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

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Abstract

A directed fishery for skate (Rajidae primarily *Amblyaja radiata*) has been prosecuted in the NRA on the Tail of the Grand Banks since the mid-1980s by Spain, Portugal, and Russia, and after 1993 by Canada inside the 200-mile-limit. Before then, significant levels of bycatch were reported most of which was discarded. Reported catches, all countries combined, averaged 13 516 t (4 948-23 420 t) since 1985. In 2006, the reported catch was 6 911 t (1 418 t for Canada, including discards 5 493 t as the STACFIS estimate in Div 3LNO) down from previous years. The Canadian fleet fishes in summer and autumn at the outer depths of where skate are aggregated, along the southwest slope of the Grand Bank, where skates are largest. Non-Canadian fleets fish a separate area on the Tail of the Grand Banks (outside Canada's 200-mile-limit) in the autumn generally catching smaller skates. Biomass indices, following a decline to their lowest historic level in the early 1990s, have slightly increased and stabilized since the late 1990s. On average (1990-2006), autumn survey estimates of biomass for the comparable area (NAFO Divisions 3LNO) were 33% higher than in the spring, indicating a seasonal change in catchability. Analysis of total lengths measured 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 autumn (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. Relative F has averaged 0.09 since 1999 (equivalent to an average catch of 10 000 t): a period when the stock was stable but was considerably lower (0.04) in 2005 due to reduced catches. Based on the relationship between relative F and relative biomass, fishing below a relative F of about 10% (presently equivalent to a catch level of 11 000-13 000 t) may allow some recovery of the stock from current low levels.

INTRODUCTION

Thorny skate (*Amblyraja radiata* Donovan, 1808 Family Rajidae), is a temperate to arctic species widely distributed in the north Atlantic (ICES 2005). In the western Atlantic, it is distributed from Greenland to South Carolina and is at the centre of its distribution on the Grand Banks (Fig. 1). There, it comprises about 90% of the rajids caught in survey trawls, and is the target of several fisheries (Kulka and Miri 2003).

The Fishery and Management

Thorny skate have been targeted and taken as bycatch in numerous Northwest Atlantic fisheries and underwent a decline in many areas particularly in the 1990s. Along the Northeast coast of the United States, it remains in an over-fished condition with NEFSC autumn survey biomass indices declining continuously over the last 40 years to a record low in 2005 (SAFE 2001, 44th SAW 2007). In June 2004, the International Union for the Conservation of Nature (IUCN) recommended that the New England population of thorny skate be listed as "Critically Endangered." In the southern Gulf of St. Lawrence, Swain *et al.* (2005) also reported a continuous decline of 84-90% in survey biomass indices over the last 32 years. Ratz and Stransky (2002) noted a reduction in bycatch levels of thorny skate in several fisheries west of Greenland. In Canadian waters, thorny skate is presently undergoing an assessment for risk of extinction by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC).

Prior to the mid-1980s on the Grand Banks, various fishing fleets collectively reported annually several thousand t of skates as bycatch (Kulka and Mowbray MS 1998). It was estimated that an average of approximately 5 000 t was discarded annually by the Canadian fleet during 1980s to early 1990s and a few hundred tonnes were recorded in Canada's annual landings statistics during that period. In 1985, Spain began targeting skate in a non-regulated fishery in the NRA (Northwest Atlantic Fisheries Organization Regulatory Area) (Junquera and Paz MS 1998, del Río and Junquera MS 2000, 2001). In 2000, Russia commenced a directed fishery for thorny skate. In 1993 and 1994, experimental fishing resulted in the first significant skate landings appearing in Canadian statistics.

A 3 000 t quota, in place within Canadian waters from 1997-2005 was generally under-fished. Catches in the NRA, unregulated until 2004, have been more variable and substantially higher averaging about 7 500 t over the past six years. In 2004, regulation of this fishery was relegated to NAFO and a 13 500 t quota was placed on skate in NAFO Divisions 3NO for 2005-2007.

Review of the Biology

A detailed review of the biology of thorny skate was provided in Kulka *et al.* (2004), and a discussion of stock structure can be found in Kulka *et al.* (2006). This section summarizes relevant details from that paper.

Skates have been aged with vertebrae (Gallagher *et al.* 2005, Gedamke *et al.* 2005, Sulikowski *et al.* 2004), and with caudal thorns (Gallagher *et al.* 2002, Henderson *et al.* 2005) in other locations. On the Grand Banks, studies on thorny skate age and growth are underway using vertebrae (Kulka, pers. comm.) but have not been completed. Thus, age-based assessments are not yet possible. Maturity studies have been undertaken (del Río MS 2002), and this information has been used to carry out life history stage-based analyses, and to examine stock recruitment relationships for thorny skate on the Grand Banks (Kulka *et al.* 2004). Maturity estimates are also being updated but not yet available (Kulka, pers. comm.). Thus, this assessment is based largely on survey indices for various stages of maturity.

Kulka *et al.* (2004, 2006) noted that abundance has been low but stable since the early 1990s having undergone a substantial decline in the late 1970s to late 1980s. Spatial dynamics are rarely determined within the contemporary framework of management of elasmobranchs, or marine fish in general. However, for thorny skates on the Grand Banks, this aspect has been examined in some detail by Kulka *et al.* (2004) who showed that spatial dynamics were quite different from the population trends. Although its biomass has been stable for more than 10 years, the area occupied by this species has continued to decline and the density has continued to increase at its centre of mass. Hyper-aggregation has been shown to be a precursor to collapse in other marine fish species (Rose and Kulka 1999).

Purpose

The purpose of this paper is to provide advice for thorny skate on the Grand Banks (Div. 3LNOPs) and partition the advice for NAFO Divisions 3LNO (including the NRA) and Subdivision 3Ps (Canada see Kulka *et al* 2006). This paper also updates biological and fishery data to 2006.

METHODS

Survey Data

Data from standard NL (Newfoundland and Labrador) demersal trawl surveys (random stratified, Engel and Campelen trawl gear, spring and autumn, post-1970 to 1983 using Yankee-41.5, Engel-145 Hi-lift to 1996 and Campelen-1800 shrimp trawl to date) were used for estimating biomass and abundance. A summary of the stratified-random survey design (STRAP) applied by the DFO - NL Region after 1970 for this analysis can be found in Kulka *et al.* (2006).

Survey series from 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 1971-2005 (3LNOPs), and autumn 1981-2006 (3LNO). A significant portion of the annual spring survey was not done in 2006, therefore there were no estimates of biomass and abundance for Subdiv. 3Ps in 2006. In other years, not all areas were surveyed every year in both time series these missing data are denoted by blank cells on biomass and abundance tables. The total area surveyed in 1996-2006 was 294 589 km^2 in 1994-96 was 283 321 km^2 and in 1986-93 was 255 542 km^2.

STRAP2 uses catch per tow within area of survey tracks extrapolated to the total area within a series of predefined strata related in part to depth added over the survey area in order to yield an index of stock size (Smith and Somerton 1981). Similarly, STRAP1 (Smith and Somerton 1981) estimates numbers at length for predefined depth strata, which facilitates age or stage-based analyses. Total abundance at length is then calculated as the sum of the strata estimates for each length group over the survey area. Due to the absence of length-weight data from DFO stratified random surveys in NAFO Divisions 3LNOPs, sexed length-weight relationships of thorny skate generated by del Río *et al.* (2002) from Spanish spring trawl surveys in 2001 for Divisions 3NO were utilized in STRAP1 staged-based calculations. These calculations assumed that weight at length remained constant throughout the entire survey period.

The most significant alteration in NL research survey design was a change in trawl gear in autumn 1995: from Engel-145 High-Lift Otter (demersal) Trawl to Campelen-1800 Shrimp Trawl. Simpson and Kulka (2005) derived a conversion factor from comparative sets where catch numbers and weights were recorded and by comparison of average size between gears. The conversion factors were determined to be 2.63 (weight) and 2.42 (number) for converting Engel values into Campelen equivalents.

Since the autumn survey series is never spatially complete over the entire designated stock area (i.e., does not include Subdivision 3Ps), spring surveys were used as the primary estimator of biomass and abundance trends of thorny skate. However, autumn estimates are also calculated as that survey is conducted when a greater proportion of thorny skates are available for capture by trawl gear. During autumn, skates are concentrated on the shelf whereas in spring, part of the population has moved to the shelf edge and a proportion apparently moves outside of the spring survey area (Kulka *et al.* 2004). In addition, the spring survey fishes shallower depths (~750 m) than in the autumn survey (~1 400 m in recent years, Table 1). When using spring survey estimates of biomass and abundance to examine trends in the thorny skate stock, it is assumed that the proportion of skate that moves outside of the surveyed area is consistent among years.

Changes in the proportion of three life stages of thorny skate were examined: young-of-the-year (YOY) immature (IMM) and mature individuals (Spawning Stock Biomass - SSB). Survey length frequency numbers at length were partitioned into recently hatched, immature, and mature components. The ogives of del Río (2001) for 1997, 1999, and 2000 and our ogives for all years since were used to estimate the proportion of mature males and females in Canadian spring survey catches 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 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 in spring and autumn surveys. 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 skate caught. This mode was used to derive a recruitment index.

The Fisheries

NAFO Scientific Council's "agreed" estimates of skate catch 2004 and forward were used for the assessment (Table 2). Prior, information was derived from four sources: Zonal Interchange Format (ZIF) datafiles for Canadian landings the Canadian Fishery Observer database for species discards NAFO STATLANT-21A for reported non-Canadian landings and C&P (Department of Fisheries and Oceans Canada - Fisheries Management Branch - Conservation and Protection) commercial inspections data (refer to Kulka *et al.* 2006 for details).

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

RESULTS

Trends

Spring and autumn survey biomass and abundance indices are presented by NAFO Division in Tables 3a&b and Figure 2a in Campelen equivalents (note that spring 3LNOPs estimates are missing in 2006, because Subdiv. 3Ps was not surveyed in that year; see Table 1 for a summary of successful survey sets). For comparable years and areas (1981-2006 in Div. 3L 1990 in Div. 3LNO), spring and autumn survey estimates of biomass showed similar trends. However, autumn estimates were more variable and consistently higher within each NAFO Division. The decline observed in the spring survey series during the early 1990s also appeared in the autumn series. After 1995, the autumn index fluctuated without trend but 85-90% of the skate biomass in Div. 3LNO was concentrated in 3NO.

Based on spring survey data, average weight of thorny skates was 2 kg in the early 1970s declining to 1.0 kg by 1997, with most of the decline occurring during the 1990s, concurrent with the decline in biomass (Fig. 2b). Average size has increased to about 1.6 kg since then. The autumn trend from the late 1990s onwards was similar.

Campelen-equivalent spring indices (Table 3a, Fig. 2a: biomass and abundance, Fig. 3: mean weight and number per tow) show similar trends in Div. 3LNO (i.e., Divisions overlapping the NRA) *versus* 3LNOPs (the entire designated stock area). One or more Divisions were not surveyed in 1974 and 1983 and therefore, are excluded from the graph. Table 3a (comparing sampled Divisions) indicates that both biomass and abundance were flat or increasing slightly to 1975. The 1976 value is the highest on record - well above any other year – and was the result of three very large sets in Div. 3O (508, 428, and 243 kg skate per standard tow). Thus, the estimate for that year may be anomalously high. From 1975 to the late 1980s, the trends fluctuated without pattern then declined until the mid-1990s. Following a small increase in the late 1990s, these indices have been stable since. Over the past 14 years, relative biomass has been stable at approximately 40% of that observed in the 1970s and 1980s.

The decline in the early 1990s was spatially uneven with most occurring in the northern part of the Grand Banks (Div. 3L) and, to a lesser extent, in Div. 3N (Table 3a). Partitioning the Grand Banks in this manner clearly illustrates that biomass and abundance in the southwest was fluctuating, but more or less stable over the entire time series whereas biomass in the northeast declined by nearly 95% between the 1970s and mid-1990s (see detailed discussion on associated distributional changes in Kulka *et al.* 2004). The ratio of 3LN/3LNOPs biomass and abundance was stable during the 1970s, but then declined steadily during the 1980s-late 1990s becoming relatively stable since then.

A scaled comparison of the Canadian Campelen survey trends from 1995-2006 in NAFO Div. 3NO and the Spanish survey trends for the same period and area is similar although annual changes were not always in the same direction (Fig. 4).

Stages

The indices for each life history stage (i.e., young-of-the-year, juveniles, and adults) increased between the early 1970s and mid-1980s then declined rapidly in 1990-1995 (Fig. 5a, upper panels). Note that 2006 was not analysed because data from part of the stock area, Subdiv. 3Ps, was not available. All three stages have been stable at a low level since the mid-1990s. During the period of decline (late-1980s to mid-1990s), the proportion of mature skates in the population declined while the immature component increased (Fig. 5a, lower panels). This trend has reversed since the 1990s. While the proportion of abundance was changing, the proportion of biomass for each stage remained relatively stable over the entire period.

Recruit per spawner (Div. 3LNOPs) in most years was between 0.5-2.0. Values were highest during the period of decline of this stock. This is due to the greater decline in adult females, as compared to the YOY (Fig. 5b). The average over the entire period was 1.4. For 2005, recruit per spawner was calculated for Div. 3LNO only given the missing data on recruits in 2006 for Subdiv. 3Ps.

The relationship between female spawning stock abundance (SSA) and recently hatched skate (YOY) is illustrated in Figure 6 (does not include 2006 because Subdiv. 3Ps was not surveyed). The upper panel shows that the ratio of YOY/SSA was low in 1980-1986 had increased in 1989-1995 then declined and stabilized at levels previously observed in the early to mid-1980s. This increase in YOY relative to SSB is concurrent with the period of decline of this stock. Figure 7 further illustrates that the female SSA and YOY followed a similar trend with and without YOY offset by one year thereby suggesting a relationship between spawning stock and recruitment. The highest three years in the series (to 2005) averaged a SSA=22 million and SSB= 41 929 t the lowest three years of female relative SSB averaged a SSA=4.3 million and SSB=8 164 t. In 2003-2005, female relative SSB averaged a SSA=12.7 million and SSB=24 151 t. Note that the 2006 point was not included in this analysis, because Subdiv. 3Ps was not surveyed in that year.

The Fisheries

A spatial representation of non-Canadian effort outside Canada's 200-mile-limit can be found in Kulka *et al.* (2004). In terms of areas fished, skate catches in Canadian waters occurred primarily in NAFO Division 3L and Subdivision 3Ps prior to 1992 (as bycatch) but have shifted to Div. 3O and Subdiv. 3Ps in recent years after the non-Canadian (3O) and Canadian (3OPs) skate-directed fishery began in 1985 and 1994, respectively. Directed Canadian effort for skate occurred mainly along the shelf edge from the Laurentian Channel in Subdiv. 3Ps to Canada's 200-mile-limit in Div. 3N.

Catches of non-Canadian countries (as reported in NAFO STATLANT-21A) are presented in Table 4, and combined catches of these countries are listed in Table 5. The latter table provides estimates derived from the Department of Fisheries and Oceans Canada's Conservation and Protection estimates for non-Canadian countries as well as values agreed to by STACFIS (NAFO). The 2006 estimate "agreed to" by STACFIS for Divisions 3LNO, plus the ZIF estimate of Canadian catches in Subdivision 3Ps, was 6 911 t, a 1 270-tonne increase over the 2005 value, but a three-fold decrease from the average in 2003-2004. Catches of skates for all countries since 1985 are illustrated in Figures 8 and 9. The catch of skates on the Grand Banks has been increasingly attributable to non-Canadian fleets fishing in NAFO Div. 3NO, now at about a 90% level (Fig. 9).

In 1985-1993, all reported Canadian skate landings were bycatch averaging 61 t per year. Commencing in 1994, Canada retained most of its skate catches in a new directed fishery (non-Canadian countries retain most of their skate catches). Current regulations dictate that all skates must be landed. Much of this Canadian bycatch came from mixed fisheries for Atlantic halibut/monkfish/white hake, and the redfish fishery. In 1994-2006, the skate-directed fishery accounted for 75% of all skates landed by Canadian vessels. Canadian skate catches have declined from an average of about 4 200 t at the beginning of this directed fishery to 1 100 t in 2006.

Since the late 1980s, 100% of skate reported by non-Canadian countries has been caught with trawl gear about 82% (1985-2006) was taken in Div. 3N on the Tail of the Grand Banks mostly in August-December. The remaining non-Canadian skate catches were bycatch in the Greenland halibut fishery that occurs throughout the year. In contrast, Canada utilized gillnets, longlines, and otter trawls in the Canadian skate fishery (Table2). In the first four years of the Canadian skate fishery (1994-1997), otter trawls caught most of the skates landed (46-75%). Since 1998, skate catches have been fairly evenly distributed between the three gears. Since July 2002, a minimum codend mesh size of 280 mm is required when directing for thorny skate in the NRA since 2005, a quota of 13 500 t (with 2 250 t for Canada) has been in place for NAFO Div. 3LNO (i.e., in addition to the 1 050 t quota in Subdiv. 3Ps for Canada).

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. 10). Relative F nearly tripled: from approximately 5% in the mid-1980s to 14% in 2003-2004. Most of this increase is attributed to increased catches in the NRA. The index has declined slightly in Subdiv. 3Ps. Relative F dropped to 4% in 2005-2006 (probably similar in 2006) due to reduced landings.

The Index of Exploitation 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 in a smaller area.

A temporal trajectory of Relative F to Relative (total) Biomass 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 inflects where Relative F ~ 0.1 and Relative (total) Biomass is ~ 110 000 t (Fig. 11).

DISCUSSION

In managing a commercially exploited species, it is important to have some knowledge of the stock structure, reproductive biology, spatial distribution, and commercial catches. Templeman (1884a, 1984b, 1987b) provided information on some of these topics: indicating limited movements (although tagging experiments were very limited), and 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 autumn 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 area the autumn series does not include Div. 3Ps. In addition, the relative difference between spring and autumn estimates has changed over time probably because of changes in patterns of migration. Thus, the thorny skate decline in the late 1980s and early 1990s may not be as great as the spring indices suggest, because the degree of migration was greater in those years. For this reason and those stated above, the spring research survey underestimates actual thorny skate biomass especially during the period of decline.

Walsh's (1992) escapement experiments with Engel trawl gear 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. 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, Engel 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 in both spring and autumn 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 Engel years (Simpson and Kulka 2004) indicate that Campelen gear is more efficient than Engel 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.

In addition, 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 Engel 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 from research surveys for thorny skates of all sizes must be viewed as minimum values (see Simpson and Kulka 2004 for a detailed discussion).

The analyses of spatial dynamics using aggregated statistics have revealed changes in the skate population that would otherwise be difficult or impossible to detect. In addition to changes in relative biomass, thorny skate has also undergone a reduction in area occupied. 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. This increases the probability of further depleting the stock given that the remaining concentrations coincide with the fishing grounds. A similar pattern of aggregation was observed for northern cod just prior to its collapse (Rose and Kulka 1999).

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.

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 (Kulka *et al.* 2004). 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 (related to SSB) has been low since the mid-1990s, except in Subdiv. 3Ps.

Both area occupied and biomass of thorny skate on the Grand Banks declined in the 1980s-early 1990s but causes for the decline 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 (historically or presently). Thus, a "cropping down" effect was not observed.

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.

CONCLUSION

Incomplete Canadian survey coverage, missing Subdivion 3Ps in 2006, has impaired this update: relative biomass and abundance of this stock as a whole cannot be determined for 2006. However, biomass has remained stable or has slightly increased for 13 years in spite of some relatively high catches in the late 1990s-2004. Although Relative F increased by almost three times over 20 years, it has dropped to near historic levels in 2005-2006 due to reduced catches. Hyper-aggregation in the late 1980s-early 1990s, plus an increasing area devoid of skates are not positive indicators, but area occupied has undergone a minor re-expansion over the past 3-4 years.

Production modeling done by Kulka *et al.* (2005) suggested that catches exceeding 11 000 t could impair stock recovery. Furthermore, that study identified a fairly strong relationship between size of SSB and recruitment (size of YOY), and thus rebuilding depends on increasing the SSB. Even if fishing mortality is sufficiently low to allow recovery, the k-selected reproductive strategy of thorny skate could mean a protracted recovery process.

Deficiencies

There remain a number of limitations to knowledge of thorny skate in Div. 3LNOPs. Although all available evidence indicates a single population in 3LNOPs, stock structure has not yet been fully verified. Information is lacking on such characteristics as individual growth rate and details on the age structure of skate population(s). Ageing thorny skates has only recently been attempted but is a work in progress. Information on maturity was updated by Junquera and del Río (MS 2001), and del Río (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, particularly historically although this assessment attempted to determine a more accurate account of skate catches.

Prognosis

Thorny skate underwent a decline in the late 1980s to early-1990s, followed by a slight increase in the late 1990s. Since then, abundance has remained relatively constant near the lowest historic level. An average exploitation rate of 10% (equivalent to an average catch of 11 200 t) over the past 7 years has resulted in a flat biomass trajectory. Although stable in recent years, skate continues to be near a historically low population size. Average index of biomass over that 7 year period was 112 000 t. The current Total Allowable Catch (TAC) for skates in Div. 3LNOPs is presently 14 550 t (= 13 500 t in Div. 3LNO + 1 050 t in Subdiv. 3Ps), which considerably exceeds the current 11 100 t average catch. However, catches have been well below the quota in 2005-2006, averaging just over 5 000 t. The results of production modelling suggest that a catch $< 11\,000$ t would be required to allow rebuilding of this stock (Kulka *et al.* 2006).

Thus, current levels of exploitation may be sustainable. If the desired strategy is to sustain current levels of biomass (i.e., no recovery), then average annual catches of 11 000 t could be maintained (which is below the current TAC of 14 550 t). Given the uncertainty in the production model, a conservative TAC (corresponding to the lower confidence limit of 7 926 t) will ensure increasing biomass for this stock. If thorny skate population growth and eventual higher yield is the fisheries management objective, then catch levels below current quota is required.

Management Considerations

A number of points must be taken into consideration when determining appropriate management measures:

1. The nature of the advice depends on whether the aim is to allow the stock to grow to previous or higher levels or to maintain the stock at current levels.

2. All available evidence suggests that thorny skates in Div. 3LNOPs comprise a single population. There is no evidence that the fish constitute different populations between Div. 3LNO and Subdiv. 3Ps. Thus, this assessment considers these skates as a single biological unit in formulating biomass trends, production, and exploitation then partitions that advice to the current management units of Div. 3LNO and Subdiv. 3Ps.

3. 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 species). The key difference is that most teleosts have the potential to produce large year classes from a small spawning stock, whereas elasmobranchs do not.

4. The recent level of exploitation has resulted in a stable biomass for more than a decade. Analyses here have shown that there is a fairly strong stock/recruit relationship, smaller SSB producing smaller year classes (YOY). Therefore, a rebuilding strategy, if that is the desired fisheries management objective, must include a reduction in exploitation of the SSB (below 11 000 t) in order to allow an increase in recruitment. Alternatively, if retaining stability at current low biomass (near historic low) is the desired objective, then a maximum catch of approximately 11 000-12 000 t is required to maintain that level. The current TAC for Div. 3LNOPs, totalling 14 550 t, considerably exceeds that level.

5. Concentration of thorny skate biomass onto the southern portion of the Grand Banks since the mid-1980s (both inside and outside the NRA), coinciding with the fishing grounds, has made this stock more vulnerable to overfishing. Historically a refuge from significant fishing pressures, the northern Grand Banks is now largely devoid of skates except along the shelf edge.

6. 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 occur in order to allow this population to rebuild to higher levels, it would be reasonable to recommend that the majority of reductions take place in the fishery outside 200 miles.

Summary

- Thorny skate biomass has been stable for about 14 years but the stock had become concentrated in a small area on the southern Grand Bank (hyper-aggregation). Once densely concentrated on the northern Grand Banks, thorny skates are now absent from much of this area. However, the species has shown a minor re-expansion in its distribution during the past 3-4 years.
- Small thorny skates (10-30 cm TL) have been largely absent from the northern Grand Banks (NAFO Division 3L) since 1996. The largest occurrence of small skates is presently found in NAFO Subdivision 3Ps.
- Since the mid-1990s, 17% of thorny skate biomass distribute outside Canada's 200-mile-limit while approximately 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 Canada's 200-mile-limit. Catches returned to lower levels in the last 2 years.

- The Exploitation Index (commercial catch/spring research survey biomass index) increased from approximately 5% in the mid-1980s to around 15% in 2000 but has declined to an average of about 5% over the past 2 years.

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Table 1. Summary of sets in Canadian Campelen spring and autumn surveys in NAFO Div. 3LNO and Subdiv. 3Ps, 1996-2006. Number of successful sets, depths, and time periods (Campelen time series). Depths are in meters.

Number of sets.

Spring	3L	# of inshore sets included	3N	3O	3Ps	Total	earliest	latest
1996	188	0	82	86	148	504	7-May	27-Jun
1997	158	0	71	81	158	468	30-Apr	26-Jun
1998	163	8	88	93	177	529	10-Apr	30-Jun
1999	177	32	82	86	175	552	13-Apr	29-Jun
2000	134	0	81	83	171	469	8-Apr	29-Jun
2001	154	12	79	79	173	497	7-Apr	24-Jun
2002	146	4	79	79	177	485	5-Apr	22-Jun
2003	155	14	79	79	176	503	5-Apr	26-Jun
2004	151		79	79	177	486	11-Apr	26-Jun
2005	133		78	79	178	468	17-Apr	18-Apr
2006	141		22	32		195	10-Jun	30-Jun
mean	155		75	78	171	469		

Depth range (m), Canadian Campelen spring surveys 1996-2006.

	3L		3N		3O		3Ps	
Spring	min	max	min	max	min	max	min	max
1996	66	664	42	665	65	685	42	613
1997	60	681	35	689	62	669	34	637
1998	53	721	38	682	64	657	40	670
1999	41	692	40	659	62	679	41	870
2000	61	681	45	664	61	694	39	608
2001	34	695	40	650	64	699	38	609
2002	42	710	40	641	63	628	37	625
2003	62	698	39	681	63	726	40	675
2004	47	710	44	675	61	636	36	591
2005	64	672	45	691	66	719	37	658
2006	60	701	46	77	64	103		
mean	54	693	41	616	63	627	38	656

Number of sets.

Autumn	3L	# of inshore sets included	3N	3O	3Ps	Total	earliest	latest
1996	211		84	61	-	356	9-Oct	17-Dec
1997	205		100	81	-	386	26-Sep	20-Dec
1998	204		122	96	-	422	10-Oct	17-Dec
1999	170		68	75	-	313	13-Oct	12-Dec
2000	176		94	100	-	370	11-Oct	18-Dec
2001	205		94	97	-	396	22-Sep	6-Dec
2002	206		94	99	-	399	5-Oct	2-Dec
2003	205		70	83	-	358	23-Sep	10-Jan-04
2004	147		69	76	-	292	31-Oct	19-Dec
2005	125		100	99	-	324	4-Oct	8-Dec
2006	185		70	74	-	329	30-Sep	18-Dec
mean	185		88	86		359		

Depth range (m), Canadian Campelen autumn surveys 1996-2006.

	3L		3N		3O		3Ps	
Autumn	min	max	min	max	min	max	min	max
1996	51	1433	37	1147	63	690	-	-
1997	35	1436	41	769	62	611	-	-
1998	34	1437	37	1447	61	1076	-	-
1999	63	1407	39	664	58	692	-	-
2000	42	1430	46	1419	62	1424	-	-
2001	38	1457	45	1410	67	1391	-	-
2002	35	1431	44	1429	65	1504	-	-
2003	32	1446	43	727	63	1382	-	-
2004	44	653	40	659	63	634	-	-
2005	59	687	42	1445	60	1410	-	-
2006	61	1401	46	650	63	674	-	-
mean	45	1293	42	1070	62	1044		

Table 2. Number of thorny skates measured for total length in commercial catches, 1994-2006. Data are from Canadian Fisheries Observers.

Year	Gear	Males	Females	unsexed	Total
1994	Otter trawl	820	298		1,118
1995	Longline	147	376		523
1998	Otter trawl	18	20		38
	Gillnet	111	218		329
	all gears	129	238		367
1999	Otter trawl	535	271		806
	Gillnet		381		381
	all gears	535	652		1,187
2000	Gillnet	2,234	5,183		7,417
	Longline	336	194		530
	all gears	2,570	5,377		7,947
2001	Otter trawl	383	247		630
	Gillnet	212	334	168	714
	all gears	595	581	168	1,344
2002	Otter trawl	75	73		148
	Gillnet	1,649	2,873		4,522
	all gears	1,724	2,946		4,670
2003	Otter trawl	68	76		144
	Gillnet	708	781		1,489
	Longline	13	64		77
	all gears	789	921		1,710
2004	Otter trawl	889	911		1,800
	Gillnet	124	261		385
	all gears	1,013	1,172		2,185
2005	Otter trawl	928	995		1,923
	Gillnet	281	605		886
	all gears	1,209	1,600		2,809
2006	Otter trawl	1,054	901		1,955
	Gillnet	67	101		168
	all gears	1,121	1,002		2,123
Total		10,652	15,163	168	25,983

Table 3a. Campelen Equivalent biomass, abundance, and mean weight of thorny skate from Canadian spring research vessel surveys, 1971-2006. Surveys were conducted with a Yankee bottom trawl (1971-1983), an Engel trawl (1984 -spring 1995), and a Campelen trawl (spring 1996-2006). Spring surveys: NAFO Subdiv. 3Ps was not surveyed in 1971, 2006; NAFO Div. 3O was not surveyed in 1972, 1974, 1983 and NAFO Div. 3N was not surveyed in 1983. Note that deep strata in Div. 3NO were not surveyed in spring 2006.

Canadian research vessel spring surveys															
	Biomass (000s of tonnes)					Abundance (000,000s)					Mean weight (kg)				
Year	3L	3N	3O	3Ps	3LNOPs	3L	3N	3O	3Ps	3LNOPs	3L	3N	3O	3Ps	3LNOPs
Yankee series															
1971	92,313	29,740			122,053	27,910	9,489			37,399	3.31	3.13			3.26
1972	61,518	94,904		43,190	199,612	26,710	37,834		13,588	78,132	2.30	2.51		3.18	2.55
1973	47,322	71,644	61,247	35,287	215,500	29,316	26,700	31,049	16,509	103,574	1.61	2.68	1.97	2.14	2.08
1974	105,863	57,394		58,986	222,243	64,423	28,137		26,949	119,509	1.64	2.04		2.19	1.86
1975	82,032	56,753	66,613	15,041	220,439	59,924	20,021	29,483	4,003	113,430	1.37	2.83	2.26	3.76	1.94
1976	105,836	103,664	211,018	77,601	498,119	68,471	51,836	69,200	46,266	235,773	1.55	2.00	3.05	1.68	2.11
1977	167,273	115,963	51,632	32,417	367,284	61,080	39,628	18,194	21,393	140,296	2.74	2.93	2.84	1.52	2.62
1978	99,792	43,116	46,823	19,919	209,650	52,948	24,482	18,340	27,273	123,043	1.88	1.76	2.55	0.73	1.70
1979	116,711	62,796	52,127	26,547	258,181	56,556	33,539	18,140	20,109	128,343	2.06	1.87	2.87	1.32	2.01
1980	108,479	68,751	56,514	55,623	289,366	46,479	38,351	40,627	29,524	154,980	2.33	1.79	1.39	1.88	1.87
1981	145,372	45,481	32,377	30,114	253,344	80,401	23,460	14,306	29,511	147,678	1.81	1.94	2.26	1.02	1.72
1982	99,330	79,323	60,144	19,365	258,163	51,767	57,168	26,753	8,621	144,309	1.92	1.39	2.25	2.25	1.79
1983				36,041	36,041				29,641	29,641				1.22	1.22
Engel series															
1984	17,881	59,765	63,188	21,038	161,872	7,574	25,226	24,615	9,417	66,832	2.36	2.37	2.57	2.23	2.42
1985	105,978	89,501	114,232	38,263	347,973	63,081	45,278	50,123	55,214	213,697	1.68	1.98	2.28	0.69	1.63
1986	72,341	114,234	48,287	49,418	284,279	51,231	53,395	21,134	36,152	161,913	1.41	2.14	2.28	1.37	1.76
1987	84,944	62,681	52,813	42,138	242,575	39,151	33,539	34,040	28,113	134,842	2.17	1.87	1.55	1.50	1.80
1988	72,630	51,445	90,472	31,055	245,603	35,030	26,475	42,991	19,043	123,539	2.07	1.94	2.10	1.63	1.99
1989	75,889	50,883	41,596	45,841	214,208	40,349	30,030	17,678	25,863	113,919	1.88	1.69	2.35	1.77	1.88
1990	46,917	49,163	64,140	25,124	185,344	43,938	71,656	40,119	21,344	177,057	1.07	0.69	1.60	1.18	1.05
1991	22,984	29,950	102,512	63,714	219,161	34,780	44,550	35,194	50,254	164,778	0.66	0.67	2.91	1.27	1.33
1992	12,158	23,865	59,982	40,065	136,071	36,886	20,645	35,567	21,511	114,609	0.33	1.16	1.69	1.86	1.19
1993	8,850	19,207	36,357	14,402	78,816	27,765	17,068	15,026	16,001	75,860	0.32	1.13	2.42	0.90	1.04
1994	4,058	10,554	29,898	17,127	61,637	15,999	17,564	19,106	19,222	71,891	0.25	0.60	1.56	0.89	0.86
1995	2,898	2,925	33,469	25,806	65,098	9,319	7,018	26,782	19,493	62,613	0.31	0.42	1.25	1.32	1.04
Campelen series															
1996	4,992	11,010	35,529	21,851	73,382	10,416	10,636	22,731	25,591	69,374	0.48	1.04	1.56	0.85	1.06
1997	3,969	9,703	28,293	20,705	62,670	6,804	13,554	25,635	18,379	64,372	0.58	0.72	1.10	1.13	0.97
1998	5,807	13,186	42,351	28,629	89,973	7,764	10,141	34,130	22,781	74,816	0.75	1.30	1.24	1.26	1.20
1999	7,278	26,254	54,045	32,062	119,639	8,273	15,967	36,042	20,212	80,494	0.88	1.64	1.50	1.59	1.49
2000	14,011	27,861	40,917	22,528	105,317	12,512	16,027	28,525	18,574	75,638	1.12	1.74	1.43	1.21	1.39
2001	10,383	29,197	59,078	24,566	123,224	8,521	16,276	33,321	17,606	75,724	1.22	1.79	1.77	1.40	1.63
2002	8,580	13,987	38,025	22,127	82,719	5,920	8,469	32,902	17,560	64,851	1.45	1.65	1.16	1.26	1.28
2003	8,411	18,216	49,707	37,072	113,406	6,737	9,645	34,735	24,615	75,732	1.25	1.89	1.43	1.51	1.50
2004	7,806	20,425	39,740	38,354	106,325	4,762	8,925	21,153	24,256	59,095	1.64	2.29	1.88	1.58	1.80
2005	19,266	33,757	46,515	34,897	134,435	11,011	15,986	26,621	27,742	81,359	1.75	2.11	1.75	1.26	1.65
2006	16,193	56,698	25,252		98,143	8,450	23,618	17,778		49,846	1.92	2.40	1.42		1.97

Table 3b. Biomass, abundance, and mean weight of thorny skate from Canadian autumn research vessel surveys in Div. 3LNO, 1981-2006. Surveys were conducted with a Yankee bottom trawl (1981-1983), an Engel trawl (1984 - autumn 1994), and a Campelen trawl (autumn 1995-2006). Some deep strata were not sampled in 2005.

Canadian research vessel autumn surveys												
	Biomass (000s of tonnes)				Abundance (000,000s)				Mean weight (kg)			
Year	3L	3N	3O	3LNO	3L	3N	3O	3LNO	3L	3N	3O	3LNO
Yankee series												
1981	95,909				81,126				1.18			
1982	171,719				87,658				1.96			
1983	171,364				103,303				1.66			
Engel series												
1984	154,342				70,979				2.17			
1985	146,052				86,070				1.70			
1986												
1987	90,955				80,879				1.12			
1988	111,733				86,633				1.29			
1989	70,282				76,793				0.92			
1990	98,973	69,849	100,950	269,772	116,758	43,855	53,191	213,803	0.85	1.59	1.90	1.26
1991	54,521	107,643	78,202	240,366	73,576	61,128	29,680	164,384	0.74	1.76	2.63	1.46
1992	41,716	54,858	43,885	140,459	94,058	33,854	24,675	152,587	0.44	1.62	1.78	0.92
1993	24,950	36,787	66,572	128,309	61,501	31,073	41,382	133,957	0.41	1.18	1.61	0.96
1994	16,776	52,755	33,059	102,590	44,196	50,142	30,749	125,087	0.38	1.05	1.08	0.82
Campelen series												
1995	11,306	40,775	44,653	96,734	23,284	37,322	30,582	91,188	0.49	1.09	1.46	1.06
1996	14,459	28,629	36,969	80,057	23,483	22,694	45,145	91,322	0.62	1.26	0.82	0.88
1997	7,534	43,075	58,160	108,769	13,448	30,540	50,047	94,035	0.56	1.41	1.16	1.16
1998	9,205	34,279	39,280	82,764	8,917	21,132	29,785	59,834	1.03	1.62	1.32	1.38
1999	13,614	32,609	42,609	88,832	10,448	25,117	31,847	67,412	1.30	1.30	1.34	1.32
2000	17,722	61,202	40,861	119,785	12,536	31,419	39,918	83,873	1.41	1.95	1.02	1.43
2001	16,420	34,311	62,156	112,887	12,655	21,353	42,095	76,103	1.30	1.61	1.48	1.48
2002	11,068	52,856	40,593	104,517	7,541	30,925	24,488	62,954	1.47	1.71	1.66	1.66
2003	9,072	36,829	46,123	92,024	5,828	19,203	34,556	59,587	1.56	1.92	1.33	1.54
2004	11,327	45,678	26,361	83,366	6,369	21,068	32,343	59,780	1.78	2.17	0.82	1.39
2005	18,315	37,442	61,595	117,352	10,242	20,027	30,553	60,823	1.79	1.87	2.02	1.93
2006	18,610	54,372	50,605	123,587	8,888	23,211	27,688	59,787	2.09	2.34	1.83	2.07

Table 4. Skate catch history for non-Canadian fleets, 1970-2006 (from NAFO STATLANT-21A). Data for 2006 are estimates "agreed to" by STACFIS (Scientific Council of NAFO).

Year	Cuba	Estonia	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	10,476	3,347	744		1	129	0	15,275
1991	0	0	0	0	0	641		0		0	0	21,097	6,462	762		0	66	1	29,029
1992	0	0	0	0	0	46		0		0	0	3,822	128	1,044	62	0		3	5,105
1993	0	0	0	0	0	11		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	1,005	1	0	0	39		0	4	0	1	795	10,130	0	2,570	0		0	14,545
2002	0	328	0	0	0	238		33	0	0	0	1,325	5,806	0	3,157	0		0	10,887
2003	0	874	0	0	0	82		64	406	0	0	1,892	7,073	0	3,273	0		0	13,664
2004	0	846	0	0	0	87		54	0	0	0	1,463	5,530	0	3,581	0		0	11,561
2005	0	479	0	0	0	2		18	48	0	0	539	2,383	0	77	0		0	3,546
2006	0	230	0	0	0	3		5	135	0	0	457	4,662	0	9	0		0	5,501

Table 5. Landings of skate in Canadian and non-Canadian waters of Div. 3LNOPs, 1985-2006. Catches inside 200 miles were calculated from ZIF files (landings) and Fisheries 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. Non-Canadian catches in 2003-2006 are estimates "agreed to" by STACFIS (Scientific Council of NAFO).

	3L			3N			3O			3Ps			3LNO		3Ps	3LNOPs
Year	Can.	Non-Can.	All	Can.	Non-Can.	All	Can.	Non-Can.	All	Can.	Non-Can.	All	STATLANT-21A All	STACFIS All	STATLANT-21A Can	STACFIS Can+non-Can
1985	1,530	1,996	3,526	704	333	1,037	1,087	939	2,026	1,240	1,003	2,243	10,397	0	0	0
1986	1,774	1,556	3,330	1,299	10,516	11,815	1,562	734	2,296	1,053	1,629	2,682	14,348	0	0	0
1987	2,215	1,293	3,507	1,680	8,527	10,208	860	675	1,535	4,978	807	5,786	18,450	0	0	0
1988	3,057	1,149	4,206	1,407	6,524	7,931	1,517	450	1,967	2,000	786	2,787	18,742	0	0	0
1989	1,184	1,183	2,367	1,784	7,526	9,310	1,220	604	1,824	1,858	2,250	4,109	14,242	0	0	0
1990	1,940	1,893	3,833	453	12,432	12,885	837	1,015	1,853	3,200	745	3,945	14,767	0	0	0
1991	1,675	1,585	3,260	542	10,507	11,049	746	724	1,471	3,989	673	4,662	28,405	0	0	0
1992	421	615	1,036	329	5,814	6,143	1,635	518	2,153	2,355	76	2,431	5,119	0	0	0
1993	303	1,100	1,403	852	4,601	5,453	3,366	201	3,567	708	15	722	6,040	0	0	0
1994	269	650	919	62	6,701	6,763	1,218	151	1,369	1,238	3	1,241	7,968	0	0	0
1995	182	250	432	3	2,600	2,603	2,553	99	2,653	1,959	4	1,963	7,514	0	0	0
1996	71	1,200	1,271	8	3,000	3,008	2,149	201	2,351	995	2	997	6,990	6,671	995	7,666
1997	45	650	695	148	7,950	8,098	3,557	275	3,832	1,491	3	1,494	13,582	12,696	1,491	14,187
1998	79	250	329	61	7,200	7,261	1,036	304	1,340	1,516	7	1,523	9,493	9,010	1,516	10,526
1999	74	634	708	85	4,166	4,251	1,166	482	1,648	1,284	5	1,288	11,931	9,793	1,284	11,076
2000	139	346	485	156	5,859	6,015	620	485	1,104	1,053	22	1,075	18,276	14,079	1,053	15,132
2001	273	905	1,178	270	6,955	7,225	644	380	1,026	2,007	39	2,047	14,860	11,200	2,007	13,207
2002	245	575	821	385	3,090	3,475	1,175	558	1,733	1,503	238	1,741	11,581	10,552	1,503	12,054
2003	80	1,675	1,755	404	10,737	11,141	1,032	1,170	2,202	2,014	82	2,097	14,252	14,262	2,014	16,276
2004	50	1,169	1,219	209	9,868	10,077	536	437	973	1,200	87	1,287	11,826	9,742	1,200	10,942
2005	40	411	451	294	2,986	3,280	798	147	945	963	2	965	3,538	4,674	947	5,621
2006	23	126	149	0	5,002	5,002	246	365	611	1,149	3	1,152	5,019	5,799	1,149	6,948

Table 6. Canadian landings of thorny skate in NAFO Divisions 3LNO and Subdivision 3Ps by gear type and month, 1985-2006.

Gear	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Not rec.
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	32	315	242	234	35	7	1	4	4
	2003	6	22	6	0	31	352	267	133	50	28	23	5	46
	2004	0	6	0	13	4	55	134	94	66	24	17	3	0.31
	2005	10	1	0	7	44	103	114	101	59	15	4	0	0
	2006	32	9	28	13	96	165	203	101	13	1	4	0	0
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	53	103	88	32	17	11	3	0
	2003	1	3	38	223	61	6	23	19	46	18	5	4	0
	2004	0	0	11	45	23	7	18	13	9	12	9	11	1.43
	2005	62	136	147	115	44	44	12	18	7	5	4	0	0
	2006	26	3	30	16	8	21	7	13	9	13	6	1	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	834	47	4	5	43	16	3	2	0	0
	2004	0	0	0	2	756	0	5	0	0	0	0	0	2
	2005	1	0	1	399	1	0	3	1	0	0	0	0	0
	2006	0	0	1	216	33	8	1	5	0	0	7	0	0

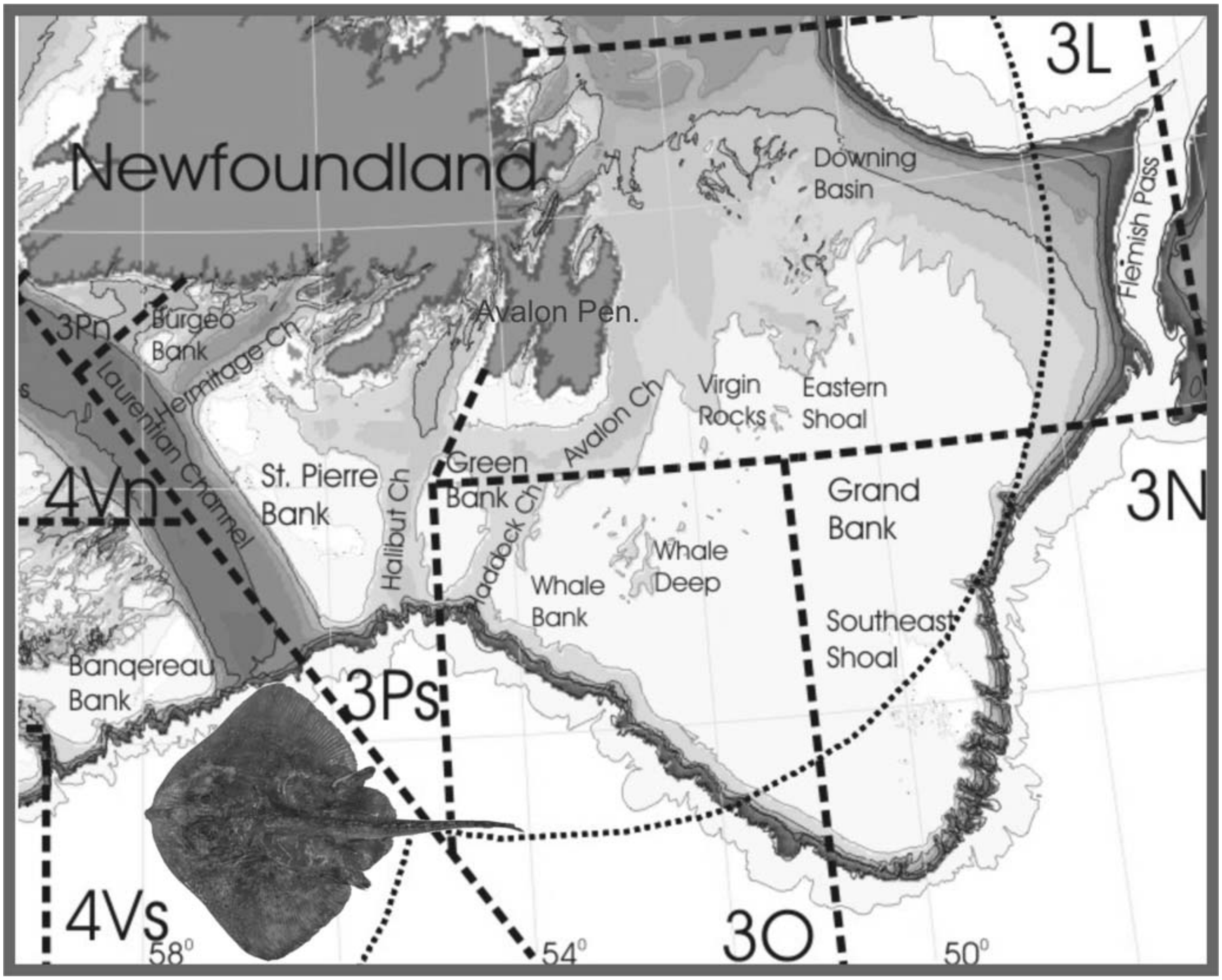


Figure 1. The Grand Banks, showing locations referenced in the text, bathymetry, Canada's 200-mile-limit, and NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps (image of thorny skate on lower left).

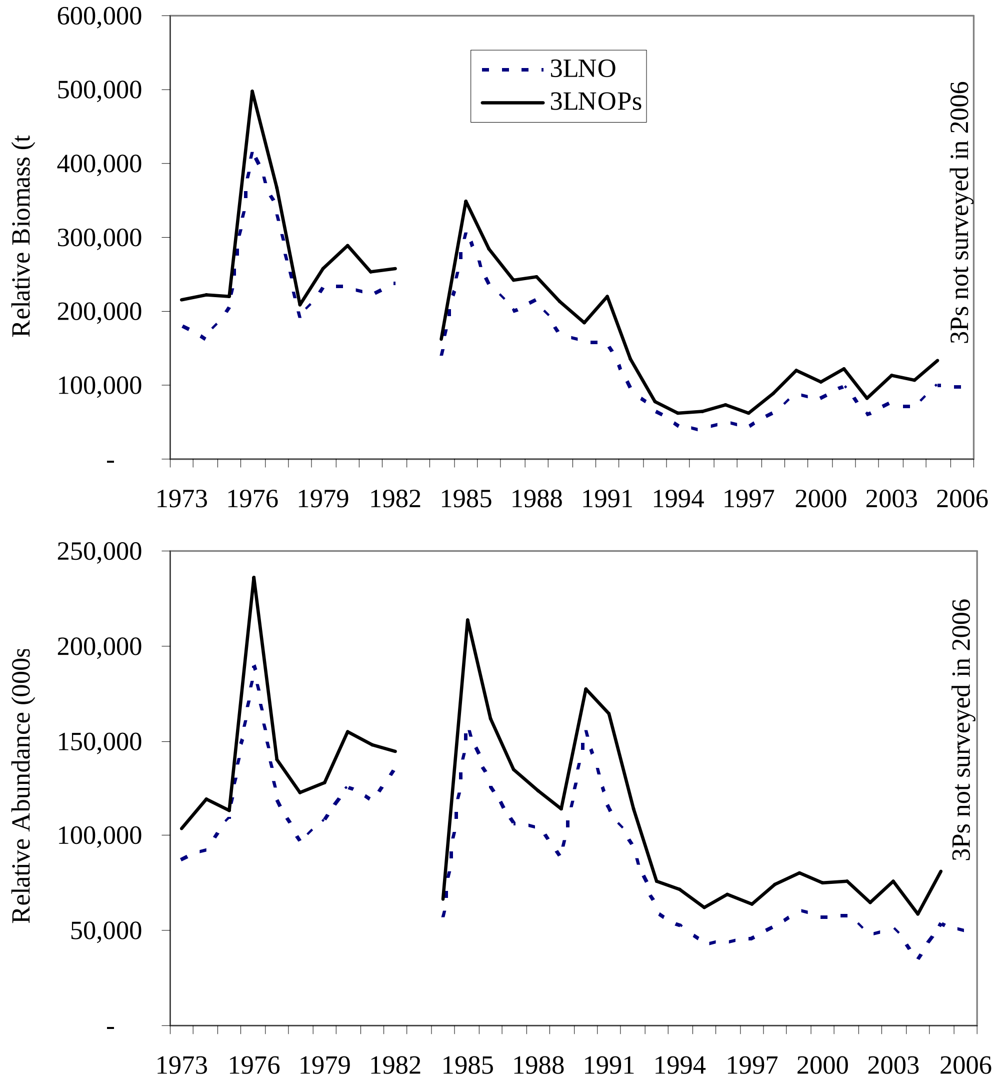


Figure 2a. Relative biomass and abundance of thorny skate from Canadian spring research vessel surveys in NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps, 1973-2006 with Engel estimates converted to Campelen equivalents. See Table 3a for an inventory of areas not surveyed.

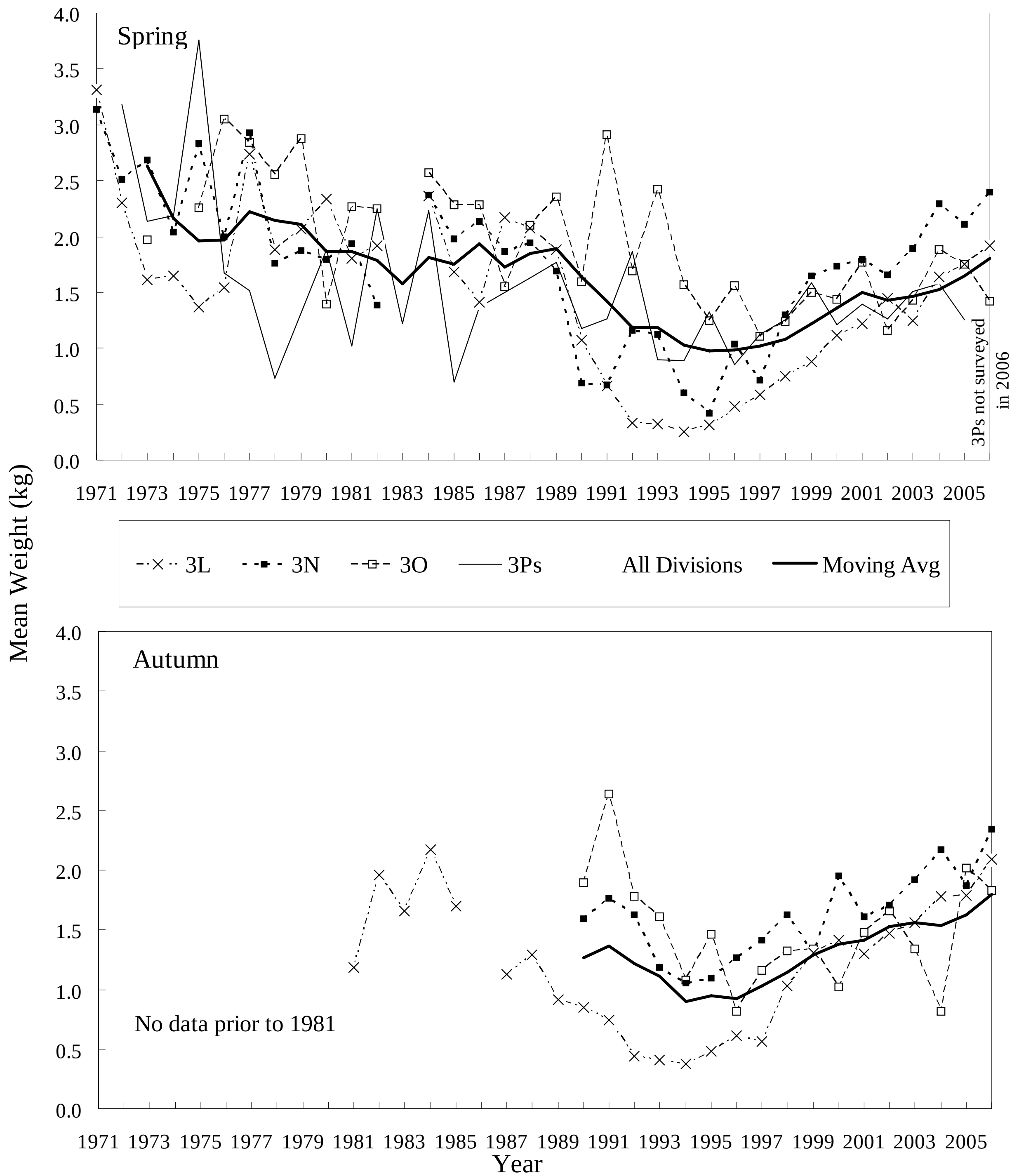


Figure 2b. Mean weight of thorny skate in spring (1971-2006) and autumn (1981-2006) surveys in NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps. See Table 3a for an inventory of areas not surveyed.

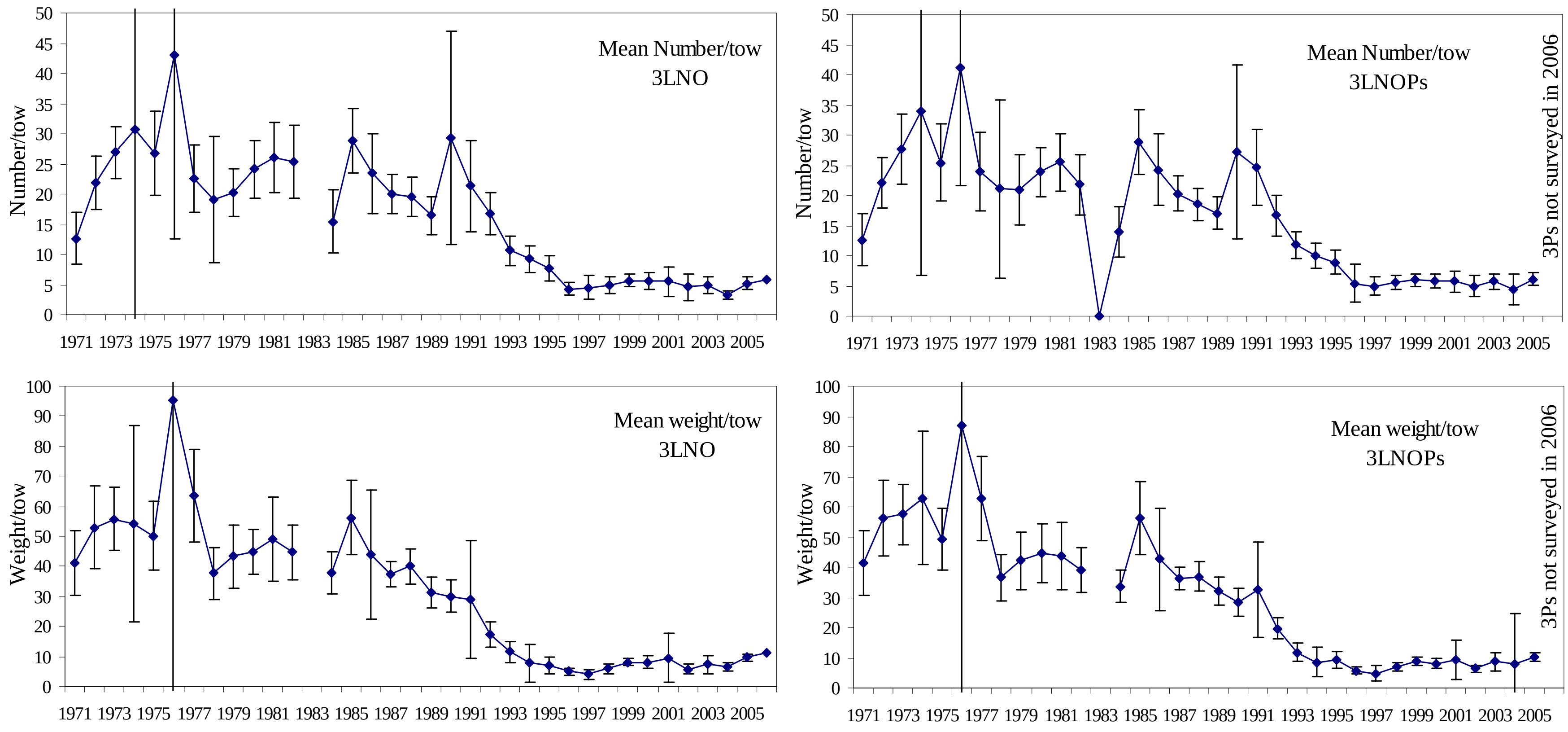


Figure 3. Mean weight and mean number per tow of thorny skate in NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps with Engel estimates converted to Campelen equivalents with error bars. See Table 3a for an inventory of areas not surveyed.

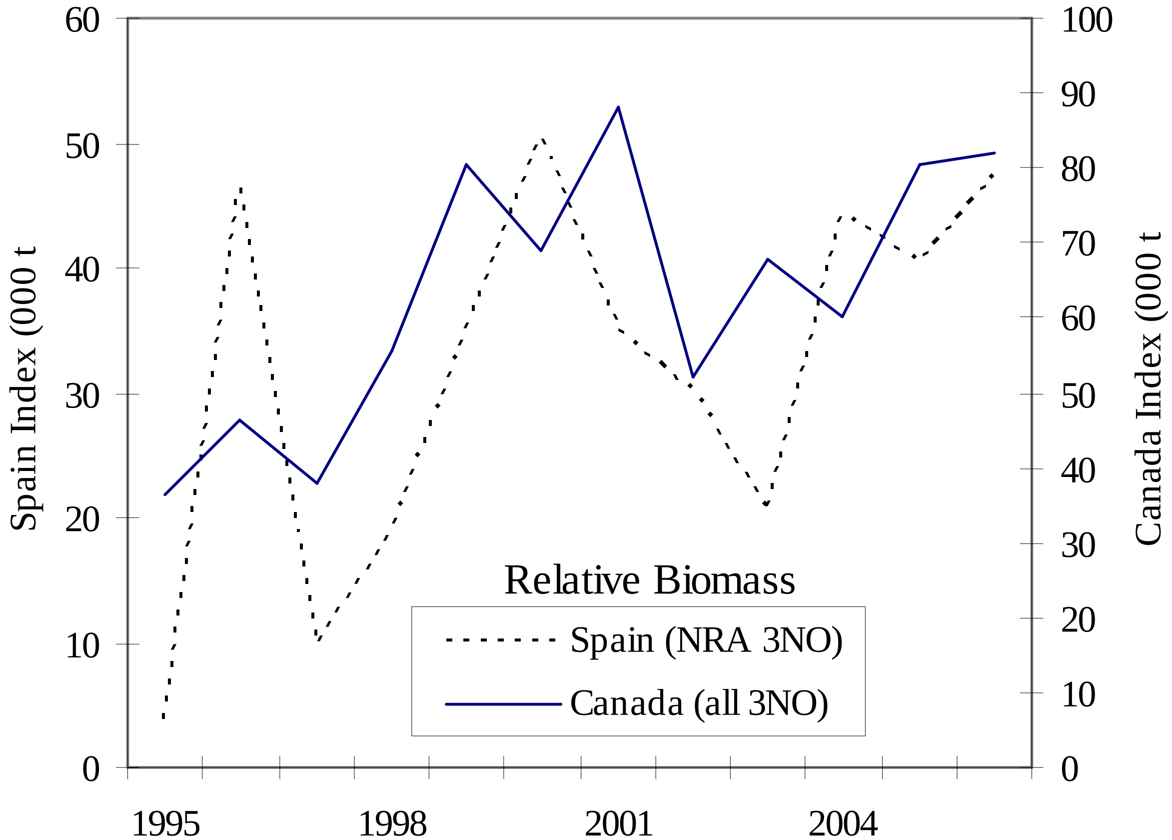


Figure 4. Scaled comparison of the Canadian Campelen survey trend with the Spanish Campelen survey trend in NAFO Div. 3NO, 1995-2006. Note that Spanish surveys occur only in the NAFO Regulatory Area (NRA).

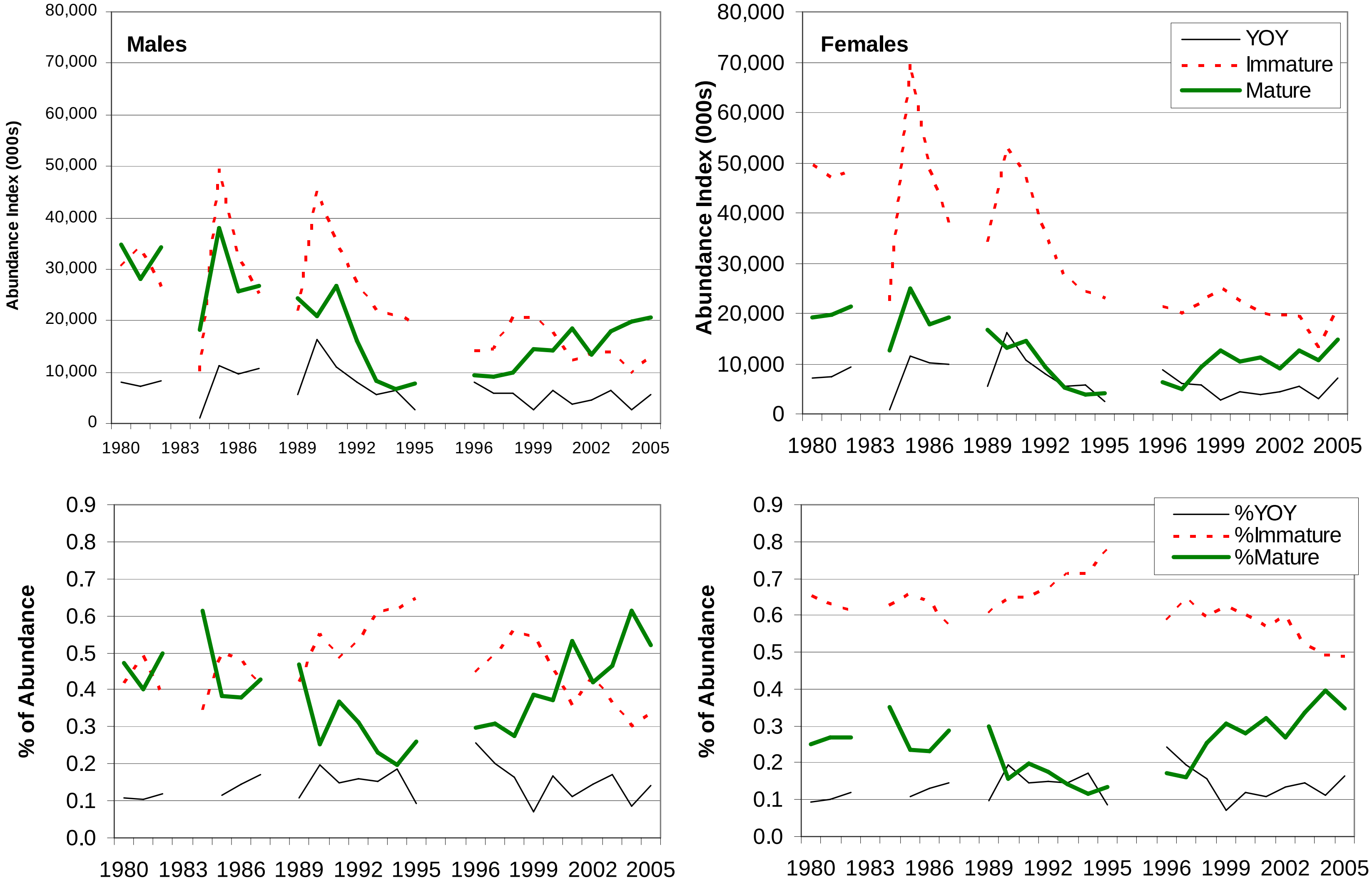


Figure 5a. Trends in abundance by stage and percent of total abundance that is young-of-the-year (YOY), immature, and mature, depicted separately by sex, 1980-2005

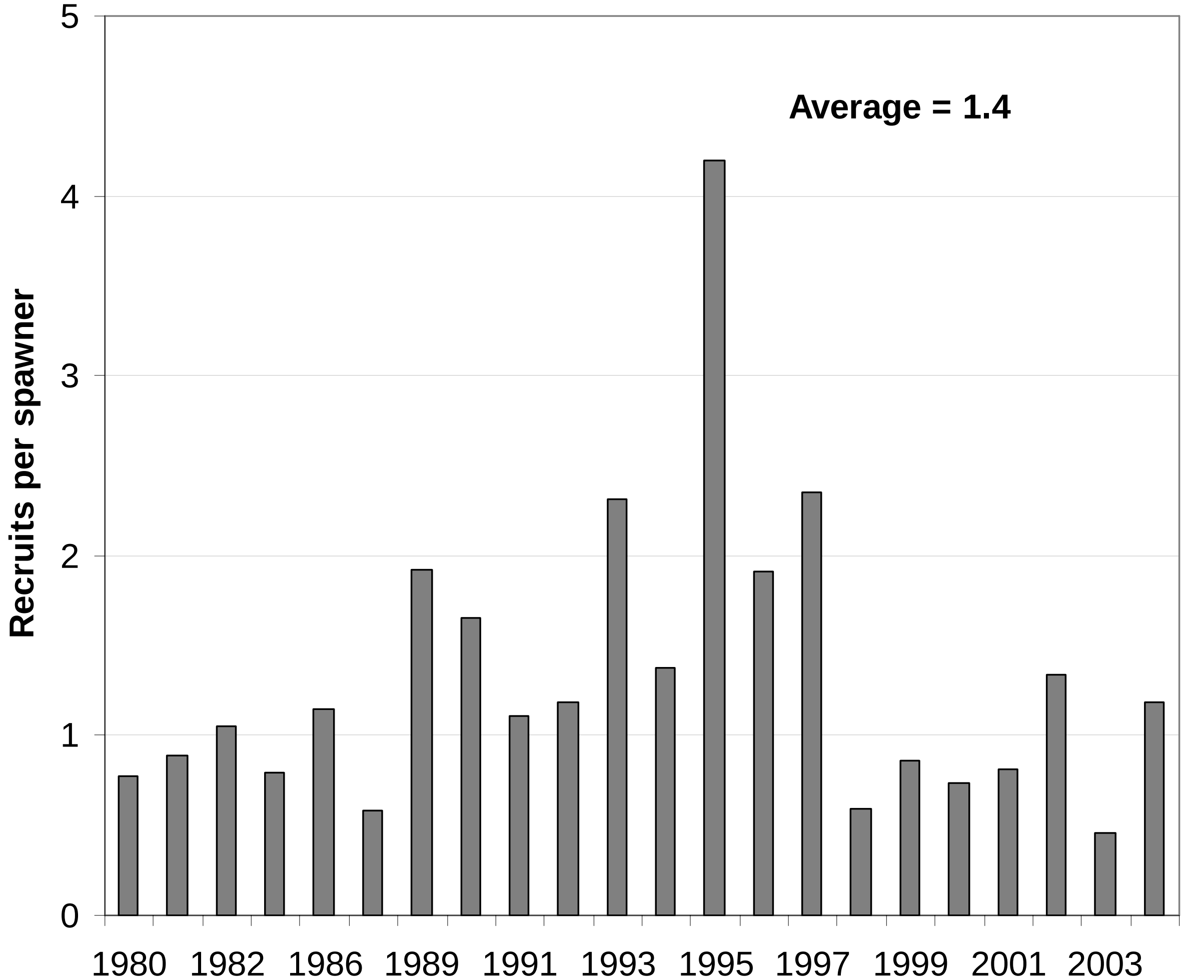


Figure 5b. Recruits per spawner expressed as number of young-of-the-year males and females (YOY produced per female) from Canadian spring research surveys in NAFO Div. 3NO and Subdiv. 3Ps, 1980-2005.

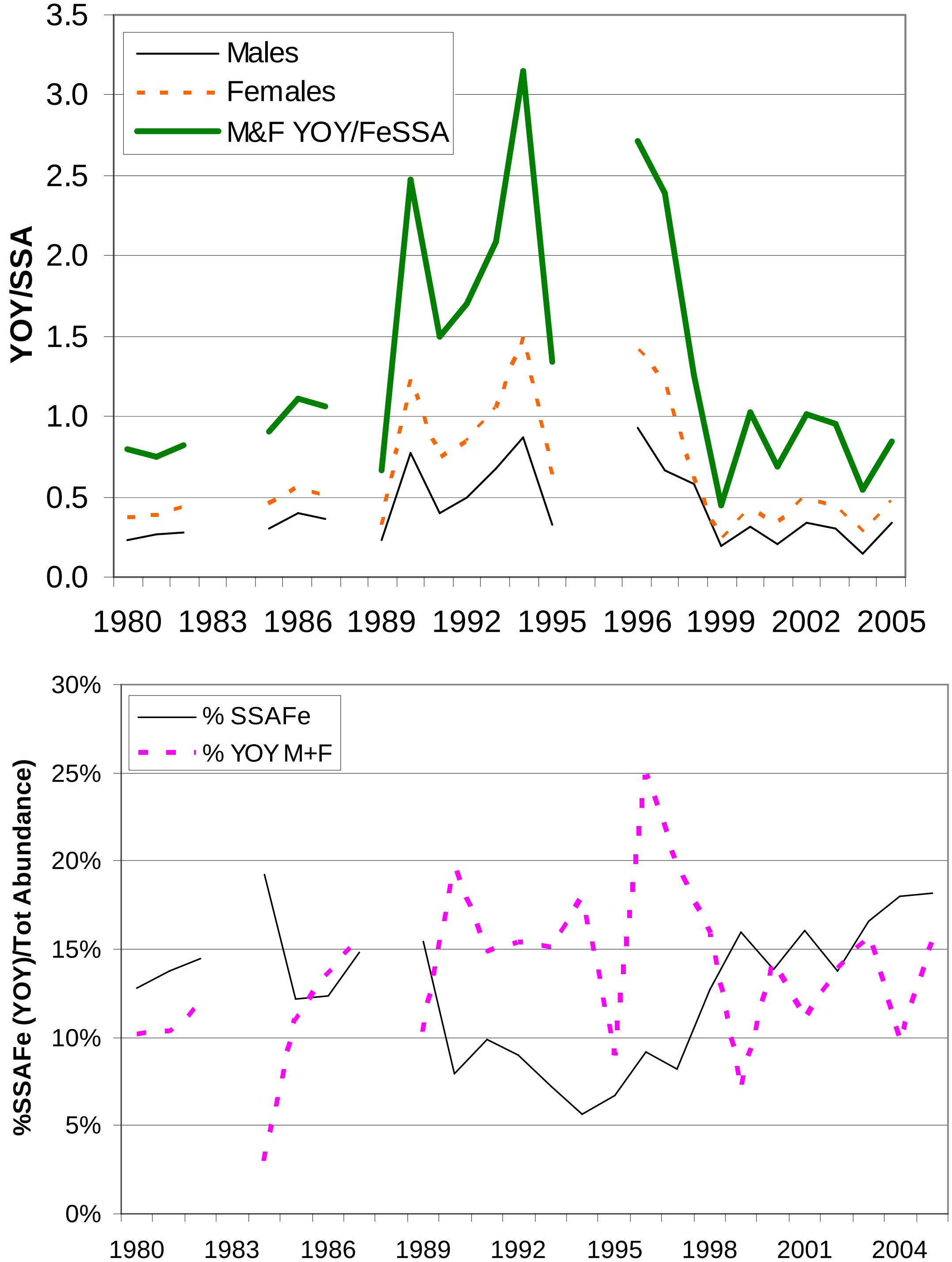


Figure 6. Relationship between male and female thorny skate young of the year (YOY) and female spawning stock abundance (SSA). Upper Panel: Ratio of YOY (young of the year) to SSA (spawning stock abundance consisting of mature females), 1980-2005. Lower Panel: relationship of YOY and SSA to total abundance derived from Spring research surveys.

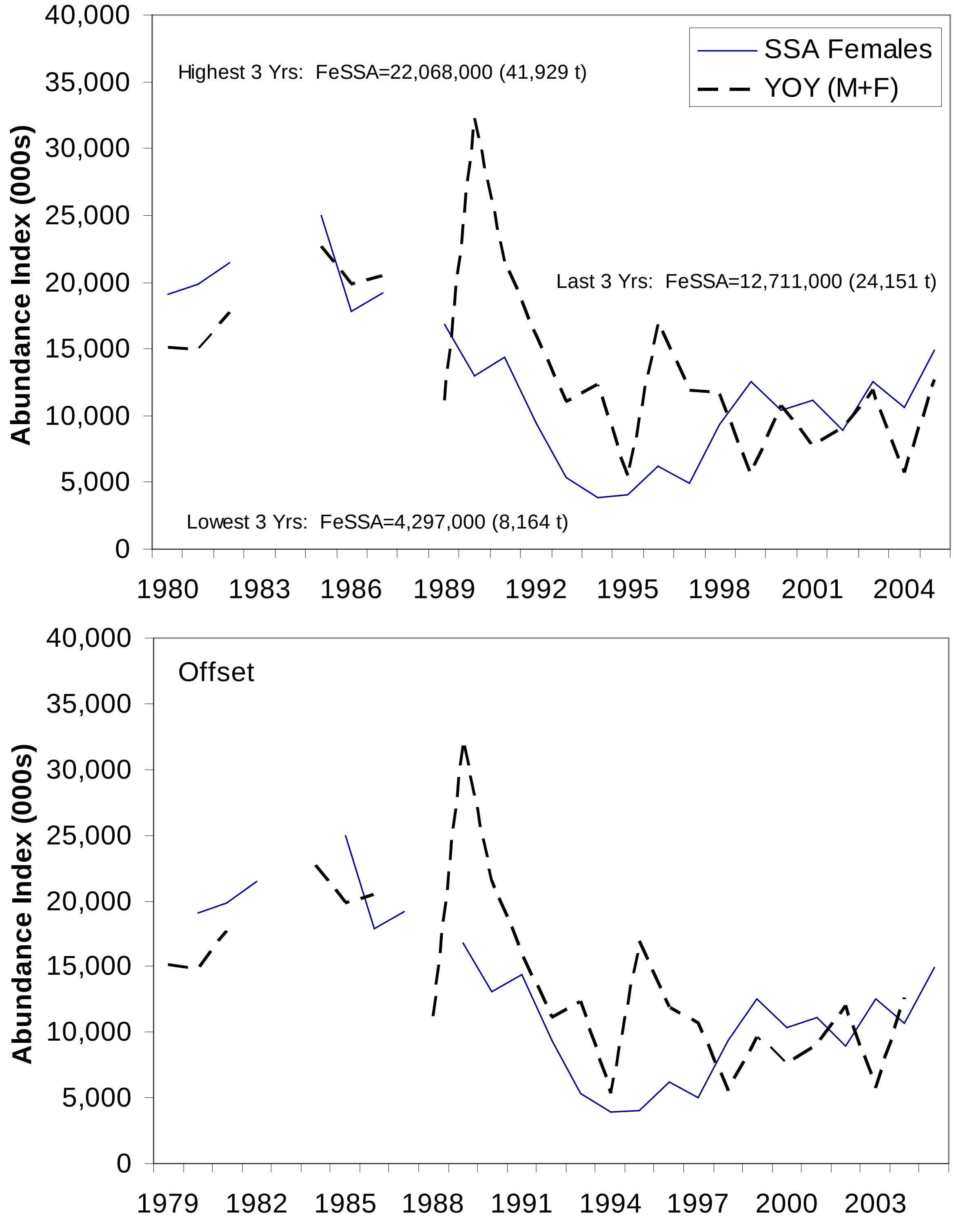


Figure 7. Recruitment Index (male plus female) and Spawning Stock Abundance (SSA female) Index for thorny skates, 1980-2005. Lower graph shows the YOY offset by one year.

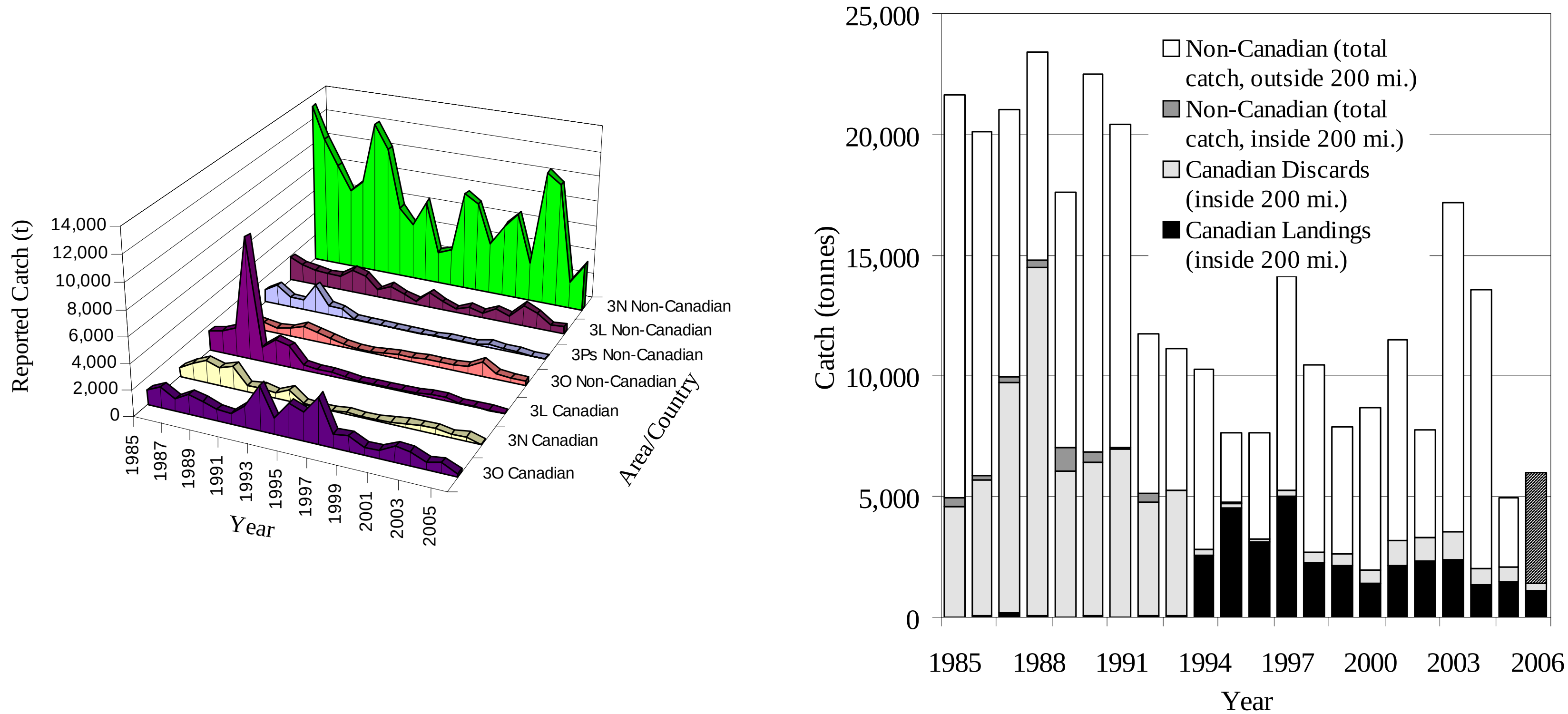
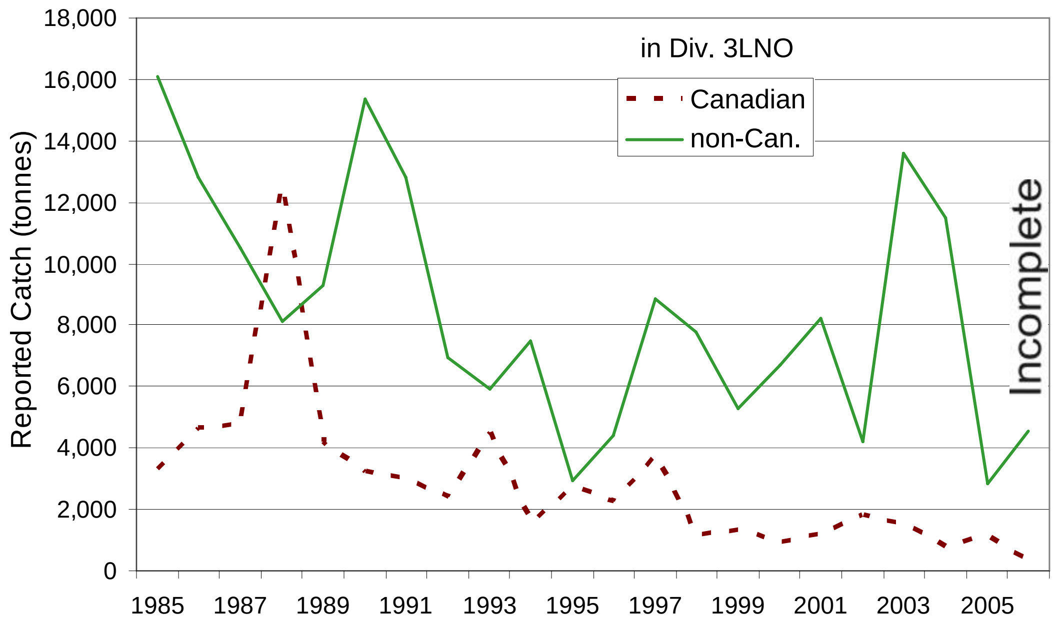


Figure 8. Reported catches of skate in NAFO Divisions 3LNOPs by all countries, 1985-2006. Non-Canadian data for 2005 are preliminary and 2006 is incomplete. Non-Canadian total catches (outside Canada's 200-mile-limit) in 2006 are taken from NAFO letters. Skate data were not speciated although Canadian Fisheries Observer data indicate that thorny skates comprise 90% of skate catches on the Grand Banks.



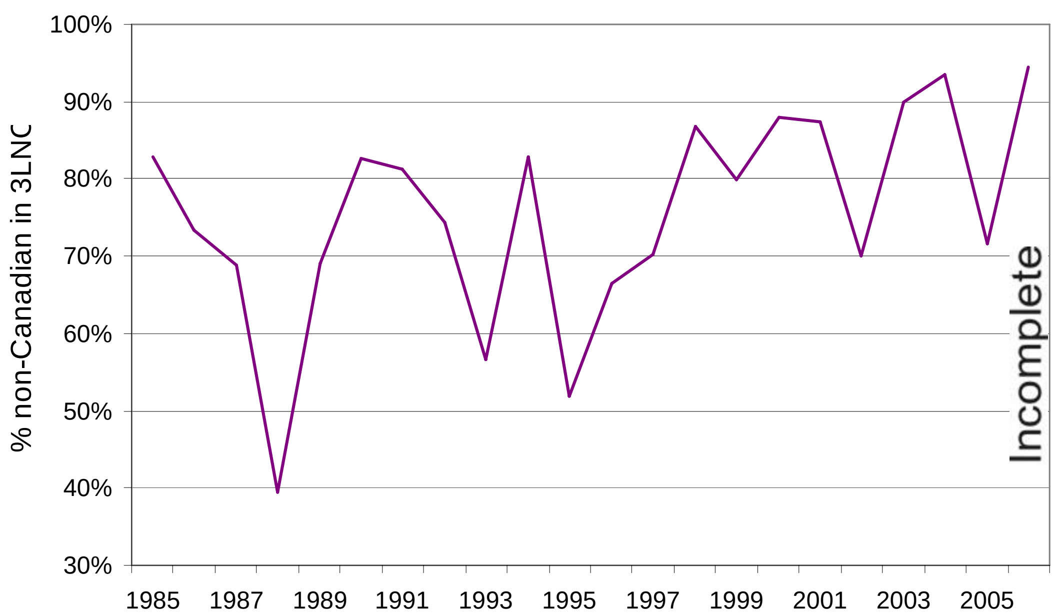


Figure 9. Reported catches of skate in NAFO Divisions 3LNO by all countries, 1985-2006. Non-Canadian data for 2005 are preliminary and 2006 is incomplete. Non-Canadian total catches (outside Canada's 200-mile-limit) in 2006 are taken from NAFO letters. Skate data were not speciated although Canadian Fisheries Observer data indicate that thorny skates comprise 90% or more of skate catches on the Grand Banks.

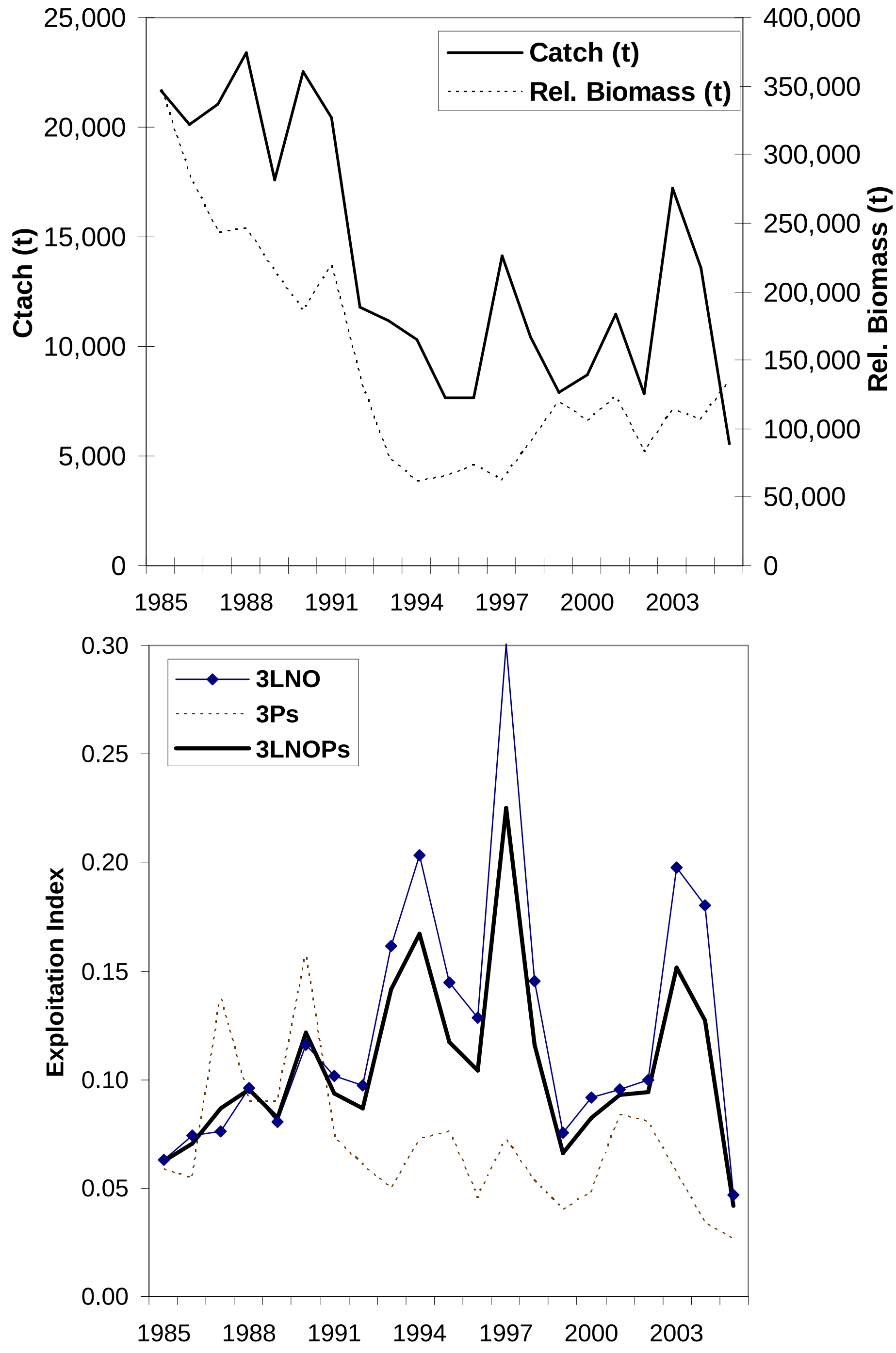


Figure 10. Upper: Total catch and relative biomass in Div. 3LNOPs. Lower: Exploitation Index (total estimated catch/Spring survey biomass index) for skate in Div. 3LNO3Ps, 1985-2006. Spring survey biomass indices converted to Campelen equivalents for 3LNO, 3Ps and 3LNOPs.

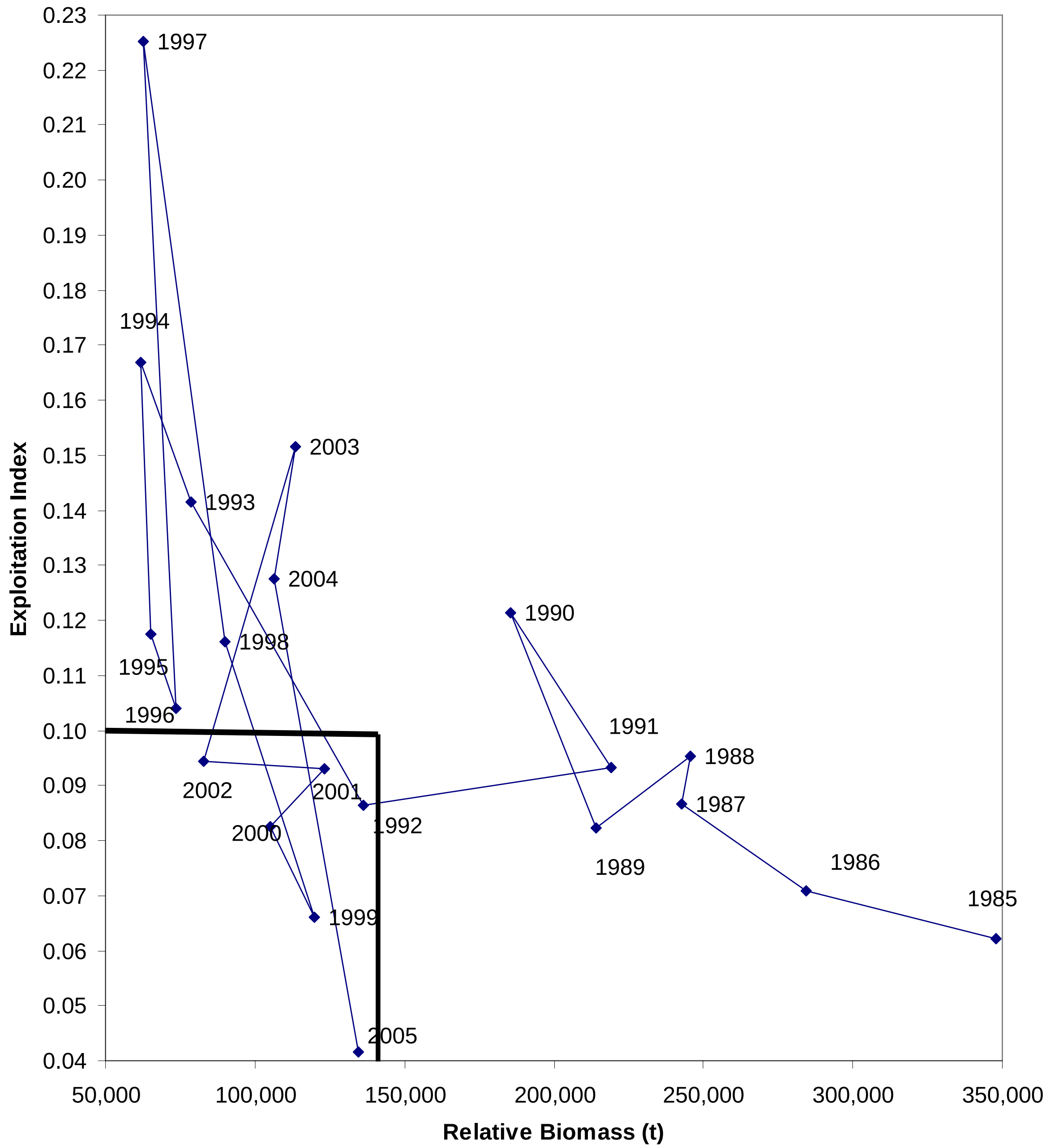


Figure 11. Relative Biomass versus Relative F trajectory. The thick line shows point of inflection. 2006 is not included because Subdiv. 3Ps survey data are not available.