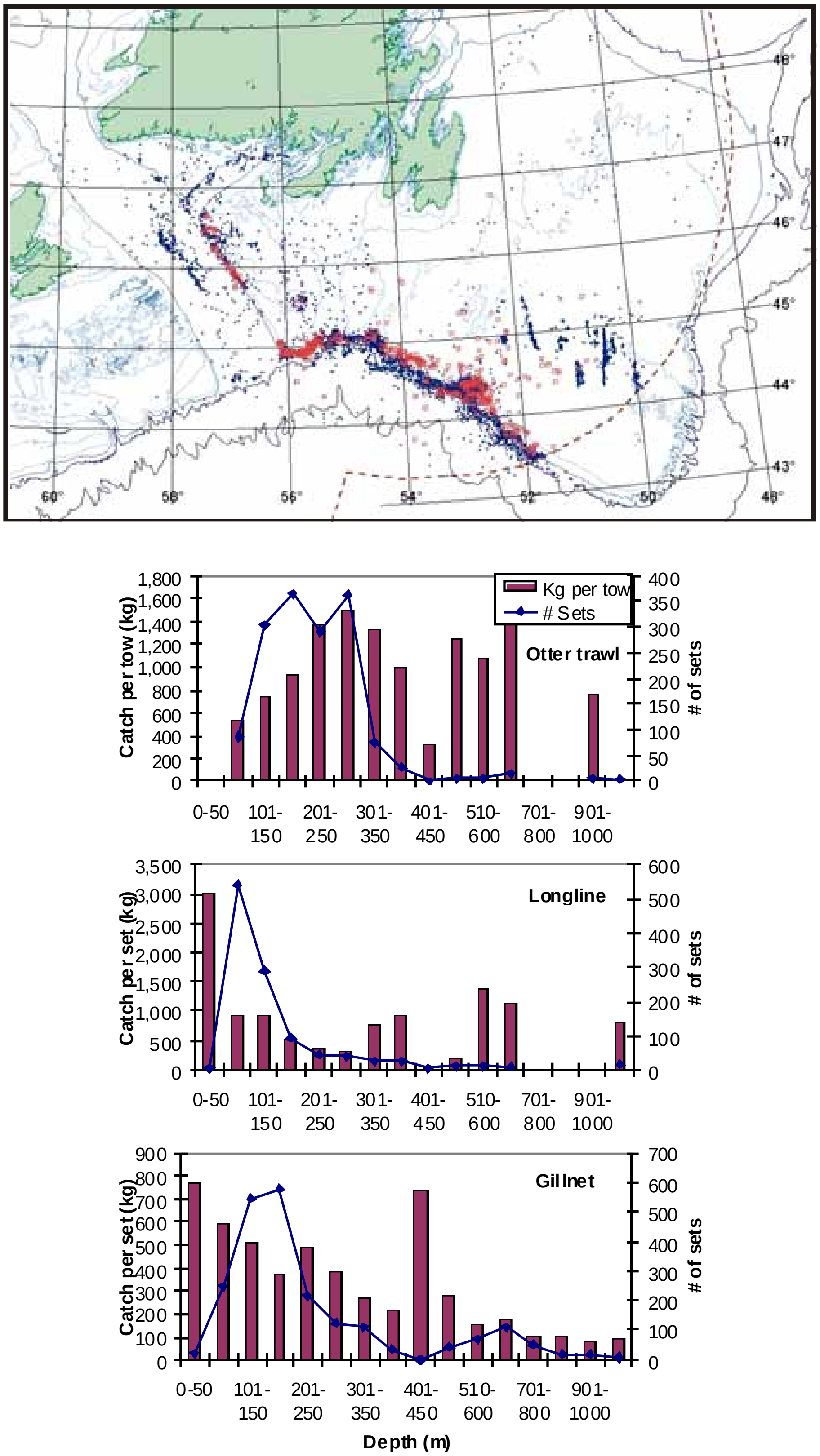


Fig. 24. Distribution of Canadian skate-directed sets for all gear types, 2002-2003.
Upper Panel: location depicted as open squares (small dots are sets for other directed species). Lower Panels: fishing effort (number of sets) and skate catch per set by depth for each gear type, 2002-2003.

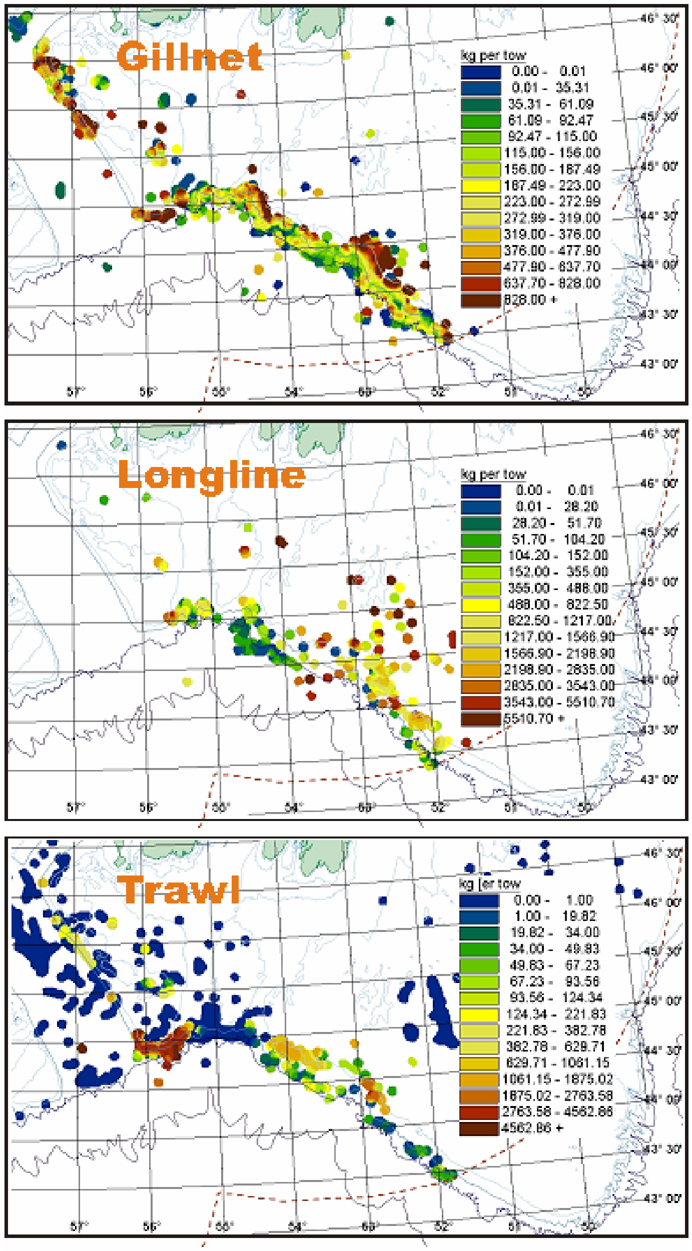


Fig. 25. Distribution of thorny skate catches by gear type in the skate/monkfish/white hake/Atlantic halibut mixed fishery on the Grand Banks, 2002-2003 Red areas denote locations with higher catch rates. Data are from Canadian fishing logs.

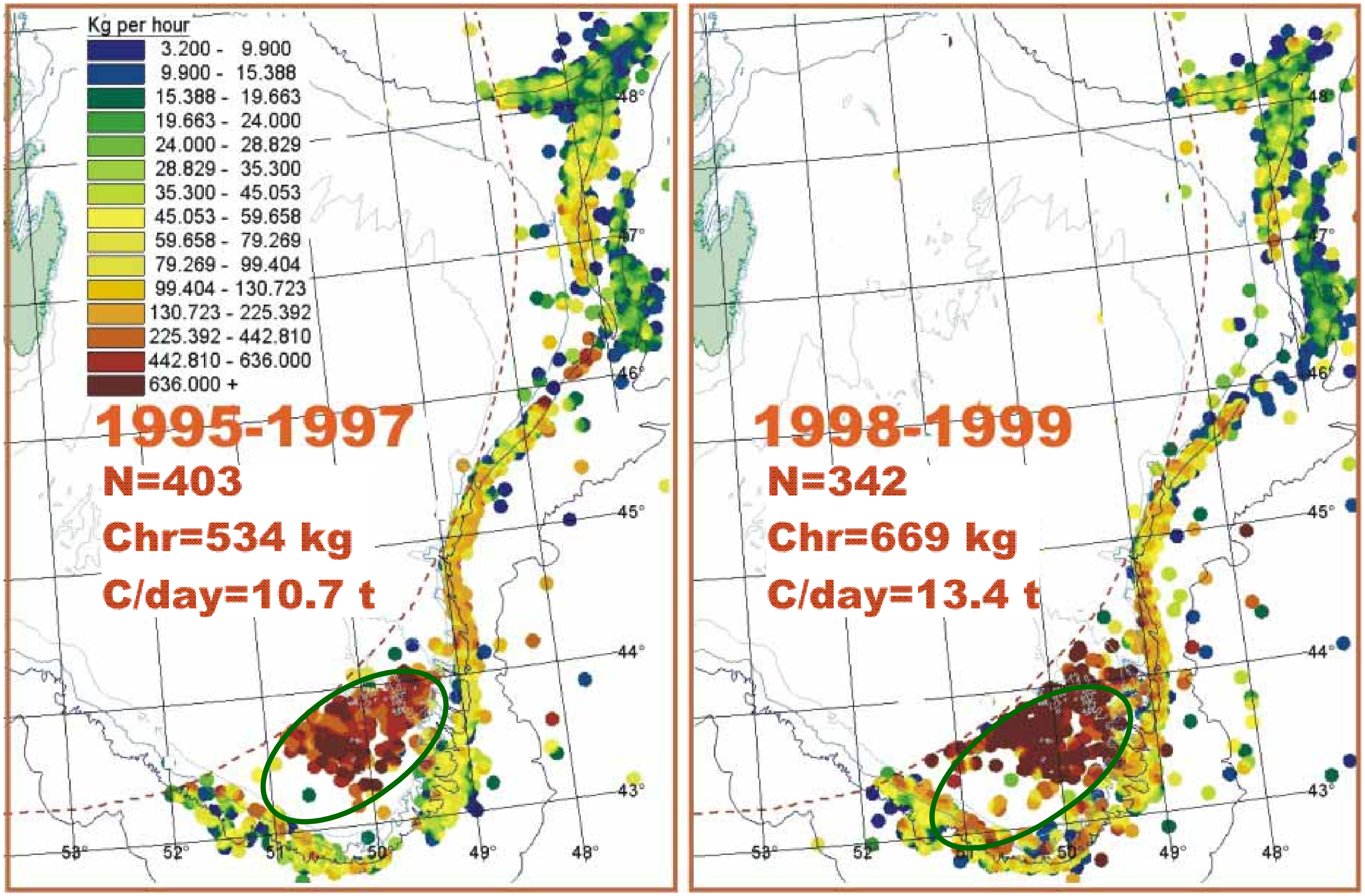


Fig. 26. Skate catch rates for the non-Canadian otter trawl fishery outside Canada's 200-mile-limit, 1995-1999: directed (encircled) and by-catch (shelf edge; primarily Greenland halibut-directed). Data were derived from fishing logbooks during Canadian commercial vessel inspections at sea (DFO Canada – Conservation & Protection Division). Statistics below the date refer only to sets within the circled area: N= number of sets; Chr= catch rate per hour; C/day= skate catch per day.

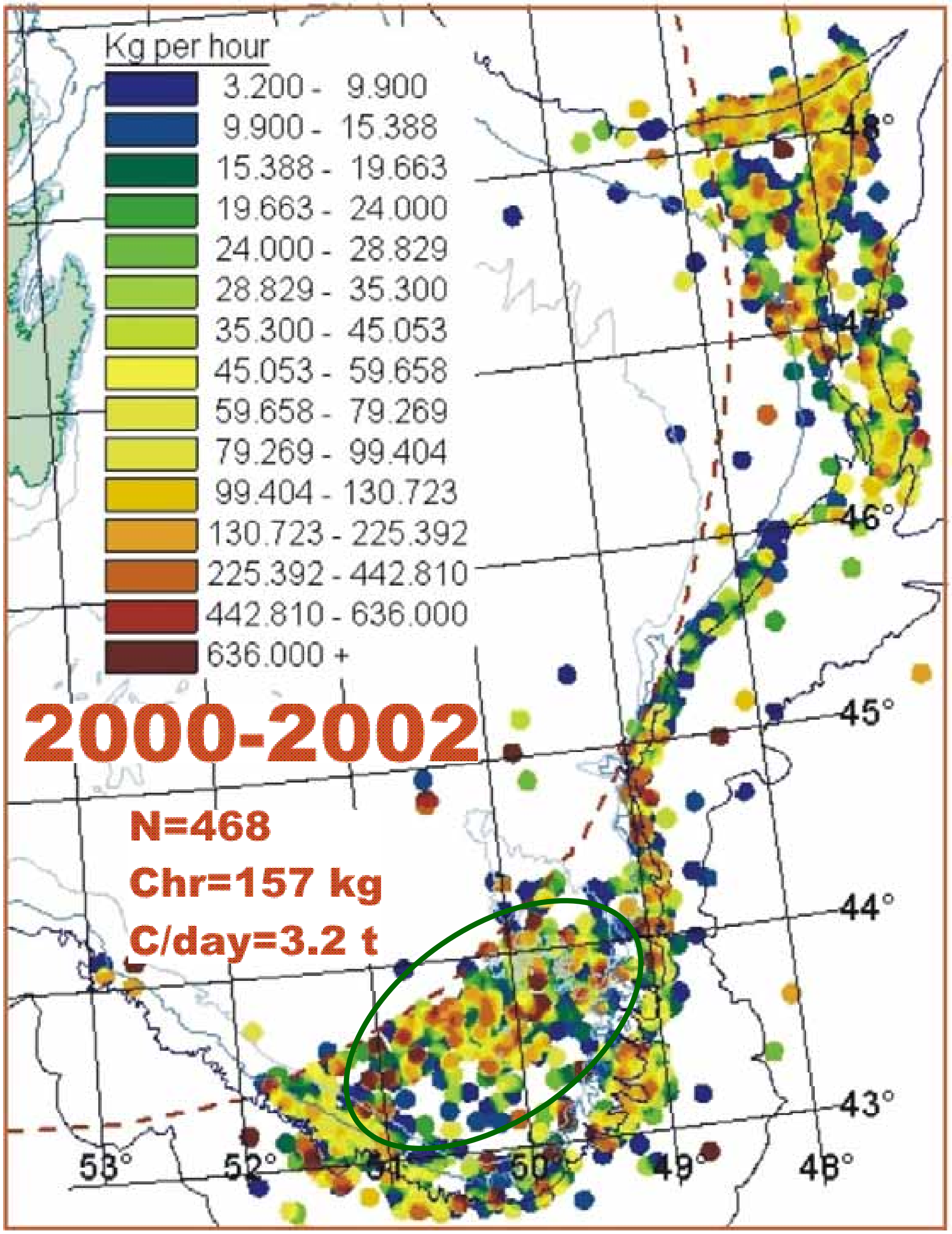
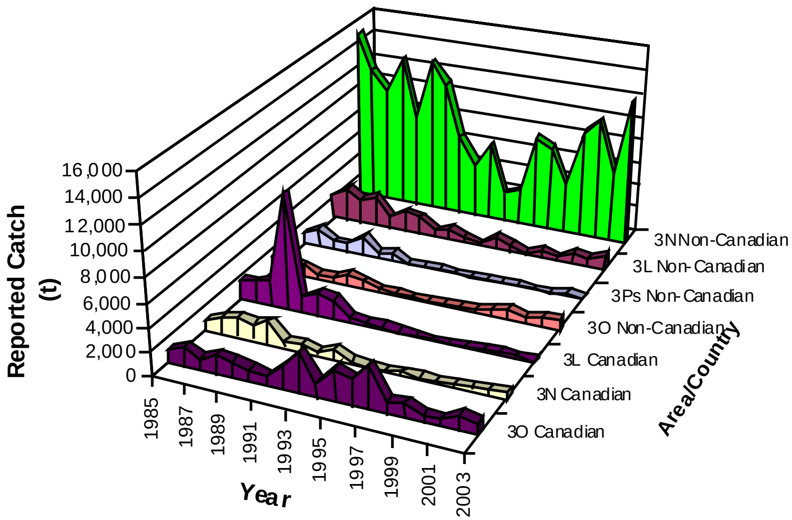


Fig. 27. Skate catch rates for the non-Canadian otter trawl fishery outside Canada's 200-mile-limit, 2000-2002: directed (encircled) and by-catch (shelf edge; primarily Greenland halibut-directed). Data were derived from fishing logbooks during Canadian commercial vessel inspections at sea (DFO Canada – Conservation & Protection Division). Statistics below the date refer only to sets within the circled area: N= number of sets; Chr = catch rate per hour; C/day= skate catch per day.



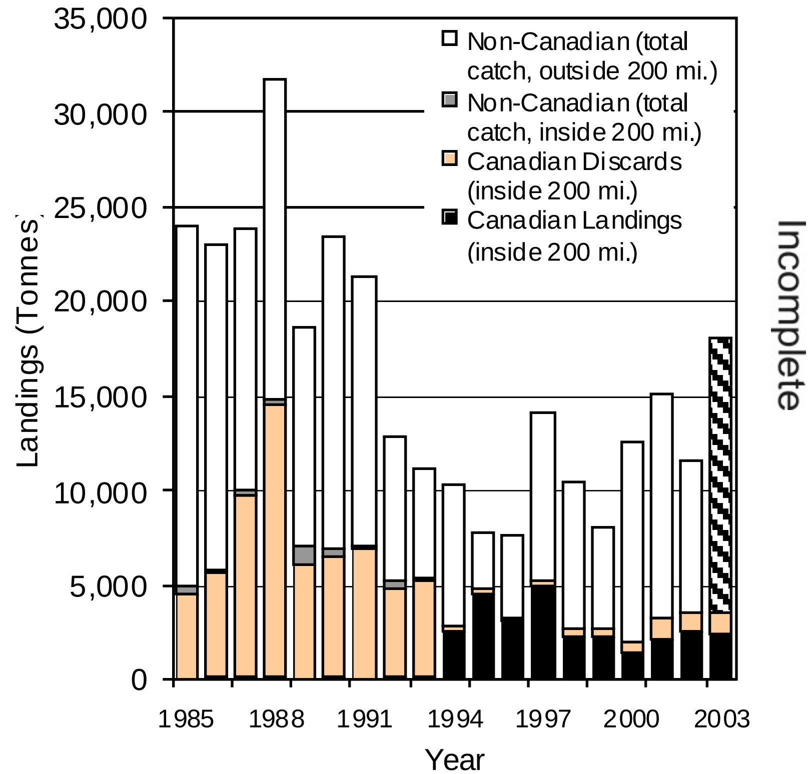


Fig. 28. Reported catches of skate in NAFO Divisions 3LNOPs by all countries, 1985-2003. Non-Canadian data for 2002 and 2003 are preliminary. Non-Canadian total catches (outside Canada's 200-mile-limit) in 2003 are taken from NAFO letters. Skate data were not speciated; although Canadian Fisheries Observer data indicate that thorny skates comprise 90% of skate catches on the Grand Banks.

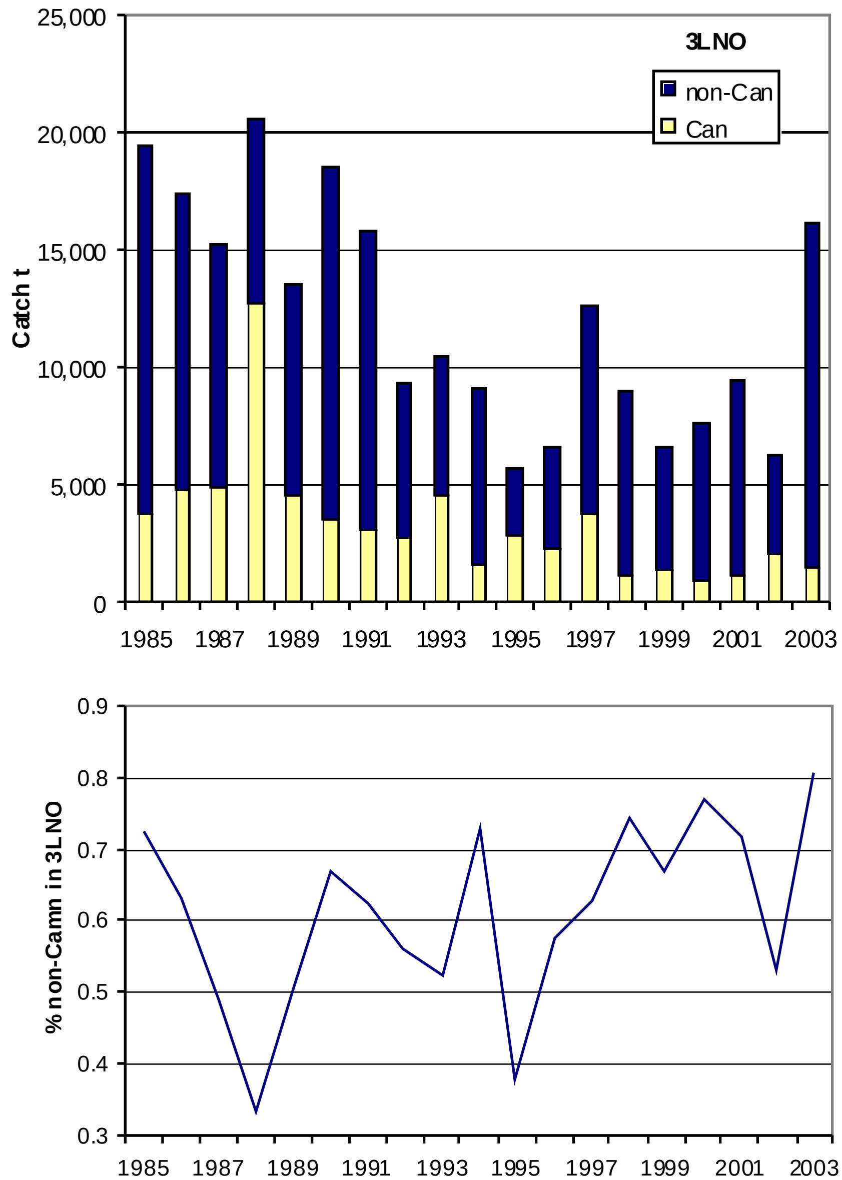


Fig. 29. Reported catches of skate in NAFO Divisions 3LNO by all countries, 1985-2003. Non-Canadian data for 2002 and 2003 are preliminary. Non-Canadian total catches (outside Canada's 200-mile-limit) in 2003 are taken from NAFO letters. Skate data were not speciated; although Canadian Fisheries Observer data indicate that thorny skates comprise 90% or more of skate catches on the Grand Banks.

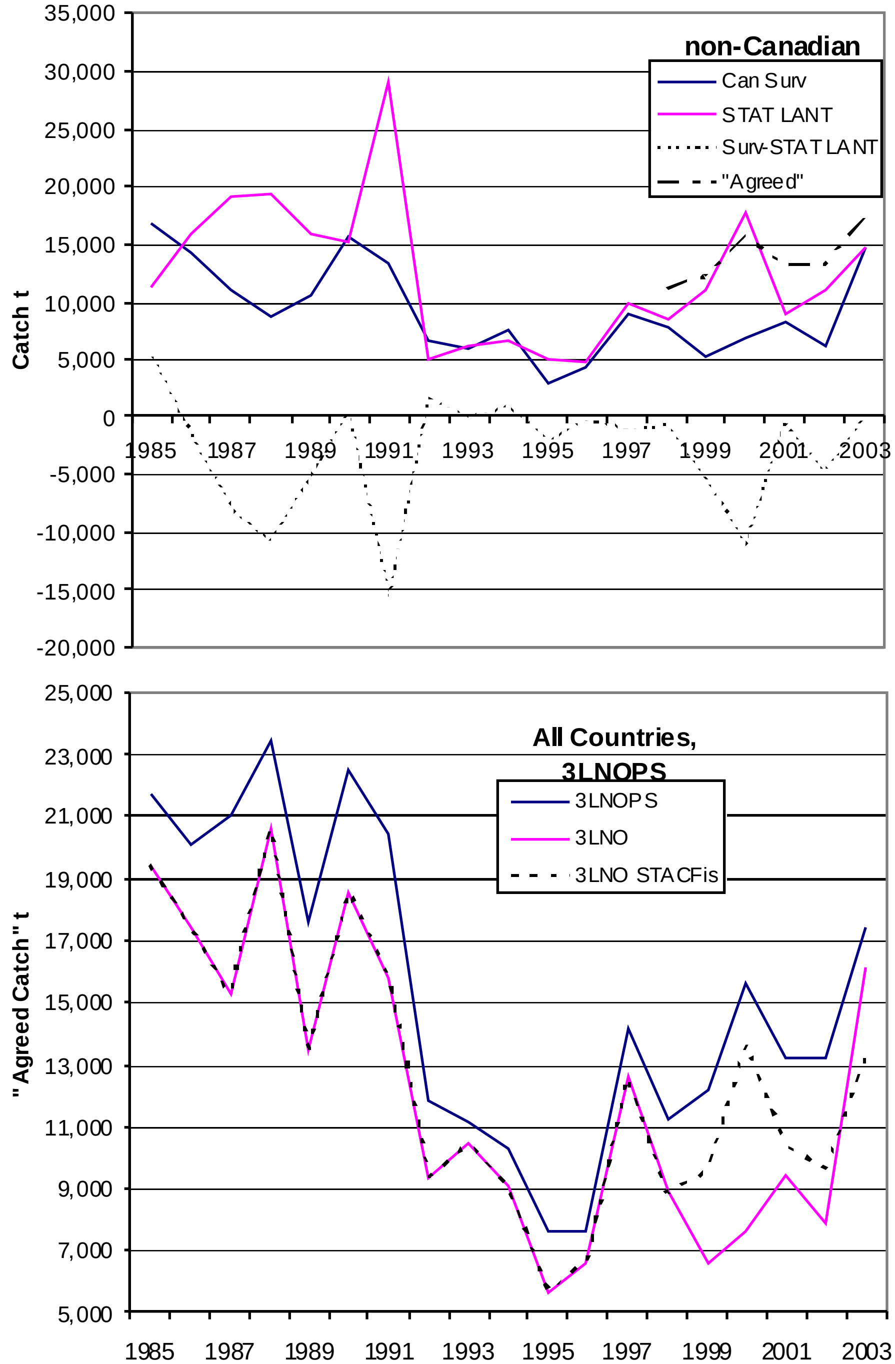


Fig. 30. Reported catches of skate in NAFO Divisions 3LNOPs by all countries, 1970-2003. Non-Canadian numbers prior to 1985 are from STATLANT. Canadian numbers assume 7 000 tons of discards annually.

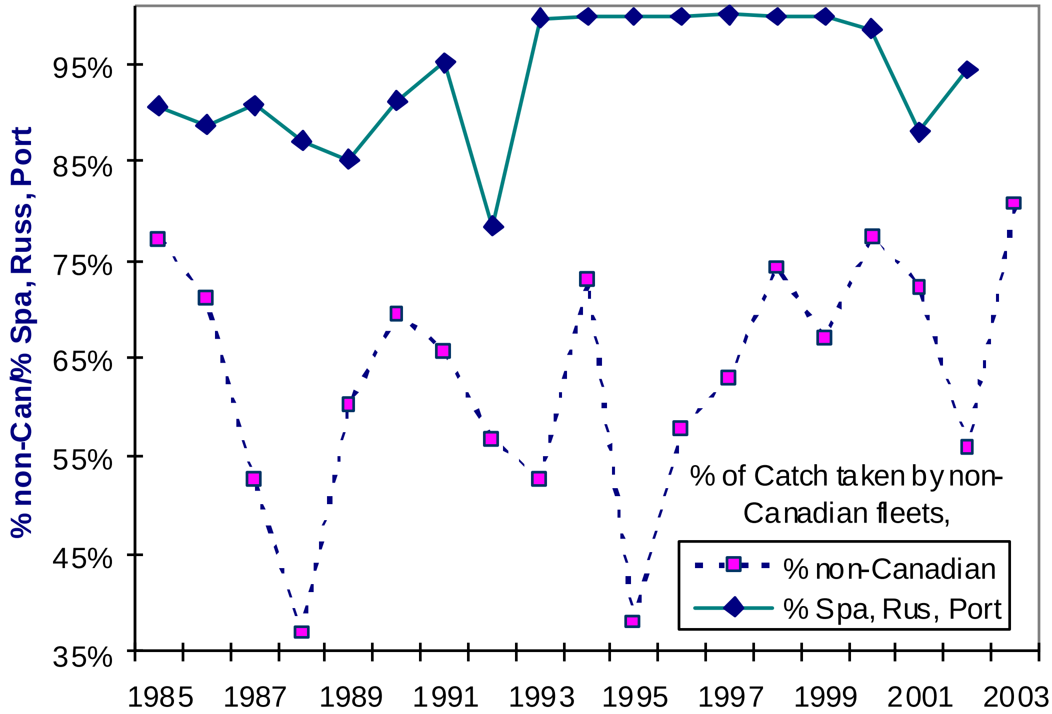
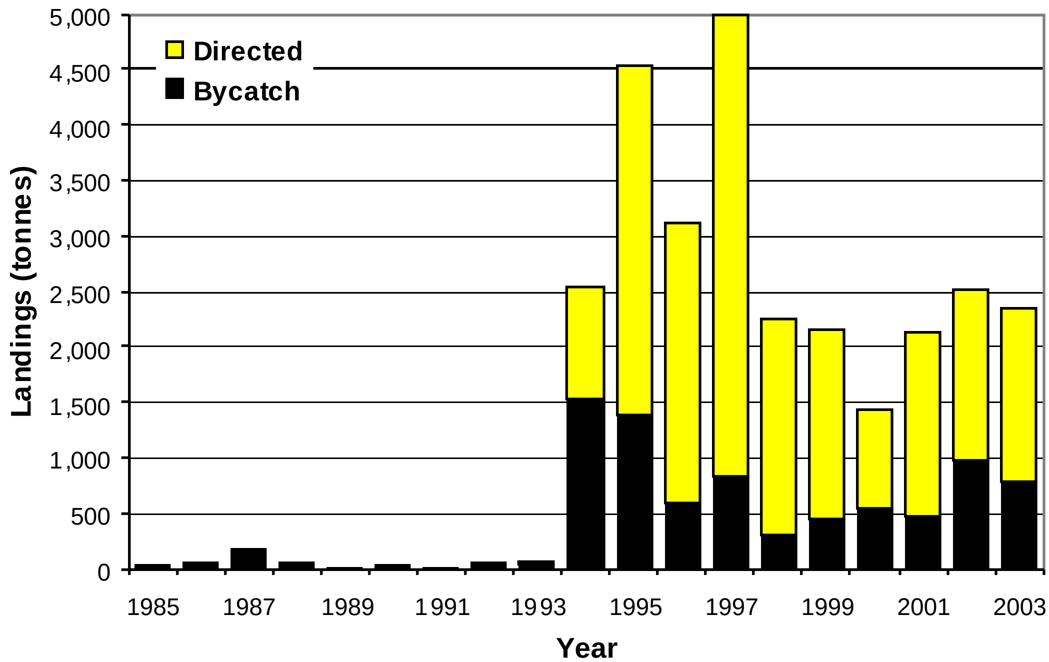
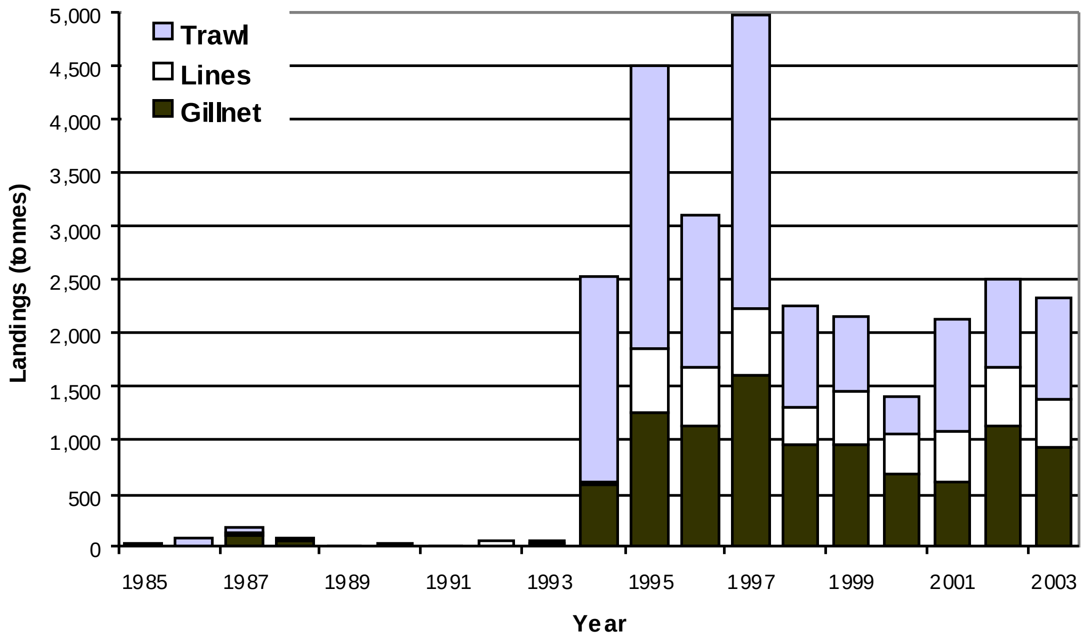


Fig. 31. Percent of total skate catches taken by non-Canadian fleets (from DFO C&P commercial vessel inspections), and percent of non-Canadian catches taken by Spain, Portugal, and Russia, 1985-2003 (from NAFO STATLANT-21A). Catches from twelve other countries comprised the remainder. Non-Canadian data 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	8	9	3	16	534	536	434	979	**2,519**	979	1,541
2003	7	0	7		315	331	449	1,238	**2,348**	778	1,569

Fig. 32a. Directed and non-directed Canadian skate landings in NAFO Divisions 3LNOPs, 1985-2003. 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	273	336	218	252	23	1,022	0	0	**2,123**	609	470	1,044
2002	779	346	160	396	37	799	0	0	**2,518**	1,125	556	837
2003	525	419	194	252	58	899	0	0	**2,347**	944	446	957

Fig. 32b. Canadian skate landings in NAFO Divisions 3LNOPs by gear type and mode (directed or by-catch), 1985-2003. Data do not include discards at sea.

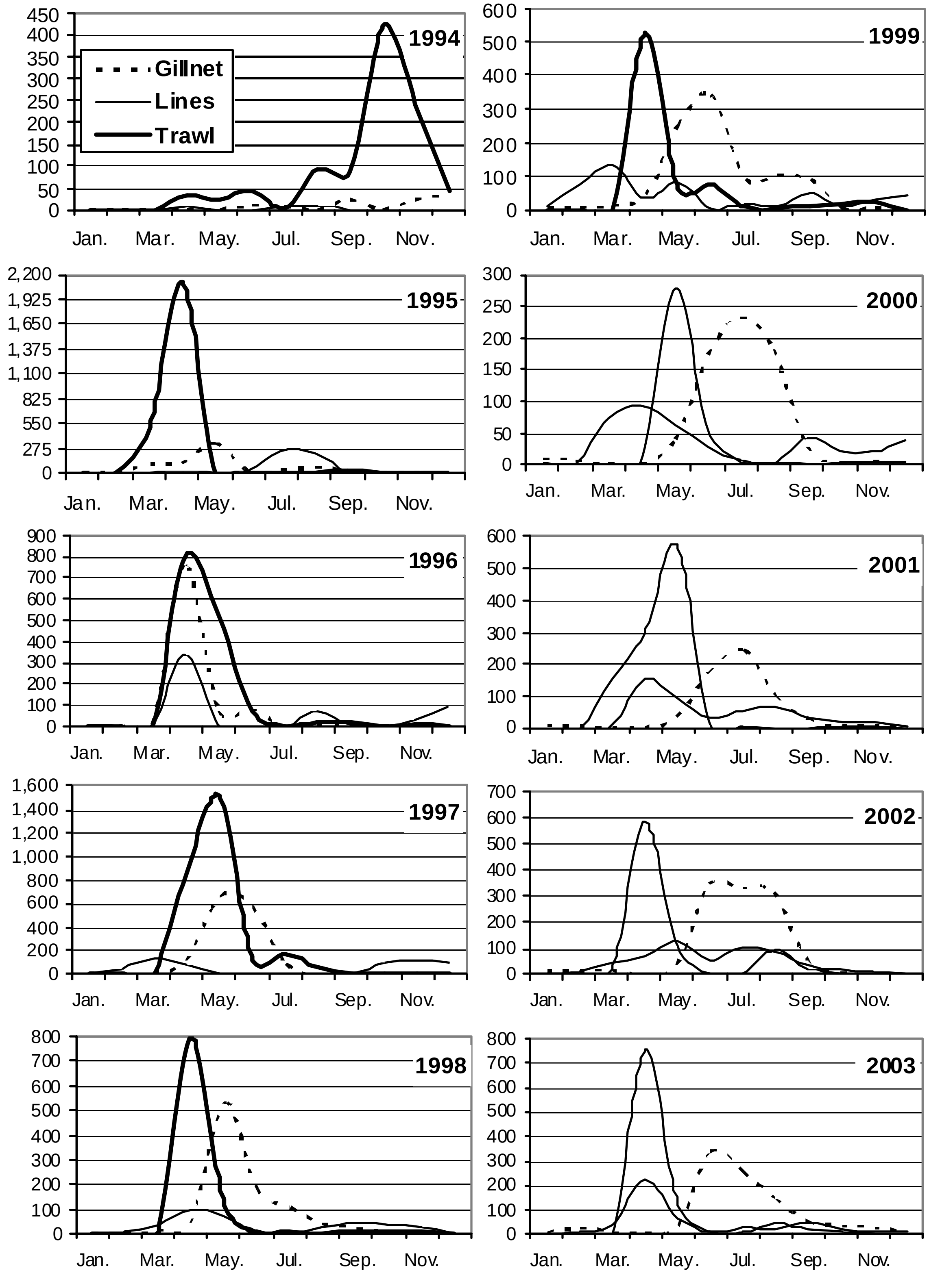


Fig. 33. Monthly Canadian landings of skate in NAFO Divisions 3LNOPs, 1994-2003. Landing records for which no month was recorded are excluded.

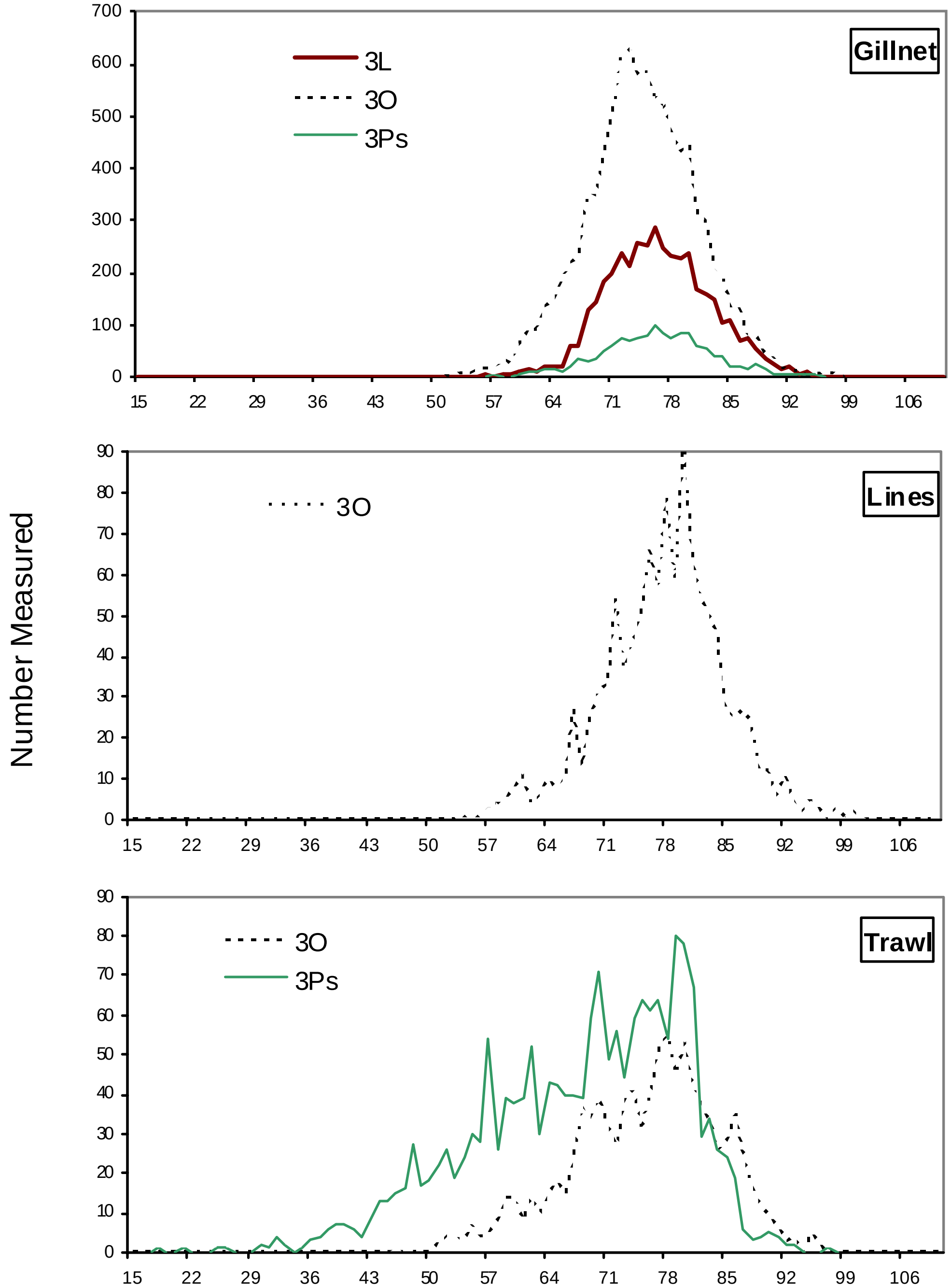


Fig. 34. Length frequencies of Canadian commercial skate catches in NAFO Divisions 3LOPs. Data are from Canadian Fisheries Observers, 1994-2003.

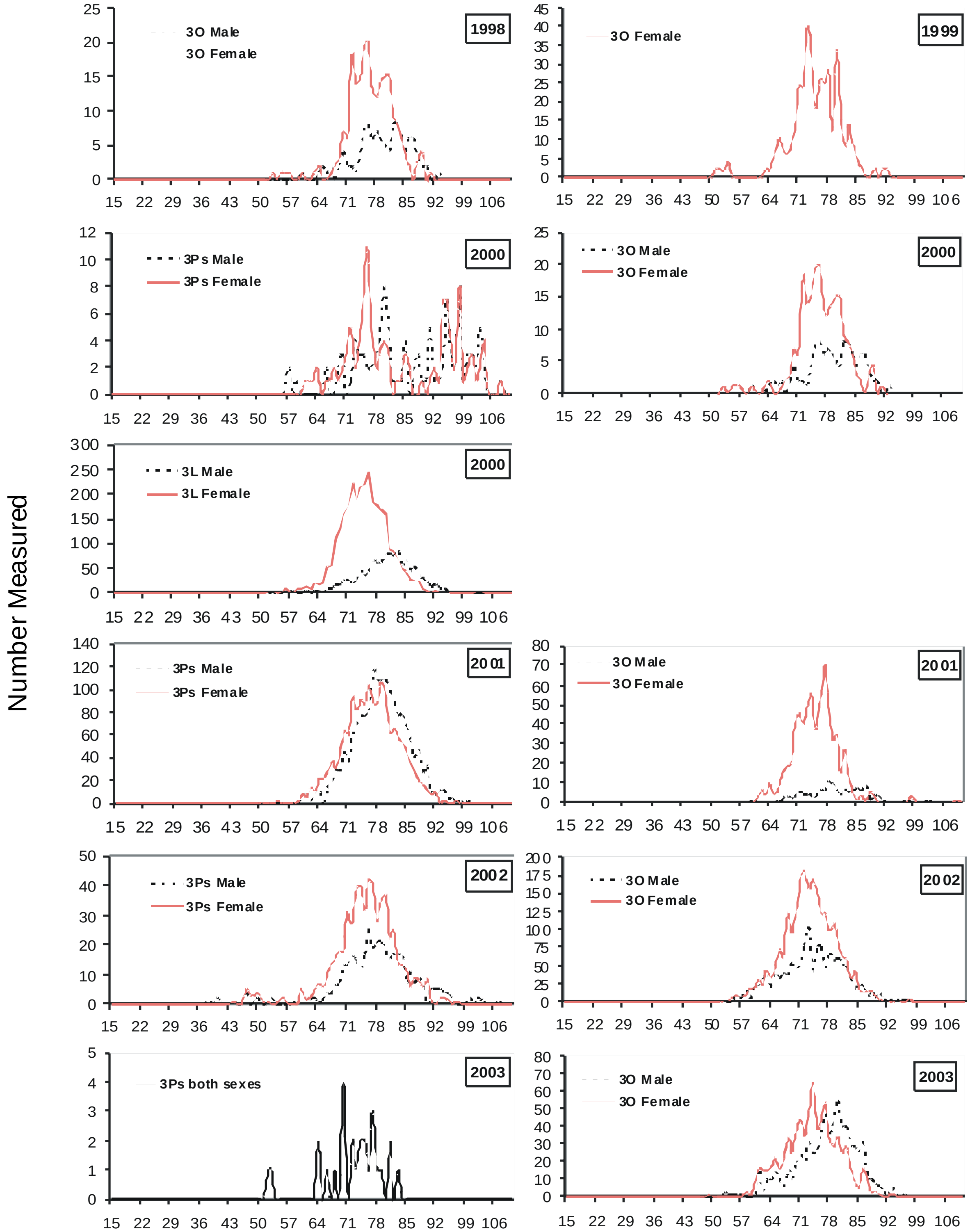


Fig. 35a. Length frequencies of Canadian commercial skate catches for gillnets in NAFO Divisions 3LOPs, 1998-2003. X-axis represents lengths of skate in centimeters. Data are from Canadian Fisheries Observers.

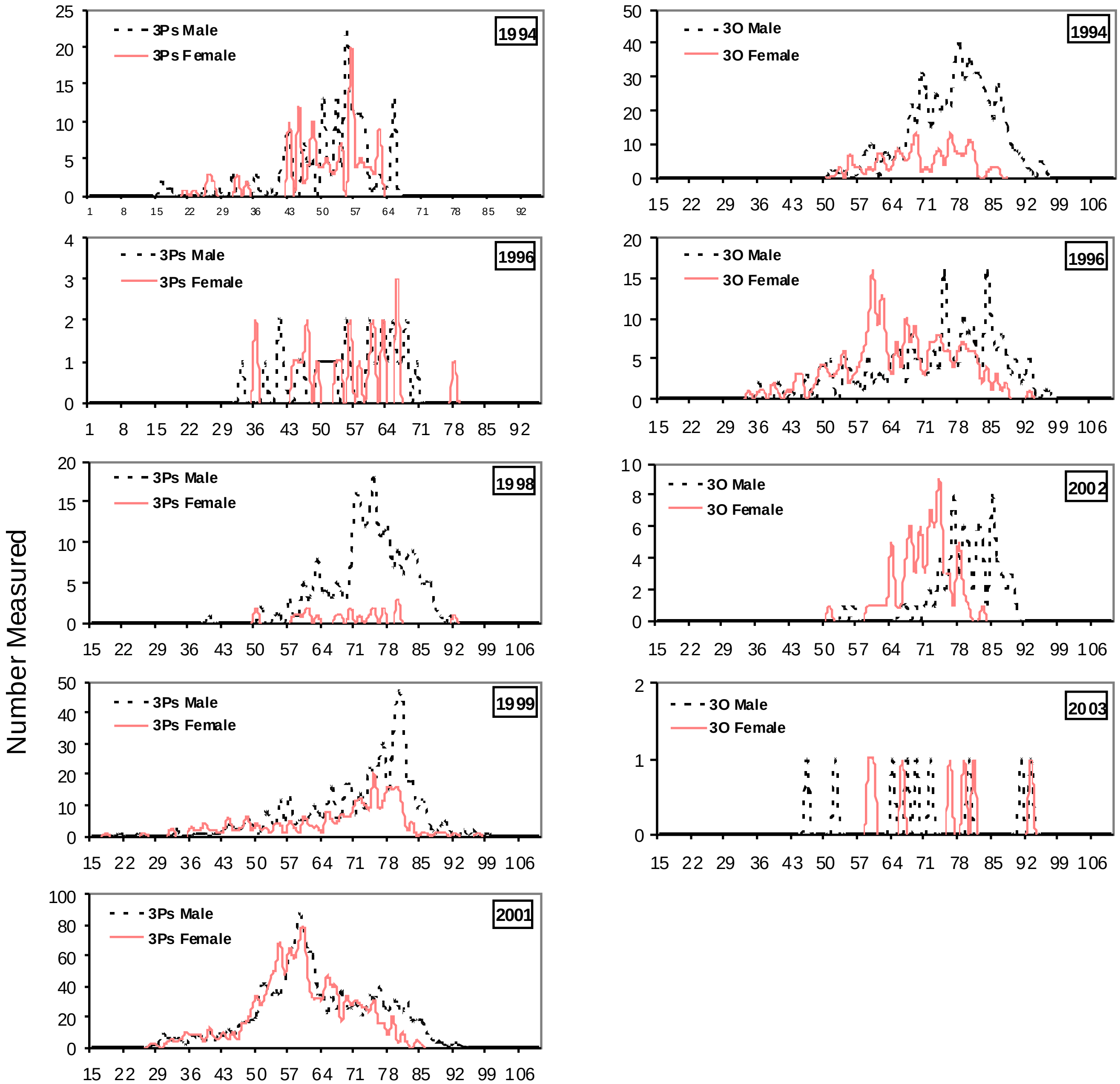


Fig. 35b. Length frequencies of Canadian commercial skate catches for trawls in NAFO Divisions 3OPs, 1994-2003. X-axis represents lengths of skate in centimeters. Data are from Canadian Fisheries Observers.

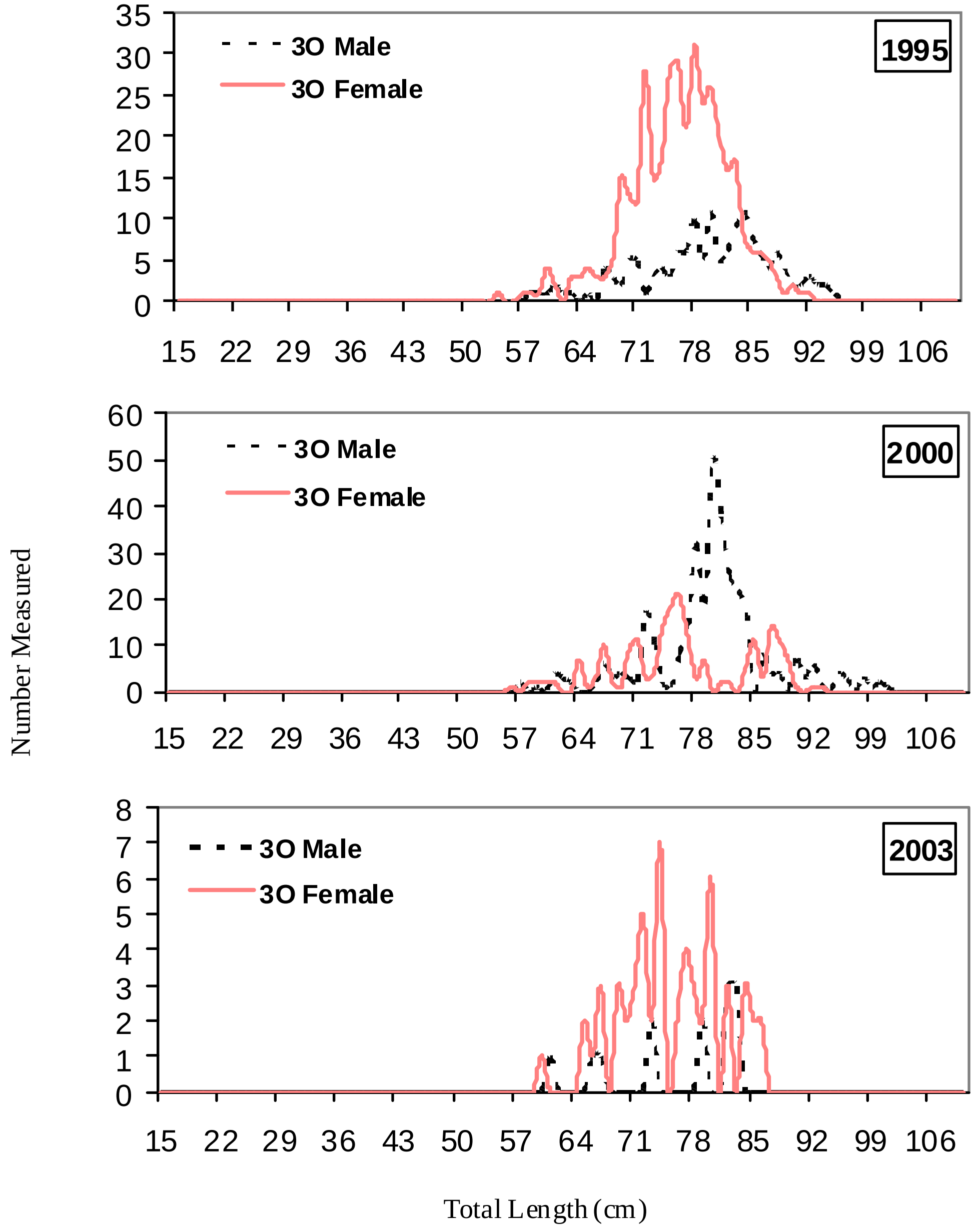


Fig. 35c. Length frequencies of Canadian commercial skate catches for lines in NAFO Division 3O, 1995, 2000 and 2003. X-axis represents lengths of skate in centimeters. Data are from Canadian Fisheries Observers.

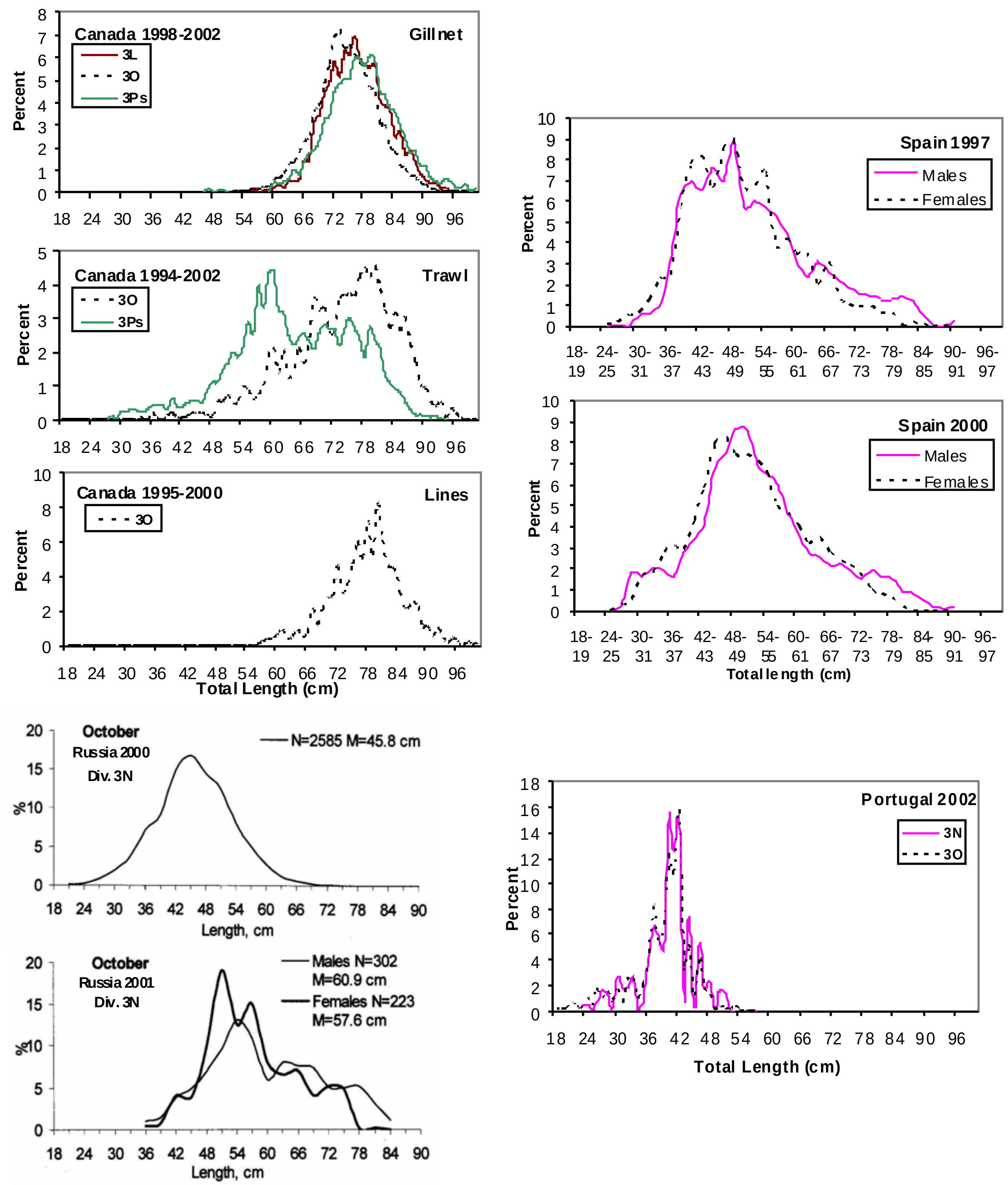


Fig. 36. Length frequencies of thorny skates in commercial catches (Canadian data from Fishery Observers; Spanish data from del Río and Junquera 2001; Russian graphs from Vinnichenko *et al*. 2002; Portuguese data from Vargas *et al*. 2003).

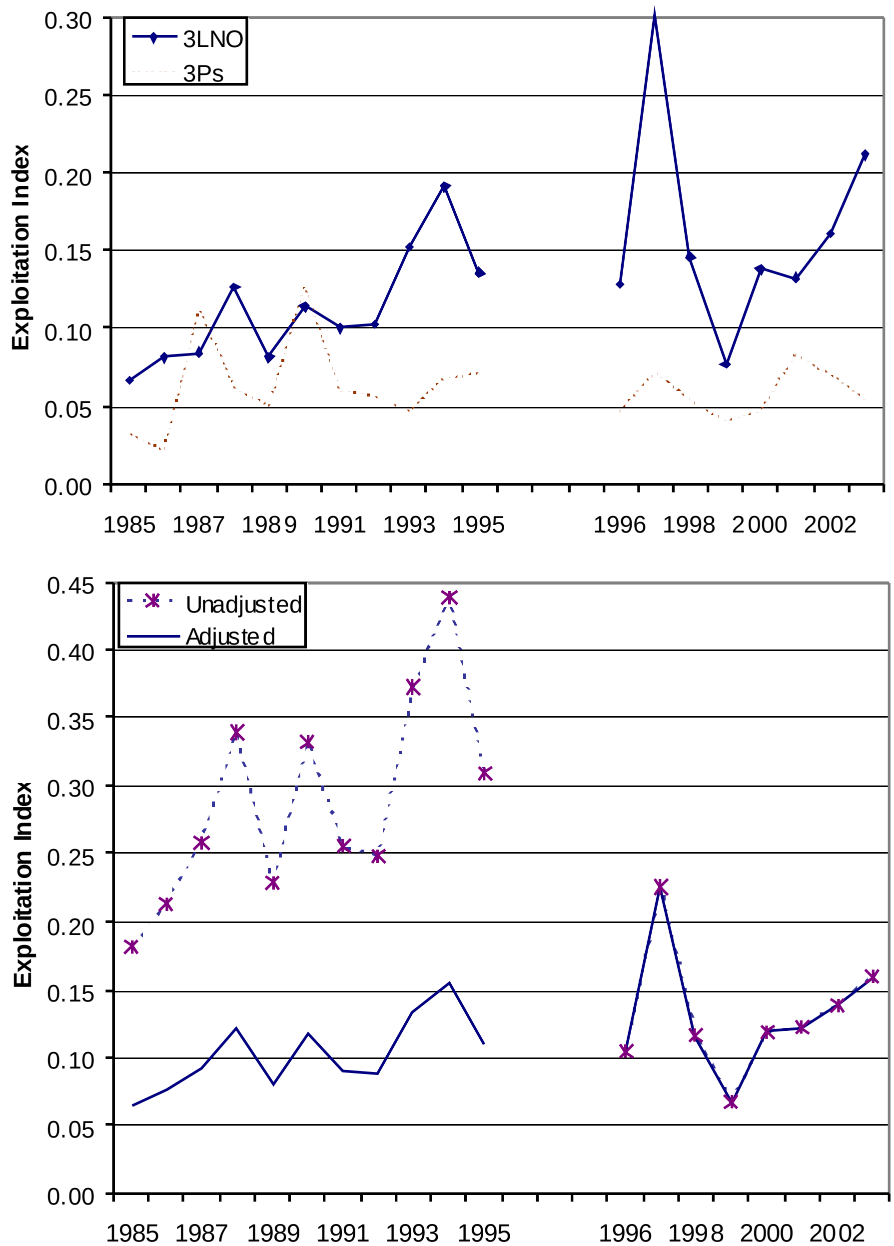


Fig. 37. Exploitation Index (total estimated catch/spring survey biomass index) for skate in NAFO Divisions 3LNO and Subdivision 3Ps, 1985-2003.Upper Panel: by NAFO Division; spring survey biomass indices converted to Campelen equivalents for 3LNO vs 3Ps. Lower Panel: for 3LNOPs, solid line represents spring survey biomass indices converted to Campelen equivalents. Dotted line is unconverted.

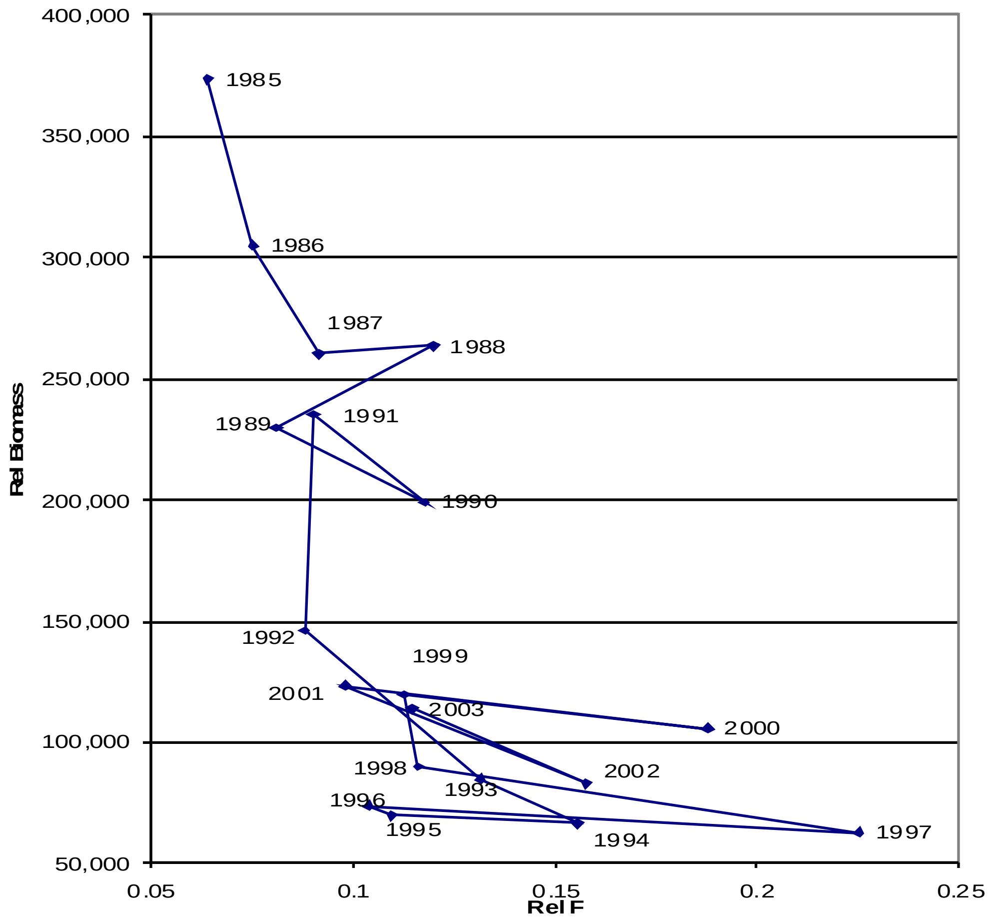


Fig. 38. Relative biomass vs relative F trajectory. The thick orange line shows point of inflection.

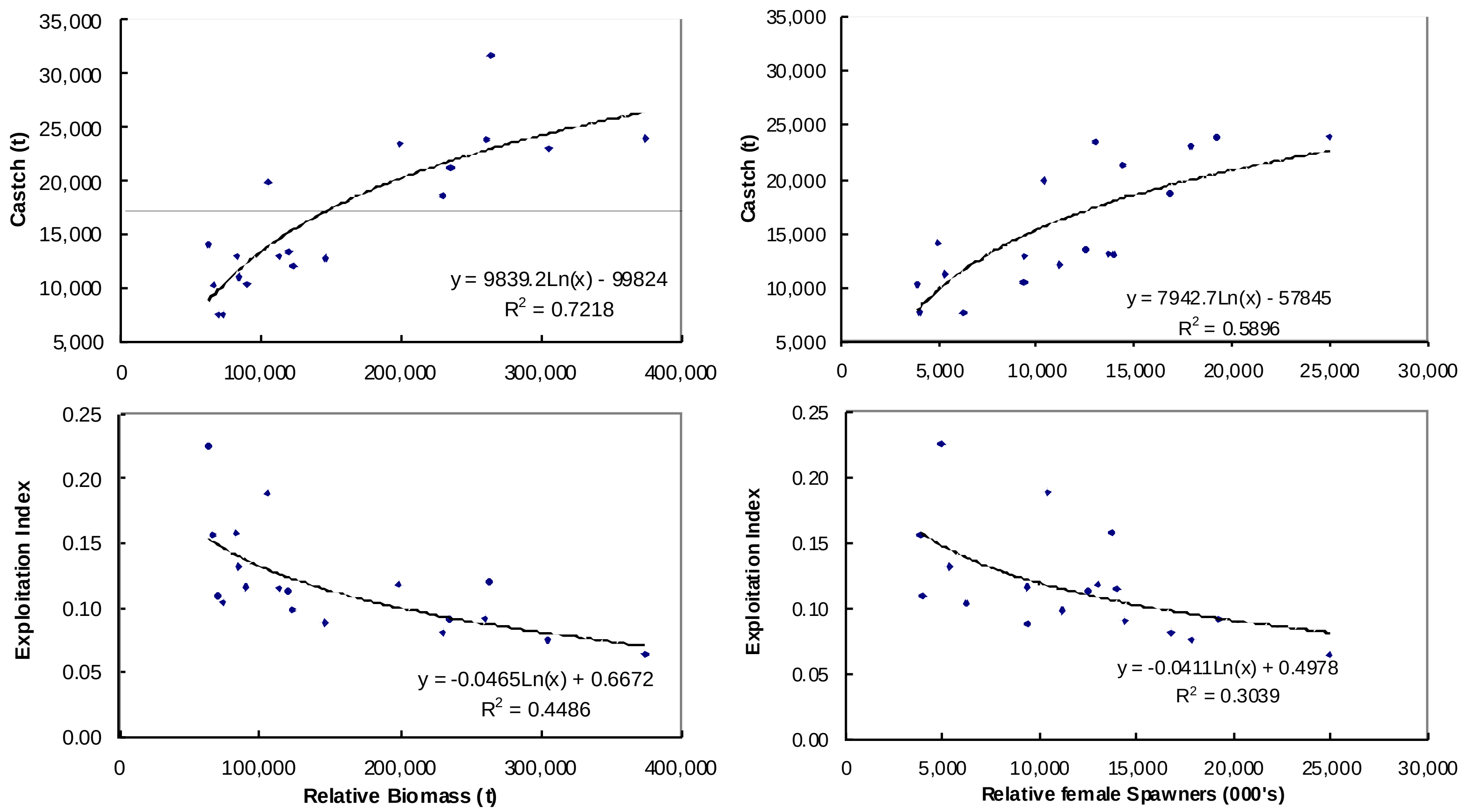


Fig. 39. Relationship between relative spring survey biomass and commercial catch (upper panels), and Exploitation Index (total estimated catch/spring survey biomass index: lower panels). The x-axes on the left panels are total relative biomass, and relative female SSB on the right panels.

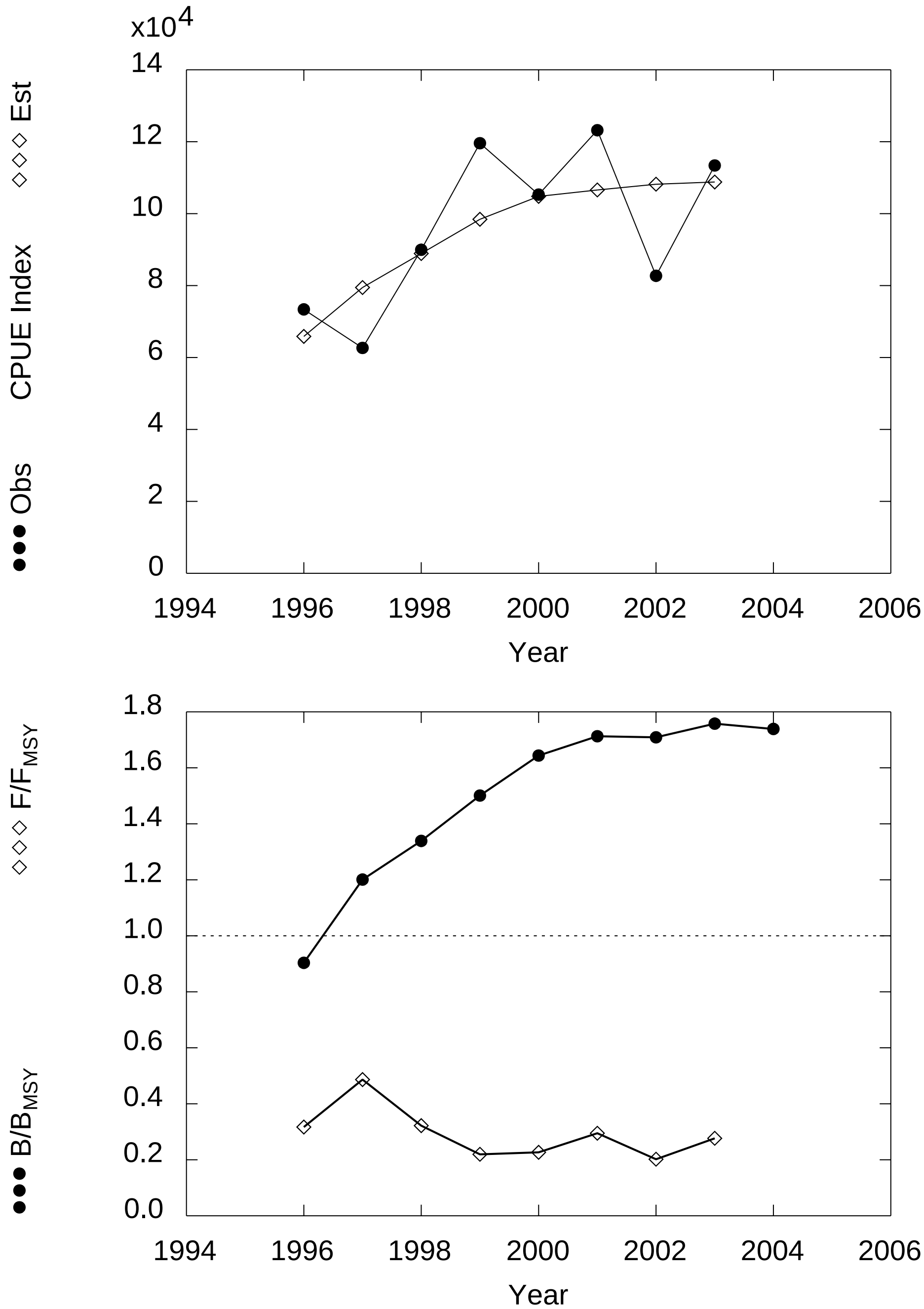


Fig. 40. Results of a non-equilibrium production model (ASPIC, Prager *et al.*, 1994). Lower panel: Relative biomass (B/B_{MSY}) and fishing mortality (F/F_{MSY}). Upper panel: Observed survey index and fitted values (relative Biomass x 4). This analysis is based on spring Campelen data.

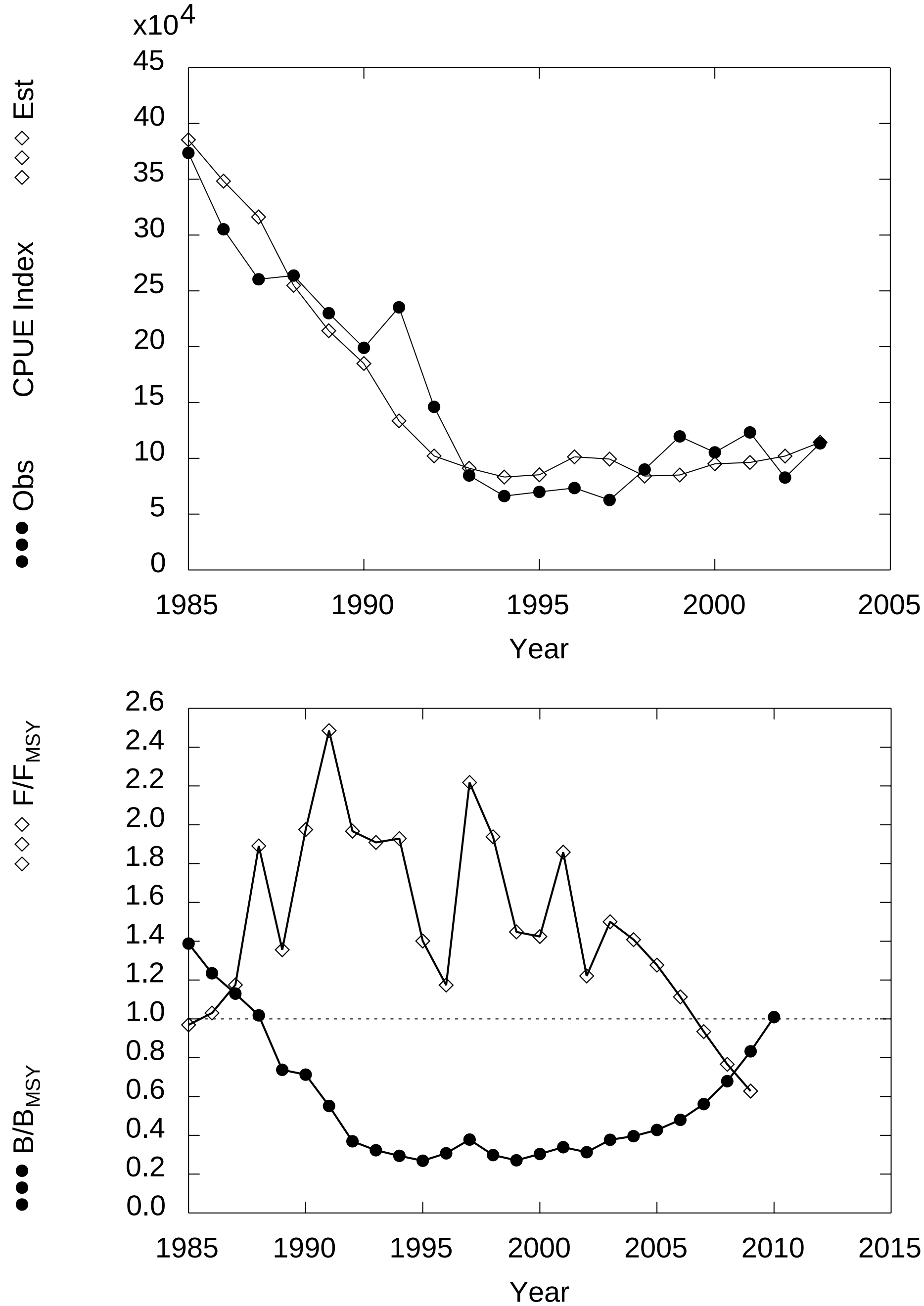


Fig. 41a. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Lower panel: Relative biomass (B/B_{MSY}) and fishing mortality (F/F_{MSY}). Upper panel: Observed survey index and fitted values (relative Biomass x 4). This analysis is based on 19 years of spring survey data Engel years adjusted to Campelen units.

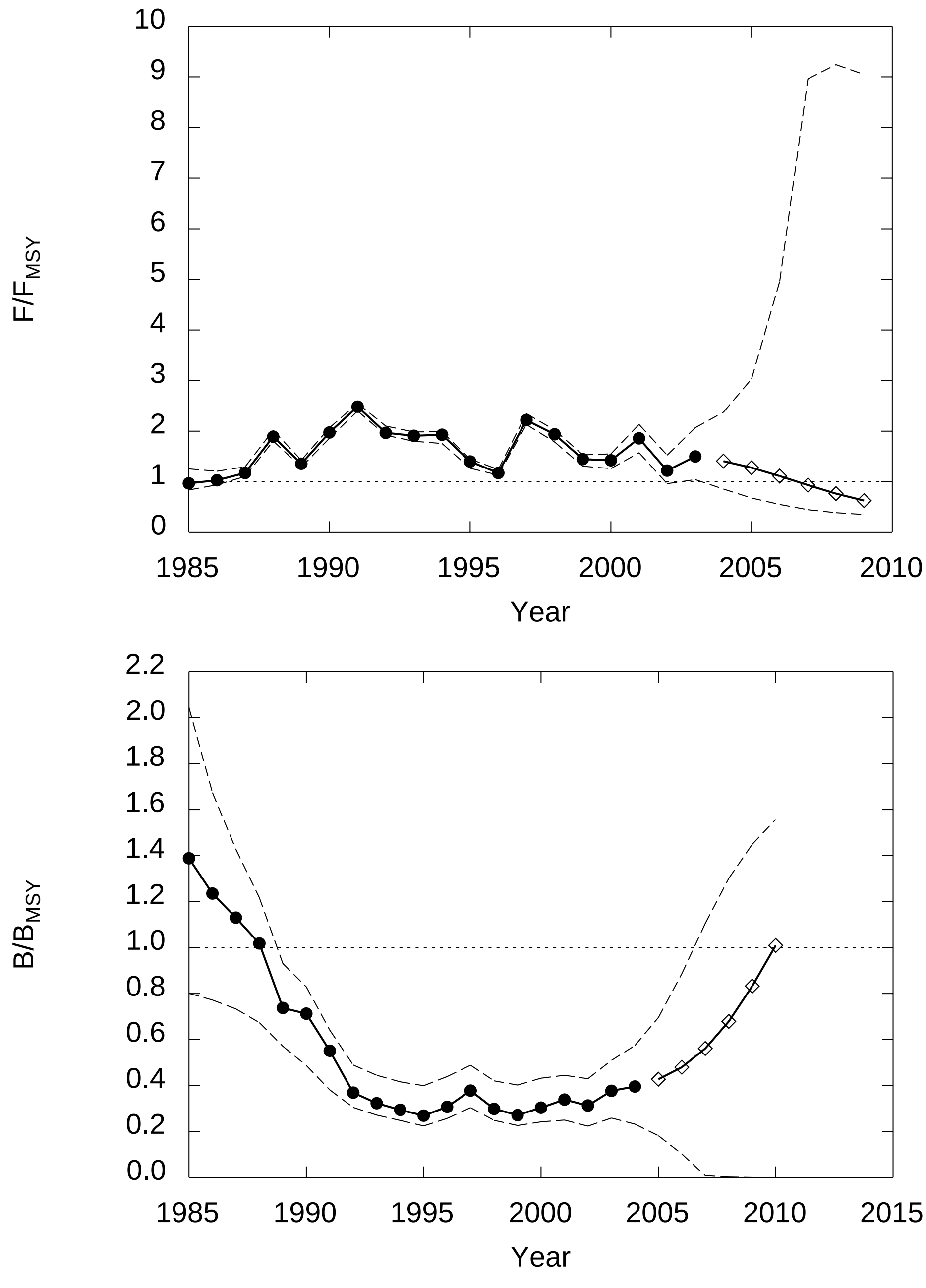


Fig. 41b. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Trends in fishing mortality (F/F_{MSY}) (upper panel) and relative biomass (B/B_{MSY}) (lower panel). This analysis is based on 19 years of spring survey data Engel years adjusted to Campelen units. The projection is for 6 years using the catch in 2003 as the predicted yield.

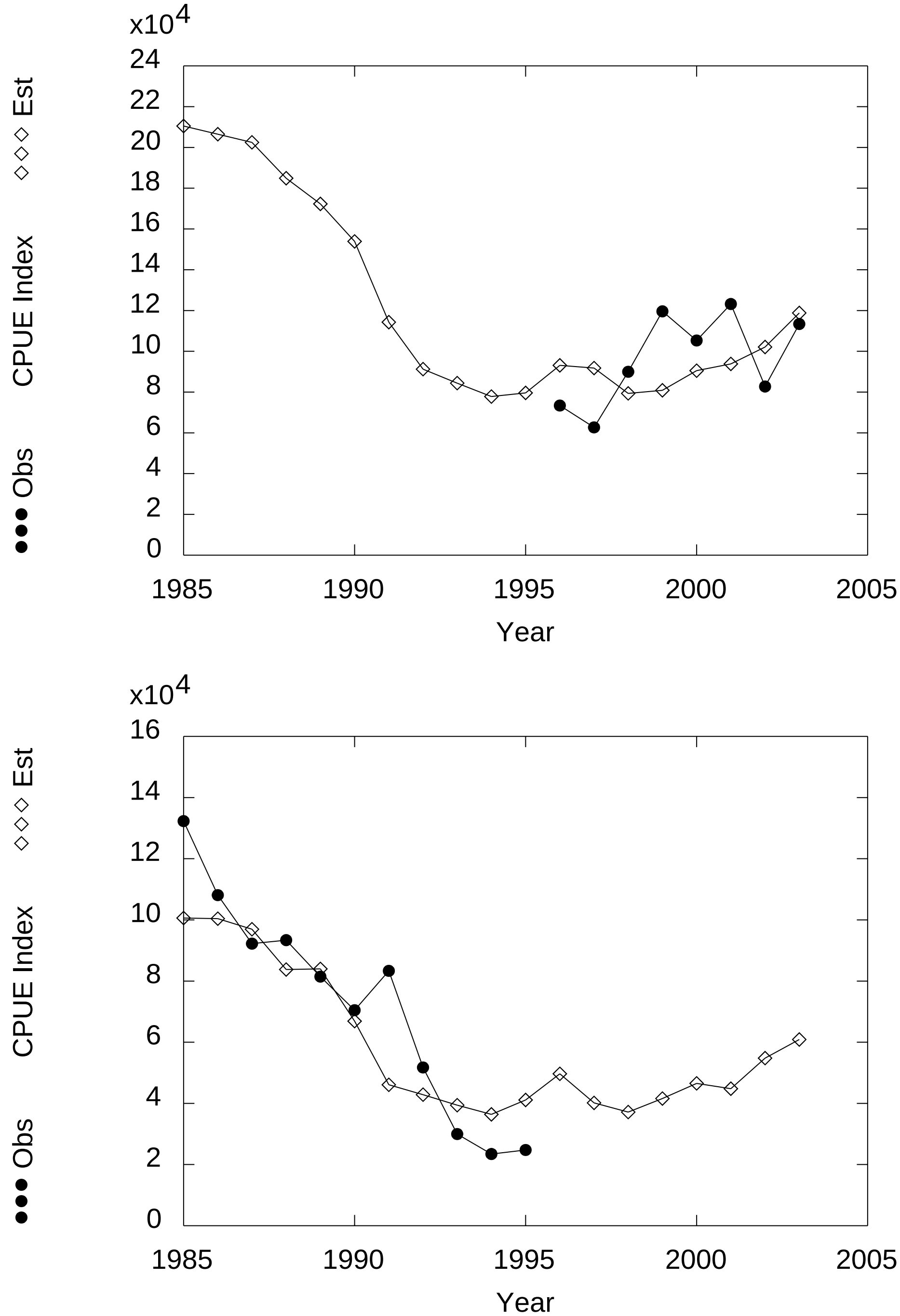


Fig. 42a. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Upper panel: Observed survey index and fitted values (relative Biomass x 4). This model (Est) is based on 8 years of spring Campelen survey data. Lower panel: This model (Est.) is based on 11 years of spring Engel survey data Engel and Campelen gears analysed as separate series.

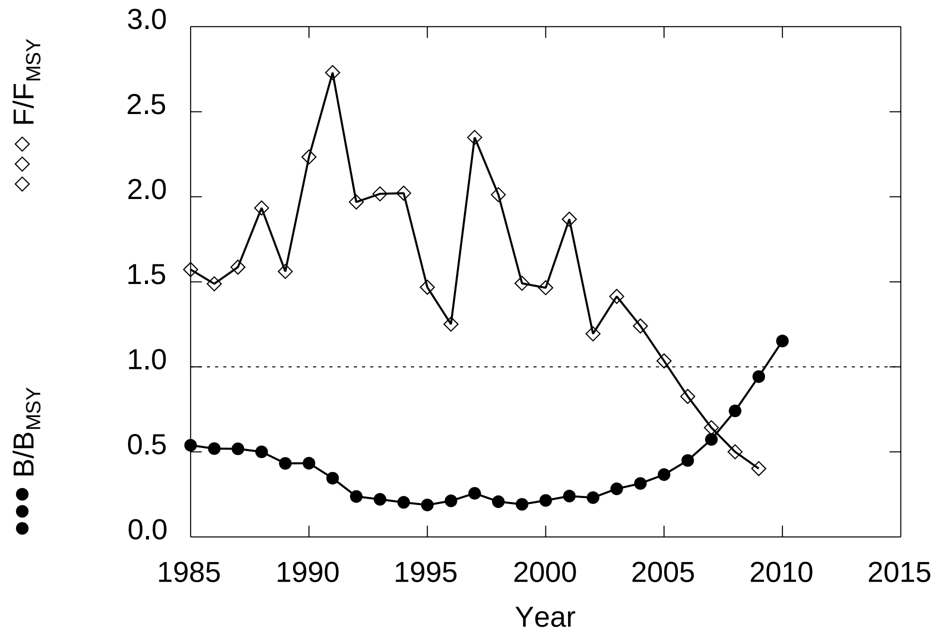


Fig. 42b. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Relative biomass (B/B_{MSY}) and fishing mortality (F/F_{MSY}). This analysis is based on 8 years of spring Campelen survey data and 11 years of spring Engel survey data.

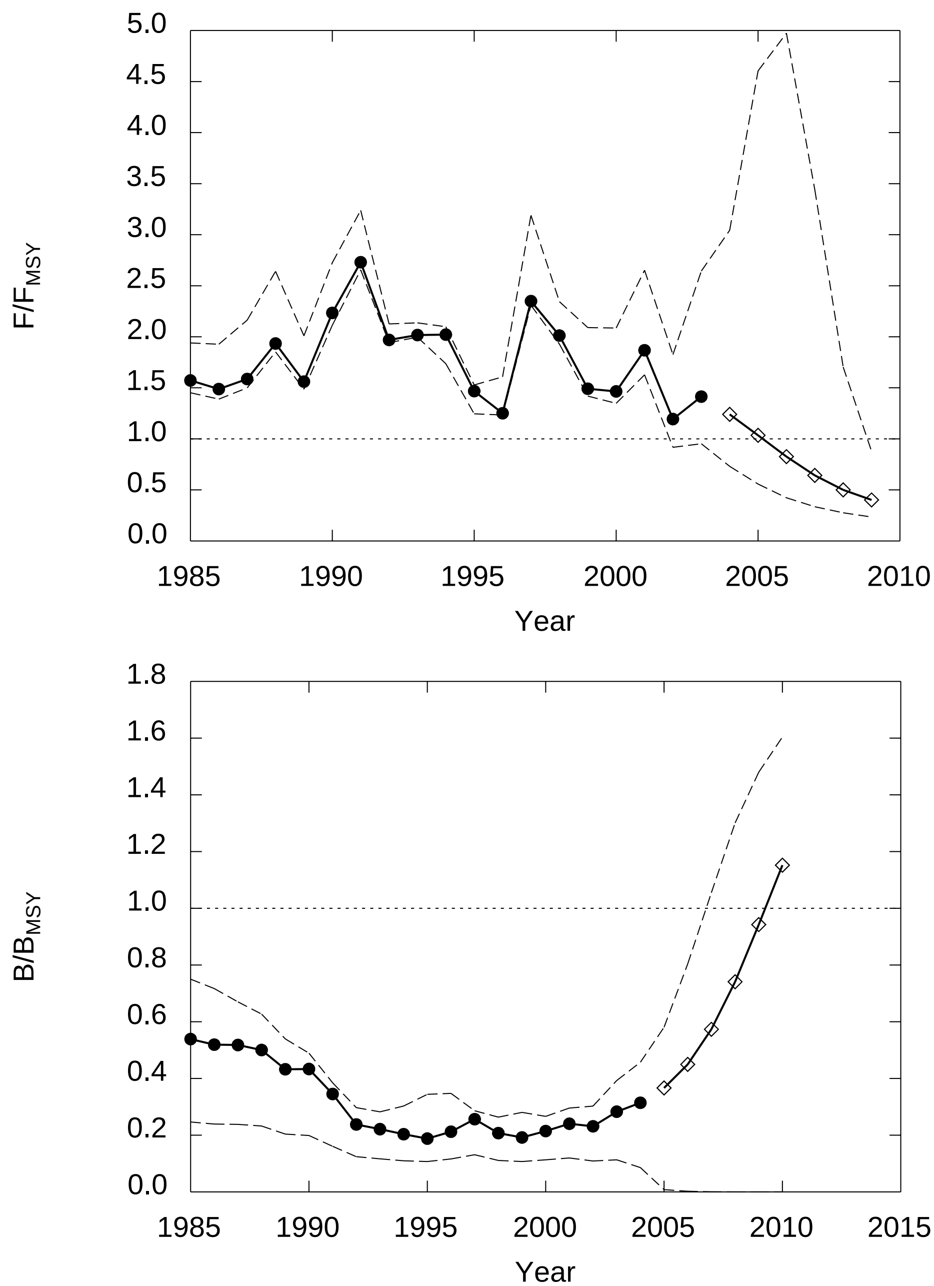


Fig. 42c. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Trends in fishing mortality (F/F_{MSY}) (upper panel) and relative biomass (B/B_{MSY}) (lower panel). This analysis is based on 8 years of spring Campelen and 11 years of spring Engel survey data analysed as separate series. The projection is for 6 years using the catch in 2003 as the predicted yield.

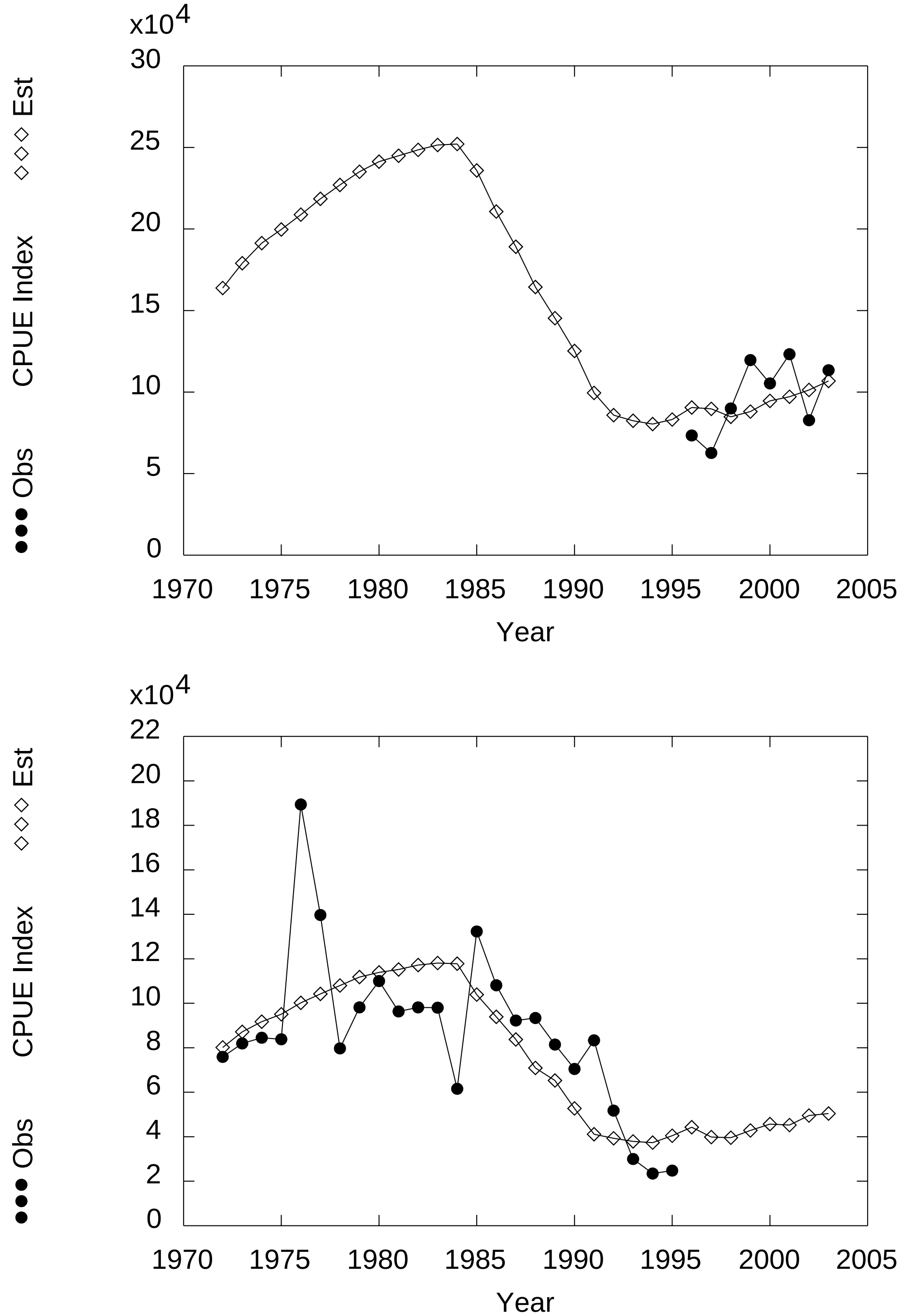


Fig. 43a. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Upper panel: Observed survey index and fitted values (relative Biomass x 4). This model (Est) is based on 8 years of spring Campelen survey data. Lower panel: This model (Est.) is based on 24 years of spring Engel survey data Engel and Campelen gears analysed as separate series.

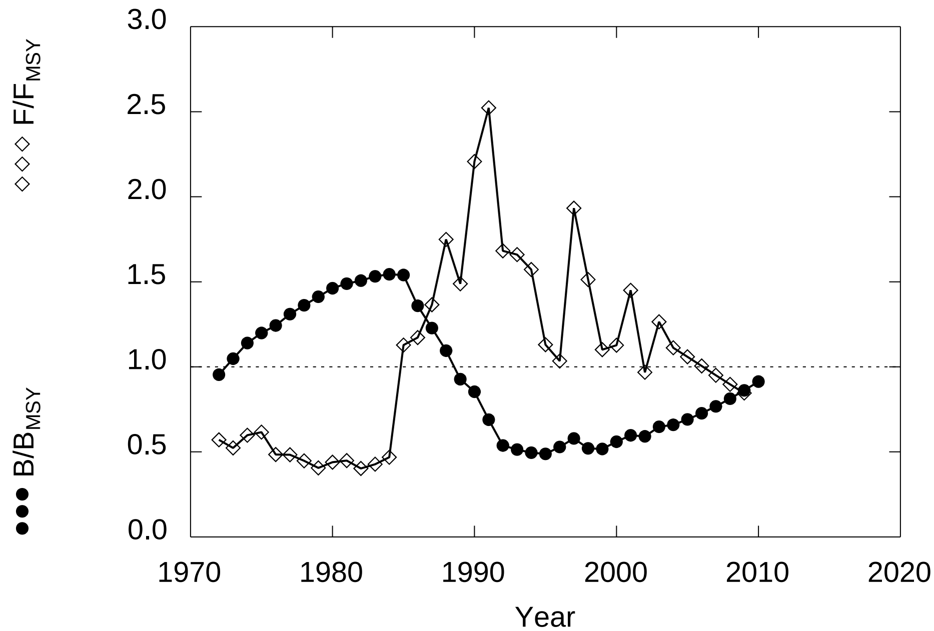
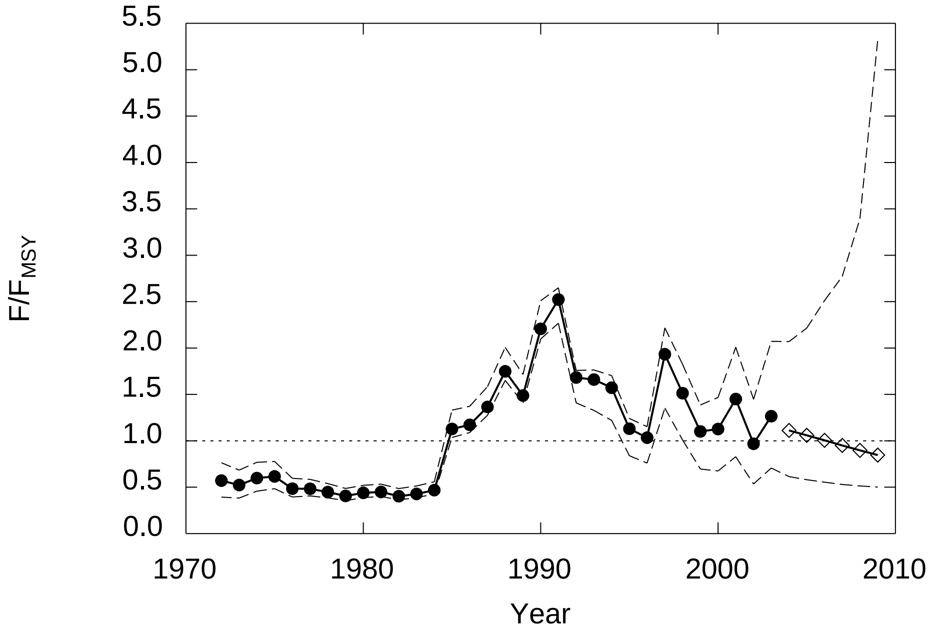


Fig. 43b. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Relative biomass (B/B_{MSY}) and fishing mortality (F/F_{MSY}). This analysis is based on 8 years of spring Campelen survey data and 24 years of spring Engel survey data.



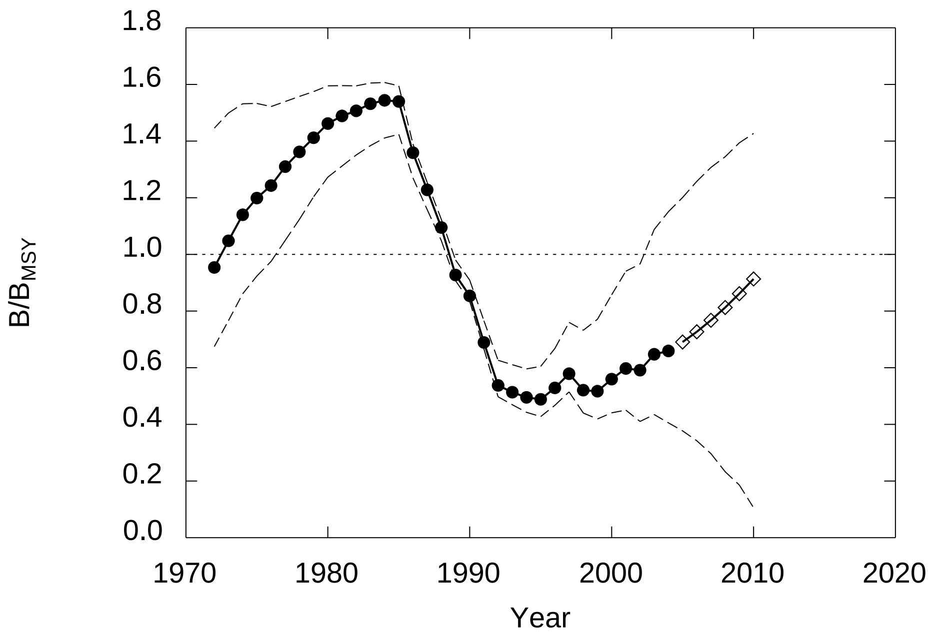
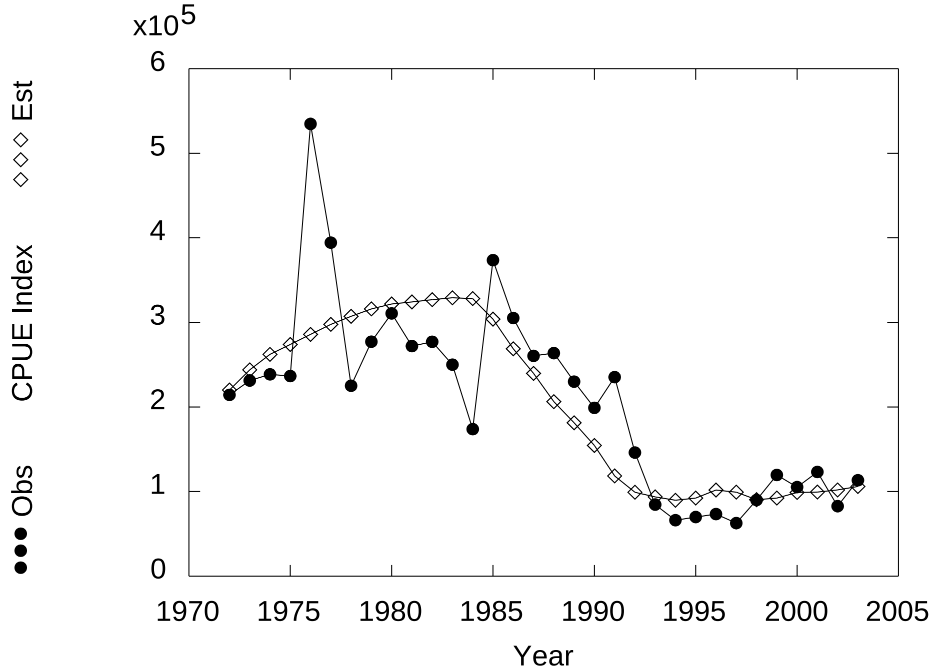


Fig. 43c. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Trends in fishing mortality (F/F_{MSY}) (upper panel) and relative biomass (B/B_{MSY}) (lower panel). This analysis is based on 8 years of spring Campelen and 11 years of spring Engel survey data analysed as separate series. The projection is for 6 years using the catch in 2003 as the predicted yield.



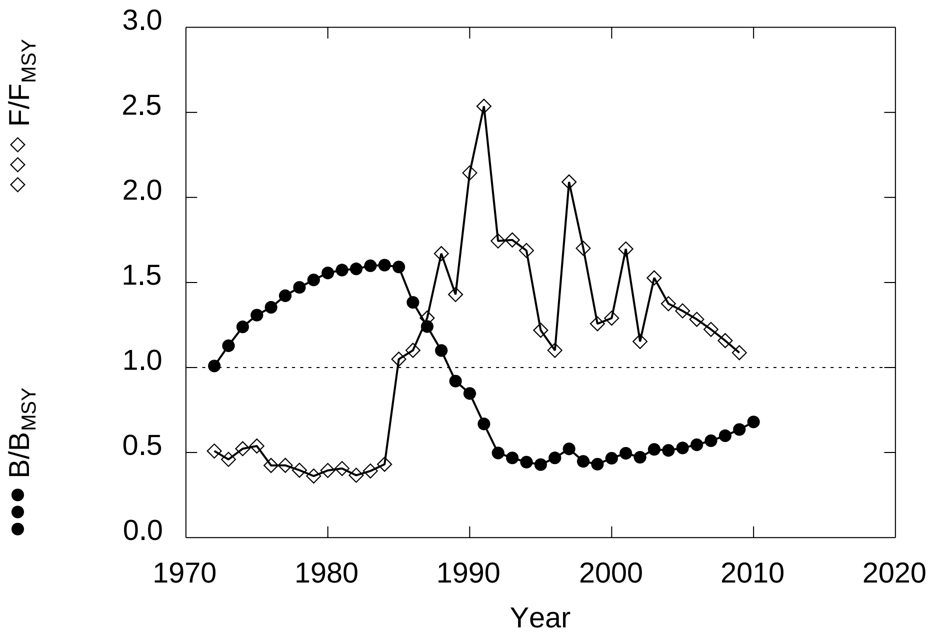


Fig. 44a. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Lower panel: Relative biomass (B/B_{MSY}) and fishing mortality (F/F_{MSY}). Upper panel: Observed survey index and fitted values (relative Biomass x 4). This analysis is based on spring Campelen and Engel series data standardized to Campelen.

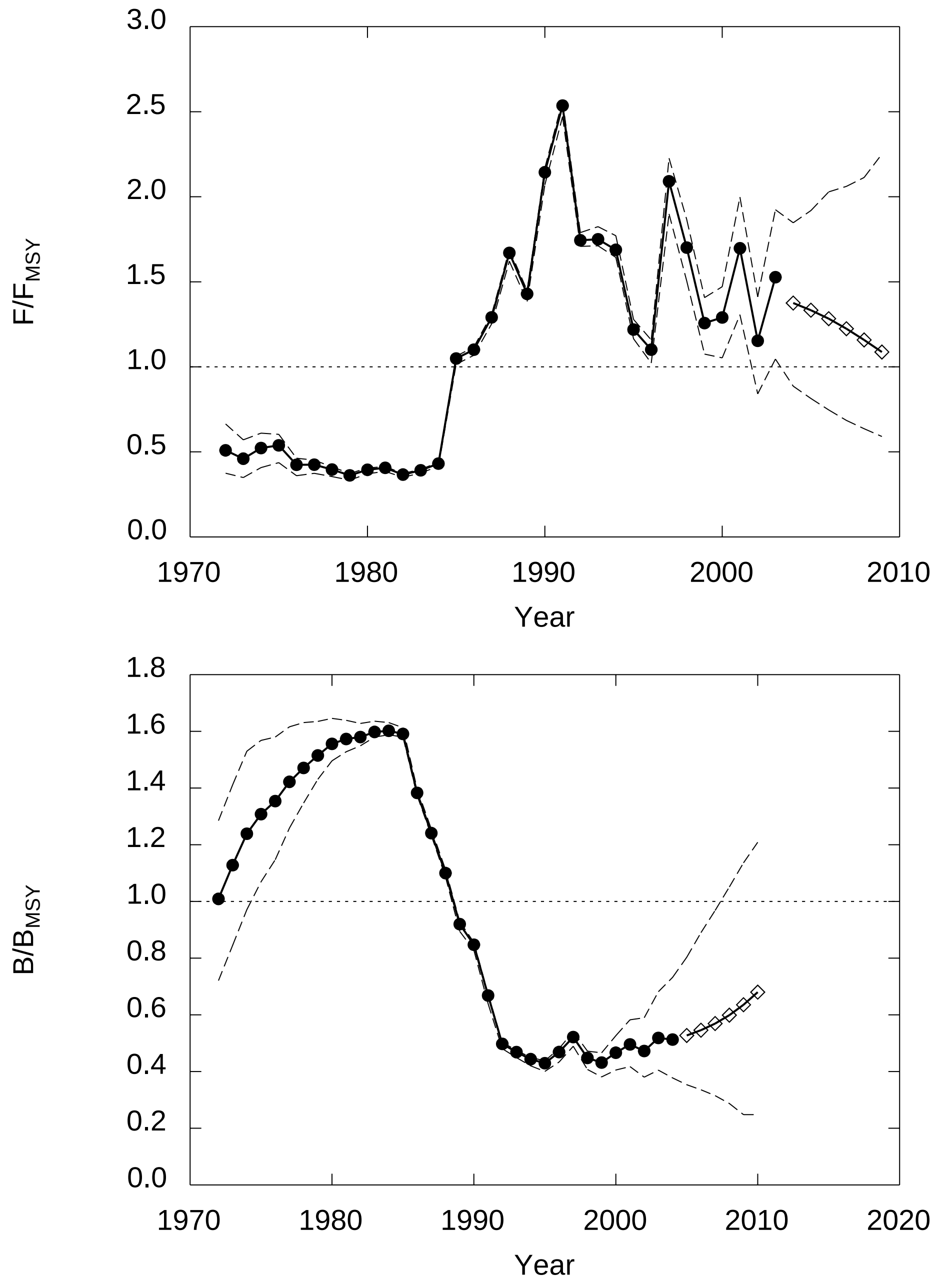
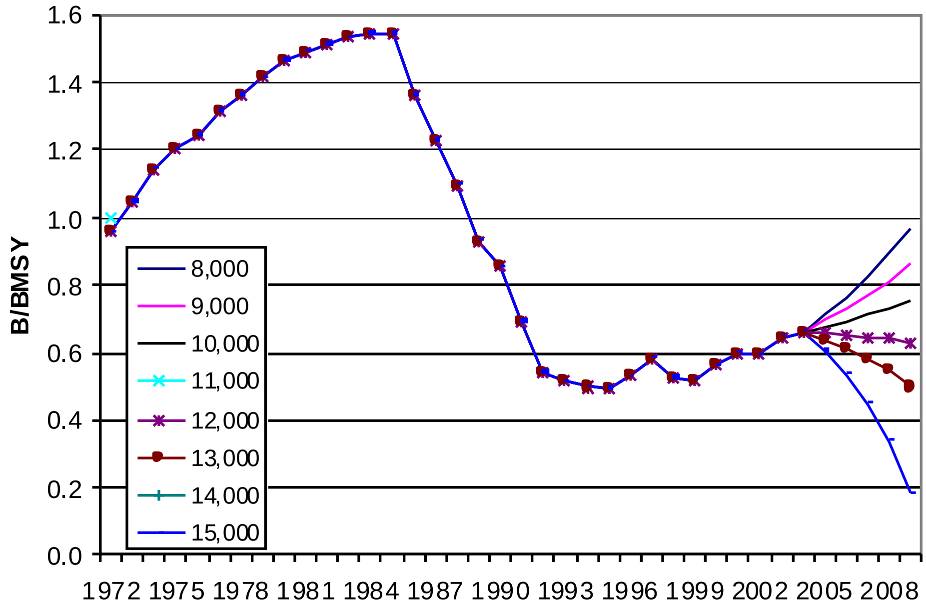


Fig. 44b. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Trends in fishing mortality (F/F_{MSY}) (upper panel) and relative biomass (B/B_{MSY}) (lower panel). This analysis is based on 32 years of spring survey data standardized to the Campelen series. The projection is for 6 years using the catch in 2003 as the predicted yield.



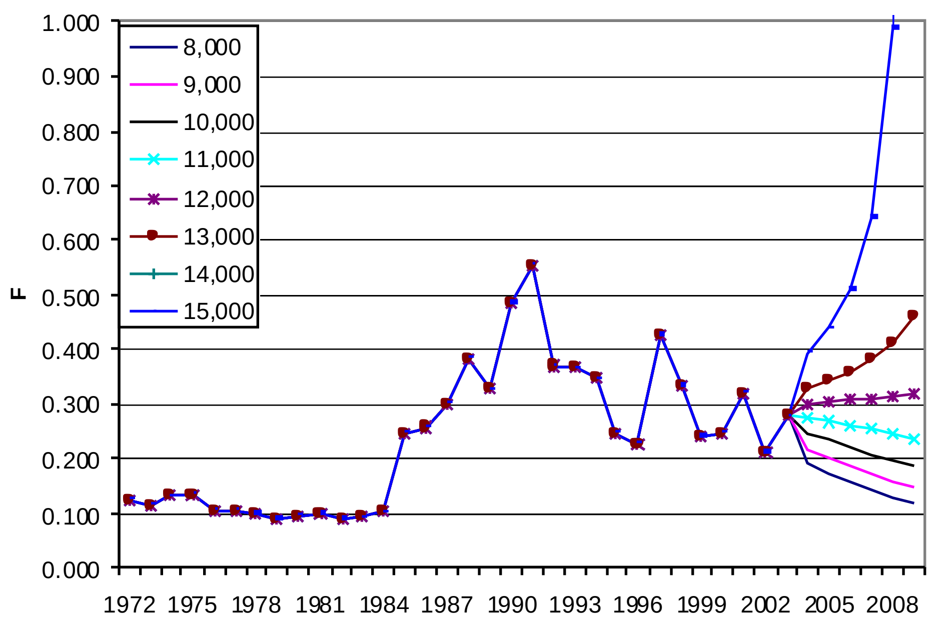


Fig. 45. Results of a non-equilibrium production model (ASPIC, Prager et al 1994). Trends and projections in relative biomass (B/B_{MSY}) (upper panel).and fishing mortality (F) (upper panel) and This analysis is based on 32 years of spring survey data standardized to the Campelen series. The projection is for 6 years using the catch in 2003 as the predicted yield.

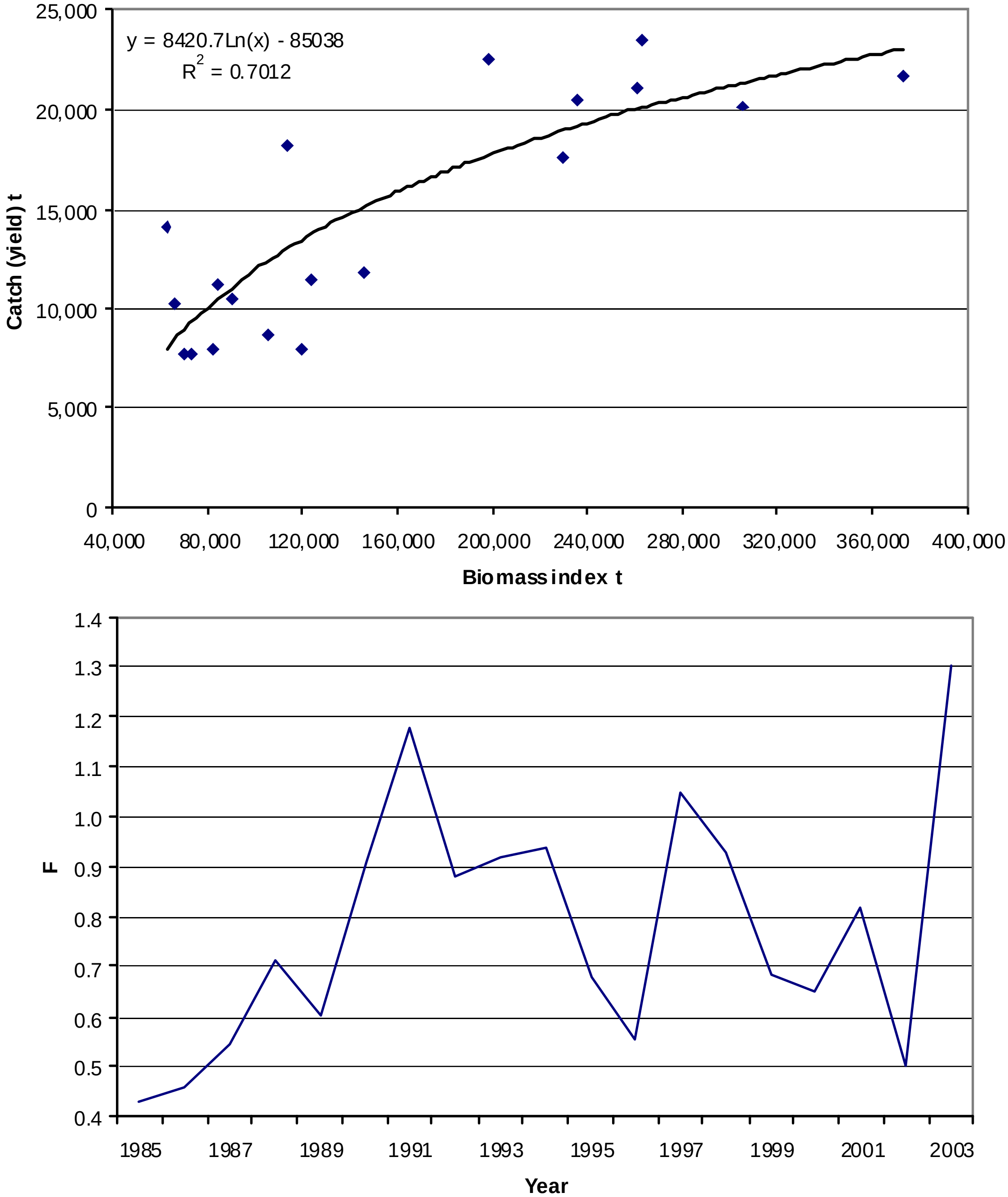


Fig. 46. Upper panel: Catch vs. Biomass (input for the ASPIC model). Lower panel: F calculated by the ASPIC model.