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An Assessment of Thorny Skate (*Amblyraja radiata* Donovan, 1808) on the Grand Banks of Newfoundland

by

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Abstract

Since the mid-1980s, Spain, Portugal, and Russia have prosecuted a directed fishery for skate (primarily *Amblyaja radiata*.) outside Canada's 200-mile-limit on the Tail of the Grand Banks. However, Canada only established a limited directed fishery for skate on the southwestern Grand Banks and southern St. Pierre Bank after the decline of traditionally exploited groundfish resources. Prior to 1993, skates in Canadian waters were taken only as bycatch, most of which were discarded. Reported catches in Div. 3NOPs, all countries combined have averaged 14 735 tons (7 651-23 420 tons, as agreed by Scientific Council) since 1985. In 2005, the reported catch was 5 147 tons (2 063 tons for Canada, including discards, 4 213 tons as the STACFIS estimate in Div. 3LNO), down from previous years. Canadian fleet fishes only at the outer fringe of where skate are aggregated, 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, 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 mid-1990s. On average (1990-2005), fall survey estimates of biomass for the comparable area (NAFO Div. 3LNO) were 40% higher than in the spring indicating a seasonal change in catchability. 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. Relative *F* has averaged 0.09 since 1999 (equivalent to an average catch of 10 000 tons), 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 to 13 000 t) may allow some recovery of the stock from current low levels. Preliminary production modeling (ASPIC) suggests that a harvest levels should not exceed 11 180 tons (80% CI: 7 926 tons, 15 710 tons). However, six different runs of the model were conducted representing different time periods. Parameter estimates from the different models suggested a wide range of values. In particular, quite different results were obtained with the same model formulation but without the 2005 estimates.

Introduction

Thorny skate, also referred to as starry ray (*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. There, it comprises about 90% of the rajids caught in survey trawls (Kulka and Miri, 2003).

The Fishery and Management

Thorny skate have been targeted and taken as bycatch in numerous northwest Atlantic fisheries and in many areas, has undergone a decline in recent years. In the Gulf of Maine, it was one of four skate species regarded as overfished (SAW, 2000; SAFE, 2001). On the Scotian Shelf, Simon *et al*. (2003) reported a decline in survey indices as a result of fishing pressure from a mixed skate fishery. Ratz and Stransky (2002) noted a reduction in bycatch levels of thorny skate in several fisheries west of Greenland.

On the Grand Banks, Kulka and Mowbray (MS 1998) reported that significant bycatches of skates had been taken since commencement of offshore fishing in the late 1940s, initially by non-Canadian fleets and later by Canadian vessels. Before the mid-1980s, non-Canadian fleets comprised the largest component of offshore fisheries on the Grand Banks, and took several thousand tons of skate as bycatch each year. Kulka and Mowbray (MS 1998) 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. In 1985, Spain began targeting skate in a non-regulated fishery in the NRA (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 ton quota, in place within Canadian waters from 1997 to 2004 was generally under-fished, resulting in relatively stable removals inside Canadian waters. Catches in the NRA (NAFO Regulatory Area), unregulated until 2004 have been more variable and substantially higher, averaging about 8 000 ons over the past five years. In 2004, regulation of this fishery was relegated to NAFO and a 13 500 ton quota was placed on skate in NAFO Div. 3NO for 2005-2007.

Review of the Biology

A detailed review of the biology of thorny skate was provided in Kulka *et al*. (2004). This section summarizes relevant details from that paper.

Although no genetic work has as yet been completed for thorny skate, a continuous distribution, a synchronous migration and lack of physical barriers suggest that skate in on the Grand Banks (NAFO Div. 3LNOPs) constitute a single reproductive entity (Kulka *et al*., 2004). As well, morphometric work carried out by Templeman (1984b, 1987a) provides no evidence of variation across the Grand Banks. However, NAFO requests advice for only a portion of this area Div. 3NO. Thus, the assessment is done on the entire population and the advice is partitioned between Div. 3NO (NAFO, various countries) and Subdiv. 3Ps (Canada).

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 both structures (Kulka, pers. comm.), but have not been completed. Thus, at this time, age-based assessments are not yet possible for this stock. Maturity studies have been undertaken (del Río, MS 2002), and this information has been used to carry out life history stage-based analyses and 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.).

Kulka *et al*. (2004) 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 dealt with within the contemporary framework of management of elasmobranchs, or marine fish in general. In the case of thorny skate on the Grand Banks, this aspect has been examined (Kulka *et al*., 2004). Although the biomass has been stable for more than 10 years, the area occupied has continued to decline and the density has continued to increase at the centre of mass of the species. Hyper-aggregation has been shown to be a precursor of collapse in other species (Rose and Kulka, 1999).

Stock Structure

Thorny skate on the Grand Banks were first assessed by Atkinson (1995) for Canada, for the stock unit 3LNOPs. Subsequent Canadian assessments in 1996, 1998, and 2003 also provided advice for r3LNOPs. This area, which includes Subdiv. 3Ps was chosen as the stock unit based largely on work by Templeman (1982. 1984a, 1984b, 1987a and 1987b) who showed that a number of characteristics of thorny skate in Div. 3L, 3N, 3O and Subdiv. 3Ps were very similar but these characteristics were different in adjacent areas. These studies were reexamined by STACFIS in the context of stock structure of thorny skate and the findings are as follows.

Templeman (1982. 1984a, 1984b, 1987a and 1987b) indicated that size at sexual maturity and observed maximum length of thorny skate is consistent within Div. 3L, 3N, 3O and Subdiv. 3Ps (L_{50}, ~70 cm) but is smaller (L_{50}, ~47 cm) for skates off Iceland to the Northeast Newfoundland Shelf and in the Gulf of St. Lawrence (4RST). He found that secondary sexual characteristics: volume of the largest egg in the ovaries, egg capsule morphometrics (albumen volume, etc.), weight of the shell gland and ratio of clasper length to total length are very similar among the Divisions of 3LNOPs but significantly smaller in 2J+3K, areas north and in 4RST. Progression toward a smoother, less thorny dorsal surface occurred at smaller sizes of skates in 2J+3K and 4RS compared to 3LNOPs and numbers of rows of alar spines, median dorsal spines and slope of the length-weight relationship were different in 3LNOPs but were significantly lower in 2J+3K and areas north and in 4RST. An examination of 2003-2004 length-weight data also shows that the relationship is almost identical in Div. 3LNO compared to Subdiv. 3Ps.

Survey indices in Div. 3O compared to those in Subdiv. 3Ps show similar trajectories (Kulka *et al*., 2004). The major concentration of thorny skate straddles the 3O/3Ps line and that this pattern was consistent among stages of skates and across years and seasons. That paper further noted that recruitment was greatest in Div. 3L in the early 1980s but has now shifted to Subdiv. 3Ps. Finally, Templeman's (1984a) tagging results indicated that about 12 recaptures out of 102 had crossed the 3PO line, in both directions indicating a degree of mixing between areas. Thus, distribution dynamics presented in those papers and the earlier studies on biological characteristics suggest a single stock within 3LNOPs. This paper treats thorny skate within 3LNOPs as the stock unit.

Purpose

The purpose of this paper is to provide advice for thorny skate on the Grand Banks (Div. 3LNOPs) and partition the advice for 3LNO (NAFO) and 3Ps (Canada). This paper updates biological and fishery data to 2005. Stage based analyses and production modelling (ASPIC Prager *et al*., 1994) are the focus of this assessment.

METHODS

Survey Data

Data from standard NL demersal trawl surveys (random stratified, Engel and Campelen trawl gear, spring and autumn, post-1970 using Yankee-41.5 to 1983, Engel-145 Hi-lift to 1996, and Campelen-1800 shrimp trawl to date) was used for the purpose of estimating biomass and abundance. A summary of the stratified-random survey design, STRAP adopted by the DFO - NL Region after 1970 can be found in Doubleday (1981). While survey design has remained constant, additional strata have been included in recent years along with modifications to some of the original strata (Bishop, 1994). One of the recent significant changes in the surveys is the addition of shallower and deeper strata after 1993 although sets at depths < 50 m were occasionally recorded in earlier years (Table 1).

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 1971-2005 and fall 1981-2005. 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 1996-2005 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 to yield an index of stock size. Similarly, STRAP1 (Smith and Somerton, 1981) was used to estimate numbers at length for predefined depth strata which facilitates age or stage based analyses. Total abundance at length was 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 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 staged based calculations. These calculations assumed that weight at length remained constant throughout the entire survey period.

The fall series does not include data from Subdivision 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 (Kulka *et al*., 2004). 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.

The most significant alteration in NL survey design was a change in gear in the autumn of 1995, from Engel 145 High Lift Otter (demersal) Trawl to Campelen 1800 Shrimp Trawl. Visual analyses indicate that the two gears have very different catchability for thorny skate. While size based conversion factors were derived from comparative surveys for the major commercial species, this exercise was not done for "minor" species, including skate. However, 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. Calculations were conducted using Robson's (1966) multiplicative model. Size composition and proportion of three stages, young of the year (YOY), immature and mature fish by sex captured in the two survey gears was confirmed to be very similar. The conversion factor for numbers caught were determined to be 2.63 (weight) and 2.42 (number) for converting Engel into Campelen equivalents.

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). 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.

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 (based on observer catch data). 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 2004-2005 were used to examine spatial distribution of fishing grounds by gear type. Catch per set was used to categorize various densities of skate. Maps of fishing grounds were generated with the potential mapping technique described in Kulka *et al.* (2004).

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 Scientific Council "agreed" statistics were then used for non-Canadian countries in 1999-2005. 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).

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 Ver. 5.1 (Prager, 1994). ASPIC provides estimates under a non-equilibrium Schaefer model. Data comprised series of catch and relative biomass from spring surveys, 1984-2005 conducted in NAFO Div. 3LNOPs. Six different runs, comprising different time periods, were used to explore options in producing Limit Reference Points (LRPs) and projections using various levels of catch. Bootstrap parameter estimates are based on 1 000 trials.

Results

Trends

Spring and autumn survey biomass and abundance indices are presented by NAFO Division in Table 3 and Fig. 2, in Campelen equivalents. For comparable years and areas (1981-2005 in NAFO Div. 3L, 1990 in NAFO Div. 3LNO), spring and fall survey estimates of biomass showed similar trends (Table 3, Fig. 1). However, autumn 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 concentrated in 3NO.

A comparison of spring and fall biomass estimates (a ratio of estimates in Div. 3LNO, the only three Divisions surveyed during both seasons) indicates that fall estimates are consistently higher (Fig. 3). From 1990-1997, concurrent with the period of decline in the population, the ratio averaged about 50%, thereafter declining to about 20-25% and relatively stable since. This indicates a difference in catchability of skate between seasonal surveys and lower values in recent years may relate to change in movement of the fish.

Based on spring survey data, average weight has undergone decline from 2 kg in the early 1970s to 1.2 kg 1996, most of the decline during the 1990s, concurrent with the decline in biomass (Fig. 4). Average size has increased to about 1.6 kg since. The autumn trend was similar.

Campelen equivalent spring indices (Table 3, Fig. 5a, biomass and abundance and b, mean weight and number per tow) show similar trends in NAFO Div. 3LNO (Divisions overlapping the NRA) *vs.* 3LNOPs (the entire stock area). One or more Divisions were not surveyed in 1974 and 1983 and thus are excluded from the graph. Table 3, 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 was the result of three very large sets in Div. 3O (508, 428, and 243 kg skate per standard tow), and thus the estimate for that year are likely anomalously high. From 1975 to the mid to late 1980s, the trends fluctuated without trend then declined until the mid-1990s. Following a small increase in the late 1990s, the indices have been stable since. Relative biomass in this century has been stable, about 40% of that observed in the 1970s and 1980s.

The decline of the early 1990s was spatially uneven, most occurring in the northern part of the Grand Banks (Div. 3L) and to a lesser extent in Div. 3N (Fig. 5c, Table 1). Partitioning of the Grand Banks in this manner clearly illustrates that the 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 the mid-1990s (see 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 to the late 1990s, stable since (Fig. 5c, lower panel).

A scaled comparison of the Canadian Campelen survey trend from 1995-2005 in NAFO Div. 3NO to the Spanish survey for the same period and area is similar although annual changes were not always in the same direction (Fig. 5d).

Size

A large range of lengths (11-101 cm TL) were present in both spring and autumn surveys with some inter-annual variation in the mix of sizes. Mode 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. 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. This suggests that recruitment was occurring there on a yearly basis, or that young skates were consistently moving into that area, likely the former. Since 1995, these young skates have been largely absent or low in number in 3L. That small mode was apparent in 2001-2003 (autumn), 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

Numbers of thorny skate at length (spring, 3LNOPs) were partitioned into young of the year (YOY), immature and mature (SSB) components. Average size of each stage has been relatively stable since 1980, immature fish undergoing the largest fluctuations (Fig. 6)

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. 7). YOY averaged close to 1:1 males to females. Ratio of immature males to females was 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.

Different stages of thorny skate by sex underwent similar changes in abundance over time (Fig. 8a, 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 is size of the biomass (late-1980s to mid-1990s) the proportion of mature fish in the population declined while the immature component increased (Fig. 8a lower panels, Fig 9, upper panel). This trend has reversed since the 1990s. While proportion of abundance was changing, proportion of biomass of each stage remained relatively stable over the entire period.

Recruit per spawner in most years fell between 0.5 and 2.0. Values were highest during the period of the decline of the stock. This is due to the greater decline in adult females compared to the YOY (Fig. 8b). Average over the entire period was 1.4.

The relationship between female spawning stock abundance (SSA) and recently hatched skate (YOY) is illustrated in Figure 10. The upper panel shows that the ratio of YOY/SSA 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 11 further illustrates that the female SSA and YOY followed a similar trend with and without YOY offset by one year plus suggesting a relationship between spawning stock and recruitment. The average of the highest three years in the series was SSA – 22 million, SSB – 41 929 tons, the lowest three years of female relative SSB averaged SSA – 4.3 million, SSB- 8 164 tons and the last three years averaged SSA – 12.7 million, SSB – 24 151 tons.

Figure 12a (abundance) and 12b (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 30 000 tons. SSB during years prior to the decline averaged about 80 000 tons.

Distribution

Within Div. 3LNO and Subdiv. 3Ps, the distribution of thorny skate has changed significantly since the early 1980s. In the early 1980s, skates were widely distributed over the entire Grand Banks in moderate to high concentrations (see Kulka *et al.*, 2004 for map series and detailed description of spatial changes). By the late 1990s, much of the biomass was concentrated in the southwest (Fig. 13). Ninety-eight percent of the banks were occupied by thorny skate. By this century, 22% of the surveyed area was devoid of thorny skate (Fig. 13). However, after 2001, the area of high concentration expanded northward and along the bank edge. The Banks is now clearly demarcated into an area of high concentration in the south and a null area in the north (Fig. 13b).

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 (Fig. 14). Thus, the area occupied by thorny skates has substantially decreased, and the population became increasingly more concentrated in a smaller area where bottom temperatures are warmest. Since 2001-2003, area of high density has increased somewhat.

The proportion of the surveyed area containing no skates increased from about 2% in 1980-1988 to 22% in 2004-2005 (Fig. 14, 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 were spread over the entire Grand Banks. By 2001-2005, 78% of the biomass was concentrated into 20% of the surveyed area. 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 the late 1990s. This indicates that the skate became progressively concentrated or hyper-aggregated within a small portion of 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 following the decline in biomass (Fig. 15). See Kulka *et al.* (2004) for a stage based description of changes in distribution.

The Fisheries

In terms of areas fished, skate catches in Canadian waters occurred primarily in NAFO Div. 3L and Subdiv. 3Ps prior to 1992 (as bycatch), but have shifted to 3O and 3Ps in recent years after the non-Canadian (3O) and Canadian (3OPs) skate-directed fishery began in 1985 and 1994 respectively. Figure 16a (upper panel) shows that directed sets for skate occurred mainly along the shelf edge in 2004-2005 from the Laurentian Channel in NAFO Subdiv. 3Ps to Canada's 200-mile limit in NAFO Div. 3N. This fishing effort distribution was similar to previous years (compare Fig. 16 to Kulka *et al.*. 2004), clustering in southern 3Ps, and in two locations in 3O and occupying only a small portion of the total extent of the high concentrations of skate as described by the trawl surveys (compare Fig. 13 to Fig. 16a). Most of the effort co-occurred with the outer edge of the concentrations of skate in depths of 100-300 m for otter trawls and gillnets, and 50-150 m for longlines (Fig. 16b,). However, catch rates (catch per set) tended to be similar across a wider range of depths: 50-800 m.

Locations of the Canadian directed trawl (Fig. 16b upper panel), gillnet (middle panel), and longline (lower panel) skate fishery in 2004-2005 occurred at varying locations along the south and west slope of the banks. The same areas were fished consistently between years and fishing patterns in 199-2001 (Kulka *et al*., 2004) are similar to 2004-2005.

A spatial representation of non-Canadian effort outside of Canada's 200-mile-limit can be found in Kulka *et al.* (2004). Fishing effort encompassed most of the available shallow Bank on the Tail of the Bank where the most dense skate concentrations straddle the NAFO line in the autumn.

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 2005 estimate for Div. 3LNO "agreed" to by STACFIS plus the ZIF estimate of (Canadian) catch in Subdiv. 3Ps was 5 147 tons, a three-fold decrease from the previous year. Catches of skates for all countries since 1985 are illustrated in Fig. 17 and 18. The catch of skates on the Grand Banks has been increasingly 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 40-92% (Fig. 18). The non-Canadian share averaged 90% during the past 3 years.

Figure 19 (lower panel - all countries, upper panel - non-Canadian) compares catch trajectories depending on information source, STACFIS or ZIF plus Canadian C&P. Estimated since 1998, the STACFIS estimates are higher than C&P prior to 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). 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 (Table 4). From 1993-2001, almost 100% of non-Canadian skate catches was taken by those three countries. Estonia catches have amounted to about 10% since 2002.

In 1985-1993, all reported Canadian skate landings were bycatch, averaging 61 tons per year (Fig. 20a). 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 bycatch came from mixed fisheries for Atlantic halibut/monkfish/white hake, and the redfish fishery. In 1994-2005, the skate-directed fishery accounted for 75% of the total skate landings for Canadian vessels. Catches have declined from an average of about 3 000 tons at the start of the fishery to about 1 400 tons in 2004-2005.
Since the late 1980s, 100% of skate caught by non-Canadian countries has been from trawls, with about 85% (1997-2005) taken in NAFO Div. 3N on the Tail of the Grand Banks (where the skate-directed fishery occurs, see Fig. 17). Most of that directed fishery is prosecuted in August-December. The remaining non-Canadian skate catches were

bycatch in the Greenland halibut fishery, which occurs throughout the year. 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. 20b).

In 1994, the first year of the directed Canadian skate fishery, most of the skate catch were taken in the fall (Fig. 21). 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).

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 2005 are summarized in Table 7a. 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 and since 2005, a quota of 13 500 tons (2 250 tons for Canada) has been set for NAFO Div. 3LNO (in addition to the 1 050 tons quota in 3Ps for Canada, Table 7b).

Size of thorny skate in the Canadian commercial catches varied considerably among gear types but less among years (Table 2) and not all gears were sampled every year. Shape and range of commercial lengths varied with gear type (Fig. 22). 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. 23).

Figure 23 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 8). 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. Proportion of percent of catch constituting mature individuals varied among years and between countries.

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. 24). Relative F nearly tripled, from approximately 5% in the mid-1980s to 14% in 2003-2004. Most of the increase is attribute to increased catches in the NRA. The index has declined slightly in Subdiv. 3Ps. Rel. F dropped to 4% in 2005 due to reduced reported landings.

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

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. 25) 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 Rel *F* ~0.1 and relative (total) biomass is ~110 000 tons.

Figure 26 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

The parameter estimates of the six ASPIC runs are illustrated in Table 9. The run that produced the best fit, and capturing the major features of the dynamics of this stock, used the observed catch and the converted spring survey data from 1985-2004 (Run 4, Table 9, Fig. 27). This model estimated an MSY of 17 970 t with a B_{MSY} of 27 840 t and an F_{MSY} of 0.65.

Estimates of B relative to B_{MSY} and F relative to F_{MSY} are shown in Fig. 27. Using this model, a 6-year series of projections was produced (Fig. 28). This analysis showed that catches above 11 180 tons resulted in an increasing F. This model suggests a stable biomass at catches of about 11 180 tons (80% CI: 7 926 tons, 15 710 tons) and an increasing biomass below that level of fishing mortality. Given the uncertainty in this model a conservative TAC, corresponding to the lower confidence limit of 7 926 tons could be proposed that will ensure increasing biomass for this stock.

Discussion

In managing a commercially exploited species, it is important to have some knowledge of the stock structure, reproductive biology, spatial distribution as well as commercial catches. 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 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 while the autumn series does not include Div. 3Ps. In addition, the relative difference between spring and fall 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 index suggests, 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 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. 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 in both spring and fall research surveys (Simpson and Kulka, 2004) 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, 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 (see Simpson and Kulka, 2004).

The analyses of spatial dynamics have revealed changes in the skate population that would otherwise be difficult or impossible to detect, using aggregated statistics. 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 areas occupied and biomass of thorny skate on the Grand Banks declined in the 1980s an 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 (presently or historically). Thus, a cropping down affect 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

Analyses of distribution by Kulka *et al*. (2004) indicated 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 and some of the earlier morphometric studies (such as in Templeman 1987a), suggest a single stock within 3LNOPs. 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. This paper treats skate in 3LNOPs as unit.

Whether the current level of exploitation of thorny skate is sustainable is uncertain. Biomass has remained stable, for about 12 years, or has slightly increased in spite of some relatively high catches in recent years. However, relative *F* has increased by almost three times over the past 20 years, the increase attributable mainly to an increase in effort in the NRA averaging 6.5 times higher than in areas fished by Canada inside 200 miles. Skate distribution dynamics. Hyper-aggregation in the late-1980s, early 1990s and increase in area devoid of skates) are not positive indicators. The results from the production modeling suggest that catches exceeding 11 180 tons (which is the case in some recent 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 increasing the SSB. Even if fishing mortality is sufficiently low to allow recovery, the k selected reproductive strategy could mean a protracted recovery process.

Deficiencies

There remain a number of important limitations to our knowledge of thorny skate in 3LNOPs. Although all available evidence points to a single population in 3LNOPs, stock structure has not been fully verified. Information is lacking on such characteristics as individual growth rate and details on the age structure of skate population(s). Ageing of thorny skate has only recently been attempted but that is a work in progress. 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, particularly back in time 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. There has been concern about the accuracy of past non-Canadian skate catch reports. 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.

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 tons) over the past 7 years has resulted in a flat biomass trajectory. Although stable in recent years, skate continues to be near a historic low population size. Average index of biomass over that 7 year period was 112 000 tons. The current TAC for skates in 3LNOPs presently amounts to 14 550 tons (13 500 tons in 3LNO and 1 050 tons in 3Ps) which considerably exceeds the current 11 100 tons average catch. The results of the production model suggest that a catch <11 180 tons would be required to allow rebuilding of the stock.

Thus, current levels of exploitation may be sustainable but would not allow for a rebuilding of the stock. If the desired strategy is to sustain current levels of biomass (no recovery) then current average annual catches of 11 000 tons should be maintained (which is below the current TAC of 14 550 tons). Given the uncertainty in this model a conservative TAC, corresponding to the lower confidence limit of 7 926 tons will ensure increasing biomass for this stock. If population growth and eventual higher yield is the objective then a reduction in current catch levels is required.

Management Considerations

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

1. Basis for Advice for Management of Thorny Skate – 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 skate in 3LNOPs constitute a single population. There is no evidence that the fish constitute different populations in 3LNO and 3Ps. Thus, this assessment treats the fish as a single biological unit in formulating biomass trends, production and exploitation then partitions that advice to the current management units: 3LNO and 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). 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)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.

4. The recent (7 year) level of exploitation has resulted in a stable biomass. Our analyses have shown that there is a fairly strong stock/recruit relationship, smaller SSB producing smaller year-classes (YOY) and thus, a rebuilding strategy, if that is the desired management objective must include reduction in exploitation of the SSB to allow an increase in recruitment (below 11 000 tons). Alternatively, if retaining stability at current low biomass (near historic low) is the desired objective then a catch of about 11 000-12 000 tons is required maintain that level. The current combined TAC for 3LNOPs totalling 14 550 tons considerably exceeds that level.
5. Concentration of the biomass of thorny skate onto the southern portion of the Grand Banks concurrent with the fishing grounds since the mid-1980s both inside and outside the NRA has made this stock more vulnerable to overfishing. Formerly a refuge where skate were distributed, the northern Grand Banks is now large devoid of fish 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 take place to allow the population to rebuild to higher levels, it would be reasonable that the majority would have to occur in the unregulated non-Canadian fishery outside 200 miles.

Summary

- Biomass has been stable for about 13 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 signs of expansion in its distribution during the past 2-3 years.
- 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 but has declined to an average of about 10% over the past 7 years. This recent level of biomass has resulted in a stable biomass.

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Table 1. Summary of sets in Canadian Campelen spring and autumn surveys in NAFO Div. 3LNO and Subdiv. 3Ps, 1996-2005. 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	07-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	08-Apr	29-Jun
2001	154	12	79	79	173	497	07-Apr	24-Jun
2002	146	4	79	79	177	485	05-Apr	22-Jun
2003	155	14	79	79	176	503	05-Apr	26-Jun
2004	151		79	79	177	486	11-Apr	26-Jun
2005	133		78	79	178	468	17-Apr	29-Jun
mean	**156**		**80**	**82**	**171**	**496**		

Depth range (m), Campelen spring surveys 1996-2005.

	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
mean	**53**	**692**	**41**	**670**	**63**	**679**	**38**	**656**

Number of sets.

Autumn	3L	# of inshore sets included	3N	3O	3Ps	Total	earliest	latest
1996	211		84	61	-	356	09-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	06-Dec
2002	206		94	99	-	399	05-Oct	02-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	04-Oct	08-Dec
mean	**185**		**90**	**87**		**362**		

Depth range (m), Campelen autumn surveys 1996-2005.

	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	-	-
mean	**43**	**1282**	**41**	**1112**	**62**	**1081**		

Table 2. Number of thorny skates measured for total length in commercial catches, 1994-2005. 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
1999	Otter trawl	535	271		806
	Gillnet		381		381
	All	535	652		1,187
2000	Gillnet	2,234	5,183		7,417
	Longline	336	194		530
	All	2,570	5,377		7,947
2001	Otter trawl	383	247		630
	Gillnet	212	334	168	714
	All	595	581	168	1,344
2002	Otter trawl	75	73		148
	Gillnet	1,649	2,873		4,522
	All	1,724	2,946		4,670
2003	Otter trawl	68	76		144
	Gillnet	708	781		1,489
	Longline	13	64		77
	All	789	921		1,710
2004	Otter trawl	889	911		1,800
	Gillnet	124	261		385
	All	1,013	1,172		2,185
2005	Otter trawl	928	995		1,923
	Gillnet	281	605		886
	All	1,213	1,601		2,814
Total		**7,852**	**12,120**	**168**	**20,140**

Table 3a. Campelen Equivalent biomass, abundance, and mean weight of thorny skate from spring research surveys, 1971-2005. Surveys were conducted with an Engels trawl during 1971-spring 1995, and Campelen trawl during fall 1995-2005.

Biomass (tonnes)

Year	3L	3N	3O	3Ps	All Divisions
1971	92,313	29,740	-	-	122,053
1972	61,518	94,904	-	43,190	199,612
1973	47,322	71,644	61,247	35,287	215,500
1974	105,863	57,394	-	58,986	222,243
1975	82,032	56,753	66,613	15,041	220,439
1976	105,836	103,664	211,018	77,601	498,119
1977	167,273	115,963	51,632	32,417	367,284
1978	99,792	43,116	46,823	19,919	209,650
1979	116,711	62,796	52,127	26,547	258,181
1980	108,479	68,751	56,514	55,623	289,366
1981	145,372	45,481	32,377	30,114	253,344
1982	99,330	79,323	60,144	19,365	258,163
1983	-	-	-	36,041	36,041
1984	17,881	59,765	63,188	21,038	161,872
1985	105,978	89,501	114,232	38,263	347,973
1986	72,341	114,234	48,287	49,418	284,279
1987	84,944	62,681	52,813	42,138	242,575
1988	72,630	51,445	90,472	31,055	245,603
1989	75,889	50,883	41,596	45,841	214,208
1990	46,917	49,163	64,140	25,124	185,344
1991	22,984	29,950	102,512	63,714	219,161
1992	12,158	23,865	59,982	40,065	136,071
1993	8,850	19,207	36,357	14,402	78,816
1994	4,058	10,554	29,898	17,127	61,637
1995	2,898	2,925	33,469	25,806	65,098
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
2004	7,806	20,425	39,740	38,354	106,325
2005	19,266	33,757	46,515	34,897	134,435

Abundance (thousands)

Year	3L	3N	3O	3Ps	All Divisions
1971	27,910	9,489	-	-	37,399
1972	26,710	37,834	-	13,588	78,132
1973	29,316	26,700	31,049	16,509	103,574
1974	64,423	28,137	-	26,949	119,509
1975	59,924	20,021	29,483	4,003	113,430
1976	68,471	51,836	69,200	46,266	235,773
1977	61,080	39,628	18,194	21,393	140,296
1978	52,948	24,482	18,340	27,273	123,043
1979	56,556	33,539	18,140	20,109	128,343
1980	46,479	38,351	40,627	29,524	154,980
1981	80,401	23,460	14,306	29,511	147,678
1982	51,767	57,168	26,753	8,621	144,309
1983	-	-	-	29,641	29,641
1984	7,574	25,226	24,615	9,417	66,832
1985	63,081	45,278	50,123	55,214	213,697
1986	51,231	53,395	21,134	36,152	161,913
1987	39,151	33,539	34,040	28,113	134,842
1988	35,030	26,475	42,991	19,043	123,539
1989	40,349	30,030	17,678	25,863	113,919
1990	43,938	71,656	40,119	21,344	177,057
1991	34,780	44,550	35,194	50,254	164,778
1992	36,886	20,645	35,567	21,511	114,609
1993	27,765	17,068	15,026	16,001	75,860
1994	15,999	17,564	19,106	19,222	71,891
1995	9,319	7,018	26,782	19,493	62,613
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
2004	4,762	8,925	21,153	24,256	59,095
2005	11,011	15,986	26,621	27,742	81,359

Mean weight (kg)

Year	3L	3N	3O	3Ps	All Divisions
1971	3.31	3.13			3.26
1972	2.30	2.51		3.18	2.55
1973	1.61	2.68	1.97	2.14	2.08
1974	1.64	2.04		2.19	1.86
1975	1.37	2.83	2.26	3.76	1.94
1976	1.55	2.00	3.05	1.68	2.11
1977	2.74	2.93	2.84	1.52	2.62
1978	1.88	1.76	2.55	0.73	1.70
1979	2.06	1.87	2.87	1.32	2.01
1980	2.33	1.79	1.39	1.88	1.87
1981	1.81	1.94	2.26	1.02	1.72
1982	1.92	1.39	2.25	2.25	1.79
1983				1.22	1.22
1984	2.36	2.37	2.57	2.23	2.42
1985	1.68	1.98	2.28	0.69	1.63
1986	1.41	2.14	2.28	1.37	1.76
1987	2.17	1.87	1.55	1.50	1.80
1988	2.07	1.94	2.10	1.63	1.99
1989	1.88	1.69	2.35	1.77	1.88
1990	1.07	0.69	1.60	1.18	1.05
1991	0.66	0.67	2.91	1.27	1.33
1992	0.33	1.16	1.69	1.86	1.19
1993	0.32	1.13	2.42	0.90	1.04
1994	0.25	0.60	1.56	0.89	0.86
1995	0.31	0.42	1.25	1.32	1.04
1996	0.48	1.04	1.56	0.85	1.06
1997	0.58	0.72	1.10	1.13	0.97
1998	0.75	1.30	1.24	1.26	1.20
1999	0.88	1.64	1.50	1.59	1.49
2000	1.12	1.74	1.43	1.21	1.39
2001	1.22	1.79	1.77	1.40	1.63
2002	1.45	1.65	1.16	1.26	1.28
2003	1.25	1.89	1.43	1.51	1.50
2004	1.64	2.29	1.88	1.58	1.80
2005	1.75	2.11	1.75	1.26	1.65

Table 3b. Biomass, abundance, and mean weight of thorny skate from autumn research surveys, 1981-2005. 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 2005.

Biomass (tonnes)

Year	Div. 3L	Div. 3N	Div. 3O	All Divisions
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981	95,909	-	-	-
1982	171,719	-	-	-
1983	171,364	-	-	-
1984	154,342	-	-	-
1985	146,052	-	-	-
1986	-	-	-	-
1987	90,955	-	-	-
1988	111,733	-	-	-
1989	70,282	-	-	-
1990	98,973	69,849	100,950	269,772
1991	54,521	107,643	78,202	240,366
1992	41,716	54,858	43,885	140,459
1993	24,950	36,787	66,572	128,309
1994	16,776	52,755	33,059	102,590
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
2004	11,327	45,678	26,361	83,366
2005	18,315	37,442	61,595	117,352

Abundance (thousands)

Year	Div. 3L	Div. 3N	Div. 3O	All Divisions
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981	81,126	-	-	-
1982	87,658	-	-	-
1983	103,303	-	-	-
1984	70,979	-	-	-
1985	86,070	-	-	-
1986	-	-	-	-
1987	80,879	-	-	-
1988	86,633	-	-	-
1989	76,793	-	-	-
1990	116,758	43,855	53,191	213,803
1991	73,576	61,128	29,680	164,384
1992	94,058	33,854	24,675	152,587
1993	61,501	31,073	41,382	133,957
1994	44,196	50,142	30,749	125,087
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
2004	6,369	21,068	32,343	59,780
2005	10,242	20,027	30,553	60,823

Mean Weight (kg)

Year	Div. 3L	Div. 3N	Div. 3O	All Divisions
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981	1.18			
1982	1.96			
1983	1.66			
1984	2.17			
1985	1.70			
1986				
1987	1.12			
1988	1.29			
1989	0.92			
1990	0.85	1.59	1.90	1.26
1991	0.74	1.76	2.63	1.46
1992	0.44	1.62	1.78	0.92
1993	0.41	1.18	1.61	0.96
1994	0.38	1.05	1.08	0.82
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
2004	1.78	2.17	0.82	1.39
2005	1.79	1.87	2.02	1.93

Table 4. Skate catch history for non-Canadian fleets, 1970-2005 (from NAFO STATLANT-21A). Catch statistics are preliminary for 2005; 2004 is incomplete. Data for 2005 are from NAFO letter of Provisional Catches for December 2005.

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	1,015	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		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		479				2		18	48			539	2,383		77				**3,546**

Table 5. Landings of skate in Canadian and non-Canadian waters of NAFO Div. 3LNOPs, 1985-2005. 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. 2005 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 Division. 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		STAT LANT		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-STAT LANT	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	3,090	1,175	558	1,544	238	821	3,475	1,733	1,782	7,812	3,350	4,462	10,887	-6,425	13,334	13,334	9,695	1,807	4,224	6,030	9,678
2003	80	1,675	404	10,737	1,032	1,170	1,999	82	1,755	11,141	2,202	2,081	17,179	3,515	13,664	13,664	0	13,499	13,499	14,625	1,516	13,582	15,098	13,416
2004	50	1,169	209	9,868	536	437	1,200	87	1,219	10,077	973	1,287	13,555	1,994	11,561	11,561	0	15,886	15,886	11,800	794	11,474	12,268	9,300
2005	28	353	308	2,441	793	223	934		381	2,749	1,017	934	5,080	2,063	3,018	3,018	0	5,147	5,147	4,213	1,129	3,018	4,146	4,213

Table 6. Canadian landings of thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps by gear type and month, 1985-2005.

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	6	0	13	4	51	116	99	42	35	23	2	0	0
	2005	0	10	1	0	0	54	82	112	99	59	13	5	1
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	11	45	23	7	15	15	9	12	8	9	5	0
	2005	0	62	136	146	115	41	44	8	10	6	5	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	834	47	4	5	43	16	3	2	0	0
	2004	0	0	2	756	0	0	0	0	0	0	0	0	0
	2005	0	1	0	1	399	1	0	1	2	0	0	0	0

Table 7a. Fishery regulations and quota allocations for thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps in 2004 and 2005.

<table>
<tr><th>Gear Type</th><th>Vessel Size</th><th>Sector</th><th>Season</th><th>Gear Restrictions</th><th>Adjustments /reason</th><th>TAC</th></tr>
<tr><td>Fixed Gear</td><td><35’</td><td>Inshore</td><td rowspan="2">3LNO
May 15, 2005-July 10, 2005

3Ps
<12miles from shore
Jul 7/05-Dec 19, 2005
(vessels <35’ only)
>12 miles from shore
Jun 2, 2005 – Aug 23, 2005
(vessels 35’-65’)</td><td rowspan="2">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”)</td><td rowspan="2">3LNO
April 30 closure due to by-catch.</td><td>3L-100
3Ps-250</td></tr>
<tr><td>Fixed Gear</td><td>35-64’</td><td>Inshore</td><td>3LN-150
3O-575
3Ps-250</td></tr>
<tr><td>Fixed Gear</td><td>65’-100’</td><td>Inshore</td><td>Apr.1/ 2004 – Mar.31/2005</td><td>GN min mesh size 12”</td><td></td><td>3LN-50
3O-150
3Ps-100</td></tr>
<tr><td>Mobile Gear</td><td><65’</td><td>Inshore</td><td>3LNO
Apr 1, 2004-Mar 31, 2005
3Ps
Apr 11, 2005-May 5, 2005</td><td>Min mesh size 300mm for codend 254 for rest of trawl</td><td></td><td rowspan="3">For all mobile gear

3LN-150
3O-775
3Ps-450</td></tr>
<tr><td>Mobile Gear</td><td>65’-100’</td><td>Inshore</td><td>Jan.1/05 – Dec.31/05</td><td>Min mesh size 300mm for codend 250 for rest of trawl</td><td></td></tr>
<tr><td>Mobile Gear</td><td>>100’</td><td>Offshore</td><td>Jan.1/05 – Dec.31/05</td><td>Min mesh size 300mm for codend 250 for rest of trawl</td><td></td></tr>
</table>

Table 7b. Fishery quota allocations for thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps in 2005 and 2006.

SKATE / RAIE — **3LNO (NAFO / OPANO) ALLOCATIONS**

	2005	2006
TAC / TPA	13,500	13,500
OTHER NAFO MEMBERS	11,250	11,250
CANADIAN QUOTA/ CONTINGENT CANADIEN	2,250	2,250
FIXED GEAR / ENGIN FIXE	1,219	1,219
fg/ef < 35'	263	263
fg/ef 35 - 64'	731	731
fg/ef > 65'	225	225
MOBILE GEAR / ENGIN MOBILE	1,031	1,031

3Ps ALLOCATIONS

	2005	2006
TAC / TPA	1,050	1,050
CANADIAN QUOTA/ CONTINGENT CANADIEN	1,050	1,050
FIXED GEAR / ENGIN FIXE	600	600
fg/ef < 35'	250	250
fg/ef 35 - 64'	250	250
fg/ef > 65'	100	100
MOBILE GEAR / ENGIN MOBILE	450	450

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***	***Run 6***
B1/K	0.187	0.71	1.3	0.754	0.205	0.2
MSY	66280	18070	19990	17970	13890	13890
K	646600	57270	97560	55680	19820	19140
q(1)	2.53	6.49	5.5	8.1	0.011	0.01
q(2)	1.47	3.267				
q(3)						
Ye(yr+1)	22120	14770	15790	11180	9197	13660
Bmsy	323300	28640	48780	27840	9909	9570
Fmsy	0.21	0.6311	0.41	0.6455	1.4	1.452
B/B_{msy}	0.184	0.5727	0.5414	0.3852	1.58	0.871
F/F_{msy}	0.484	1.497	0.5736	0.6455	0.285	1.2
Ye/MSY	0.334	0.8174	0.7898	0.622	0.662	0.9833
R^2	0.48/-0.54	.399/.905	0.213	0.839	0.669	0.555

Run 1 corresponds to the time period 1984 to 2005 using the Spring campelen time series tuned with the 1984-1995 Engel time series. **Run 2** corresponds to the same data series reduced to include only to 2004. **Run 3** corresponds to the 1984 to 2005 time series using the established conversion factor (2005 SCR), while **Run 4** corresponds to the same series limited to 1985 to 2004. **Runs 5 and 6** correspond to only the Campelen survey series from 1996 to 2005 and 1996 to 2004, respectively.

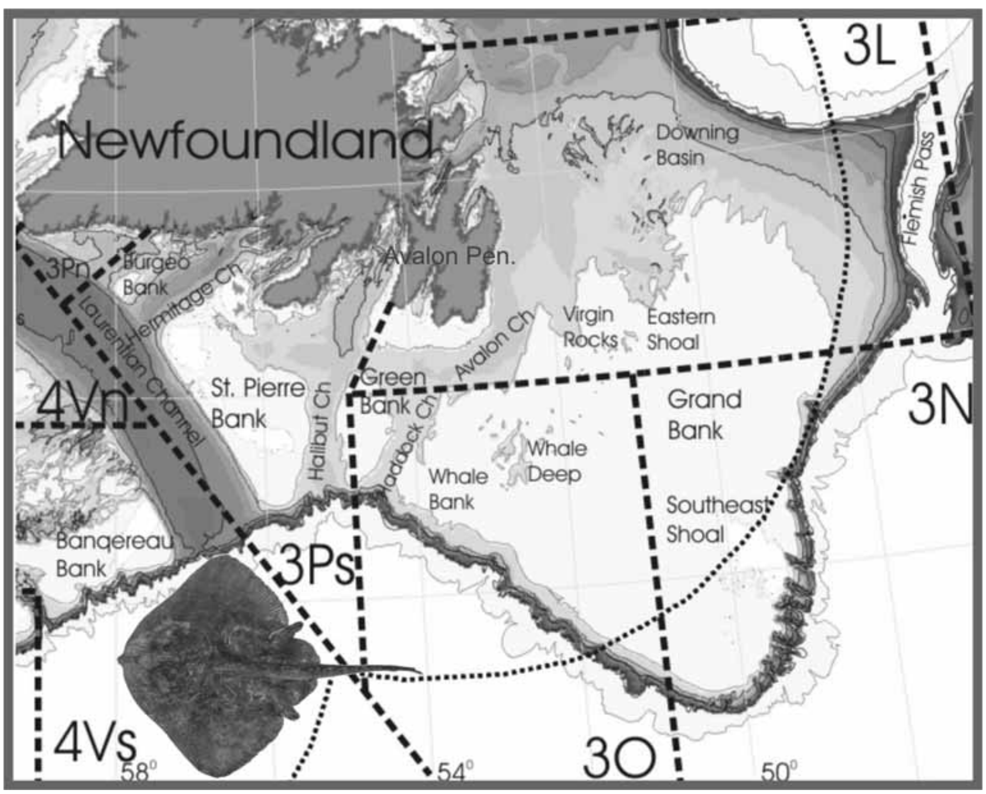


Fig. 1. The Grand Banks, showing locations referenced in the text, bathymetry, Canada's 200-mile limit, and NAFO Div. 3L, 3N, 3O, and Subdiv. 3Ps (image of thorny skate on lower left).

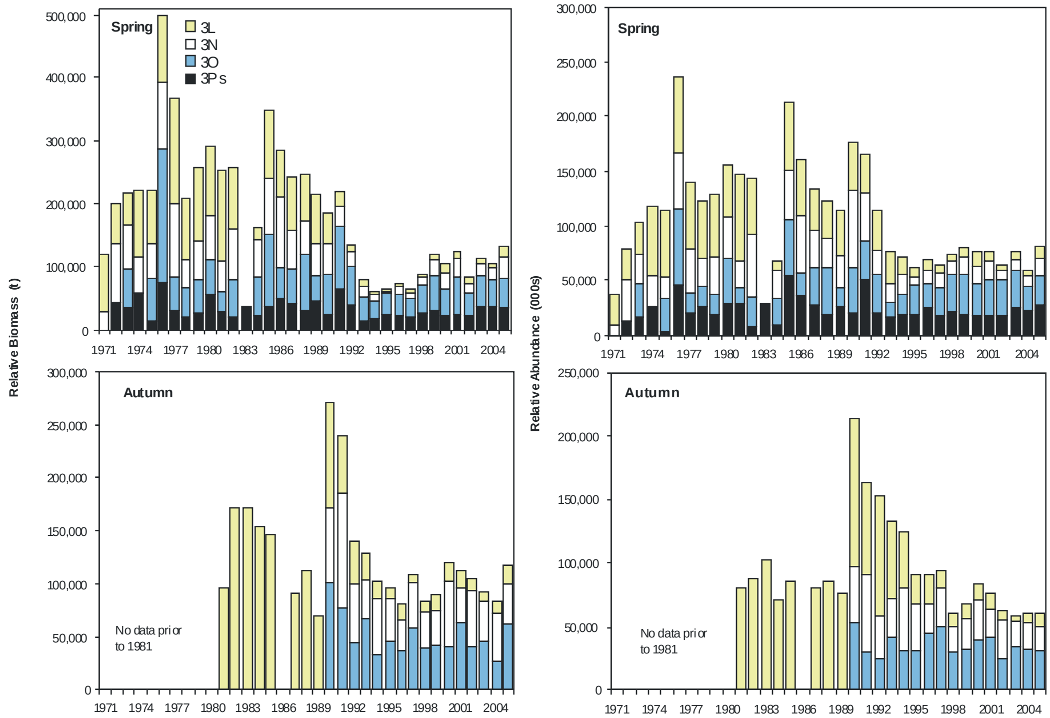


Fig. 2. Spring and fall survey biomass and abundance indices for thorny skate in NAFO Div. 3L, 3N, 3O, and Subdivision 3Ps, **1971-2005.** Indices are not adjusted for the change in survey gear.

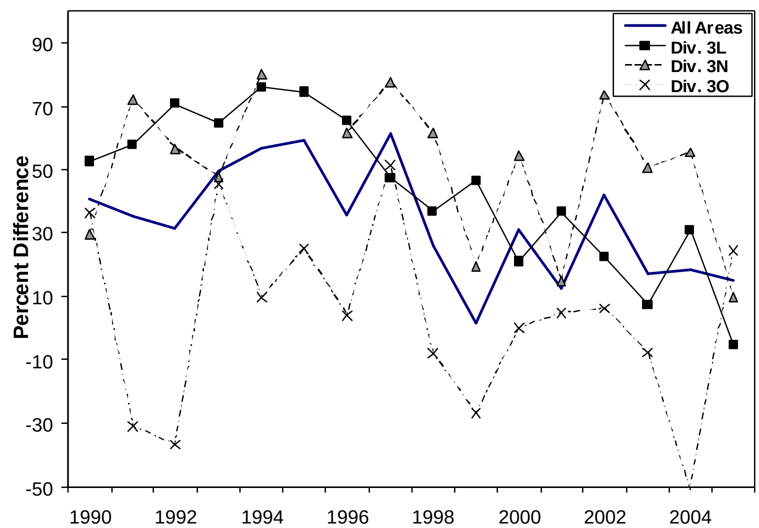


Fig. 3. Percent difference between spring and fall survey biomass estimates for thorny skate in NAFO Div. 3LNO, 1987-2005.

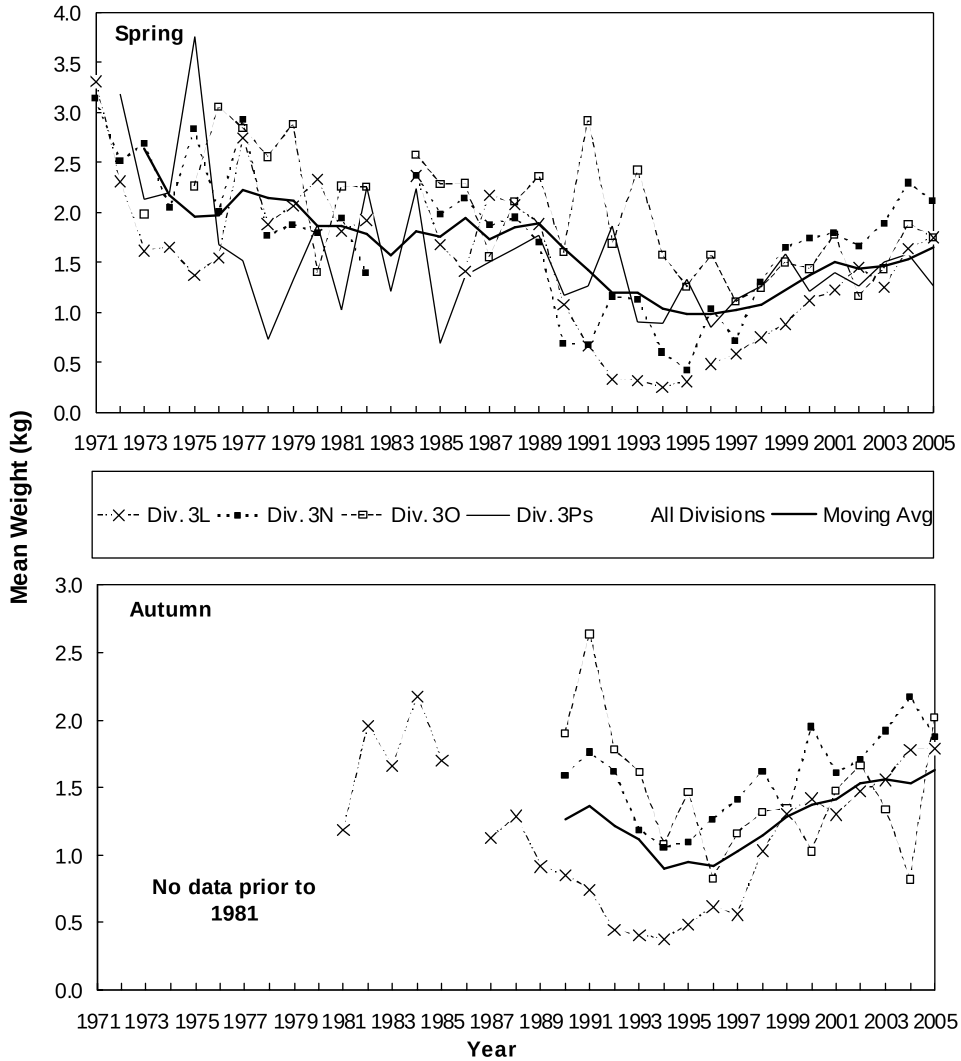


Fig. 4. Mean weight of thorny skate in spring (1971-2005) and autumn (1981-2005) surveys in NAFO Div. 3LNO and Subdiv. 3Ps.

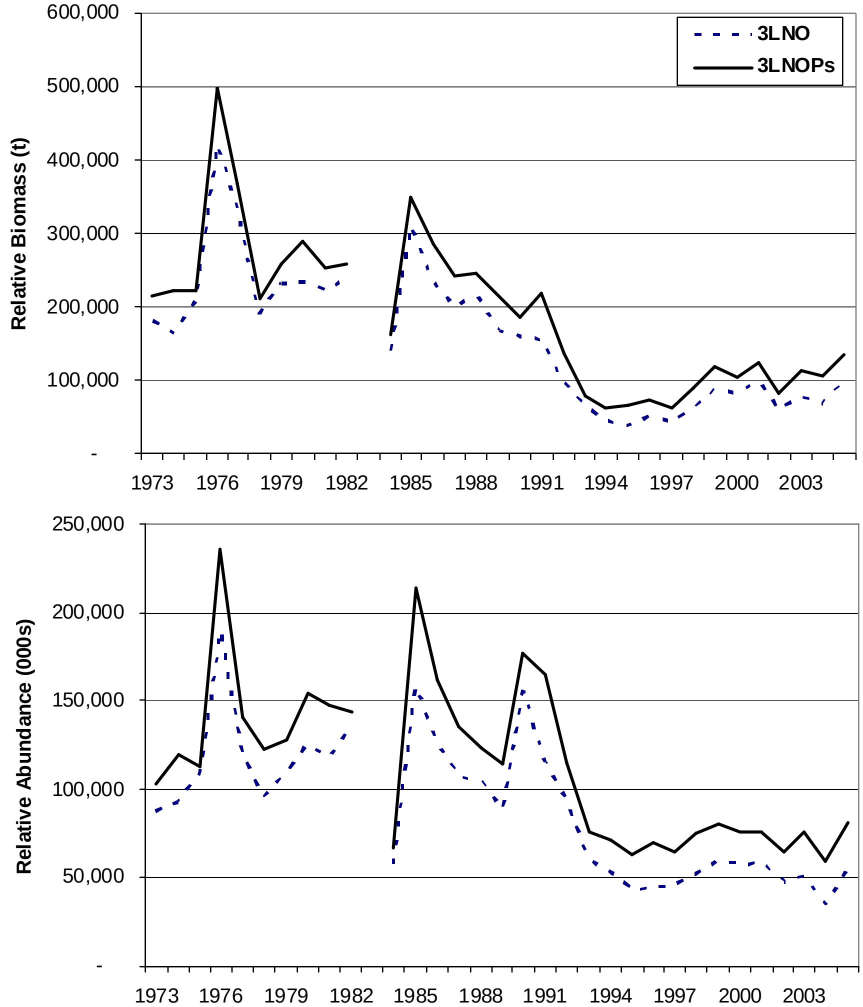


Fig. 5a. Relative biomass and abundance of thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps, 1973-2005; with Engel estimates converted to Campelen equivalents. Some Divisions were not sampled in 1983, and thus are not illustrated.

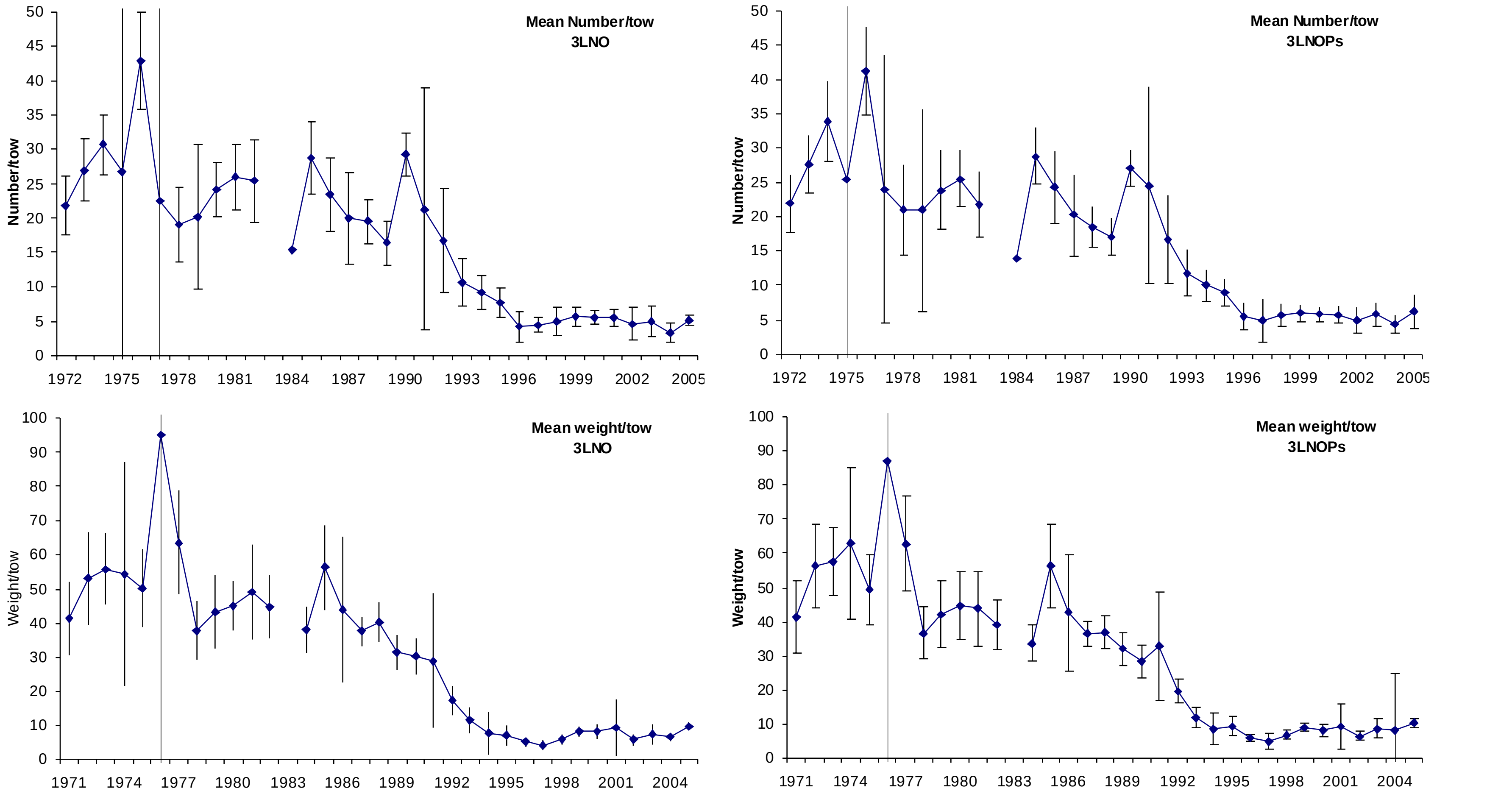


Fig. 5b. Mean weight and mean number per tow of thorny skate in NAFO Div. 3LNO and Subdiv. 3Ps, with Engel estimates converted to Campelen equivalents, with error bars. Some Divisions were not sampled in 1983.

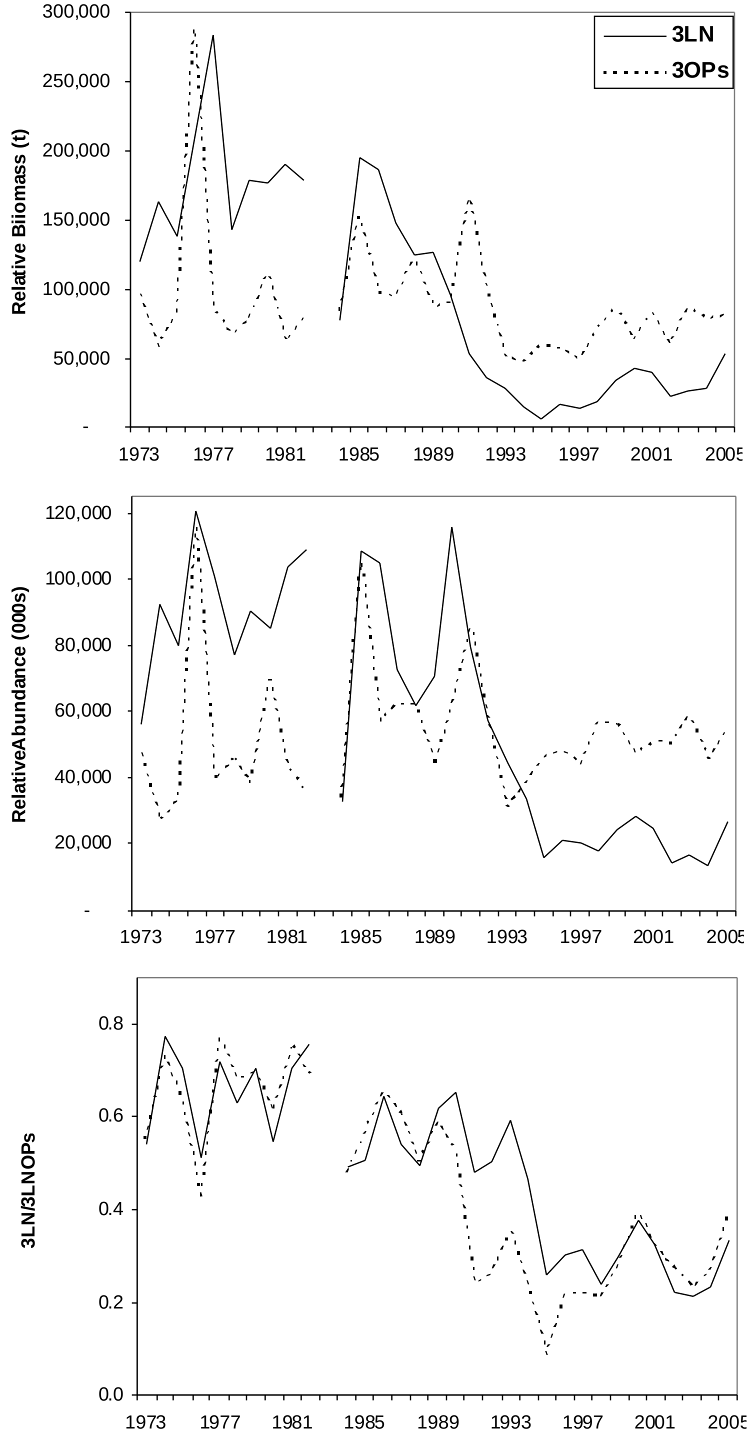


Fig. 5c. Relative biomass of thorny skate in 3LN *versus* 3OPs, 1973-2005; with Engel estimates converted to Campelen equivalents. Some Divisions were not sampled in 1983.

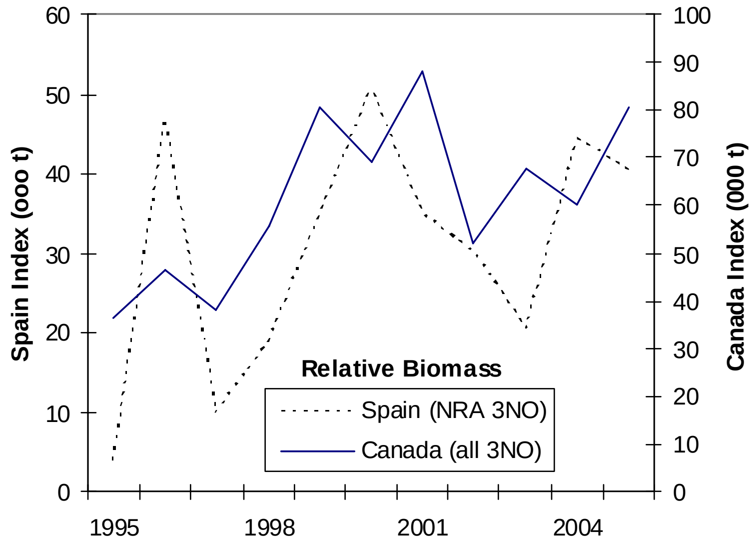


Fig. 5d. Scaled comparison of the Canadian Campelen survey trend with the Spanish Campelen survey trend in NAFO Div. 3NO, 1995-2005 (Spanish surveys only in NRA).

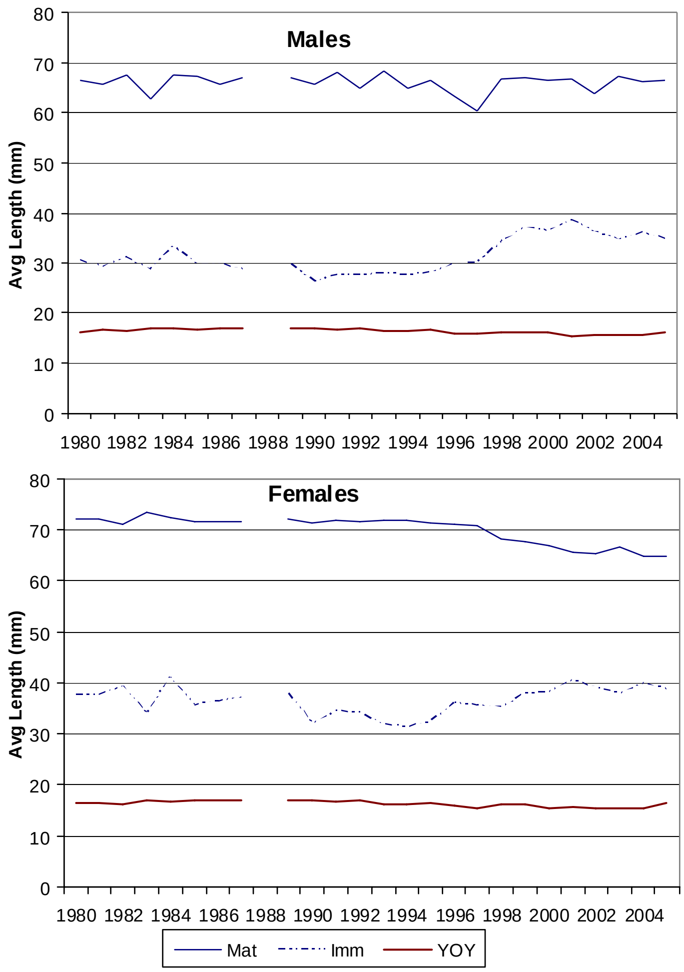


Fig. 6. Average length of Young of the Year (YOY), Immature, and Mature in 1980-2005 (size at maturity based on del Río 2002 ogives).

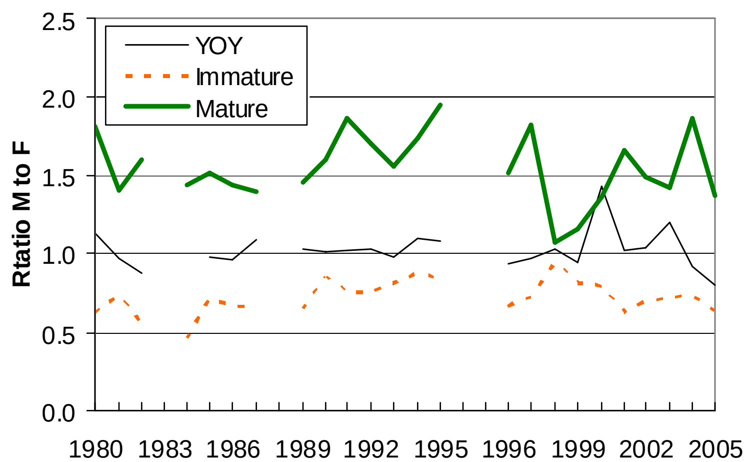


Fig. 7. Ratio of males to females for YOY (young of the year), immature, and mature thorny skates, 1980-2005.

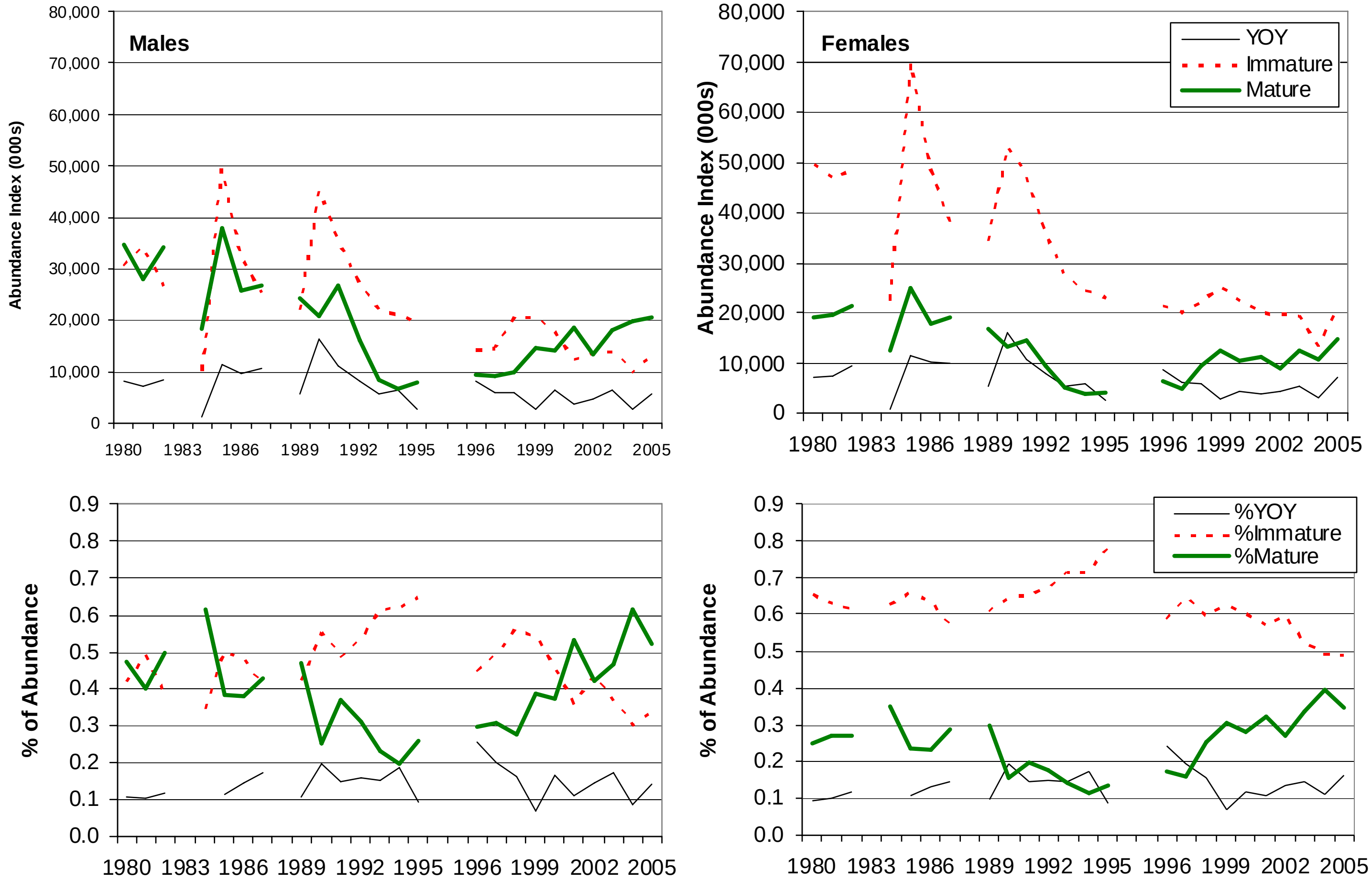


Fig. 8a. Trends in abundance by stage and percent of total abundance that is young of the year (YOY), immature, and mature, depicted separately by sex, 1980-2005.

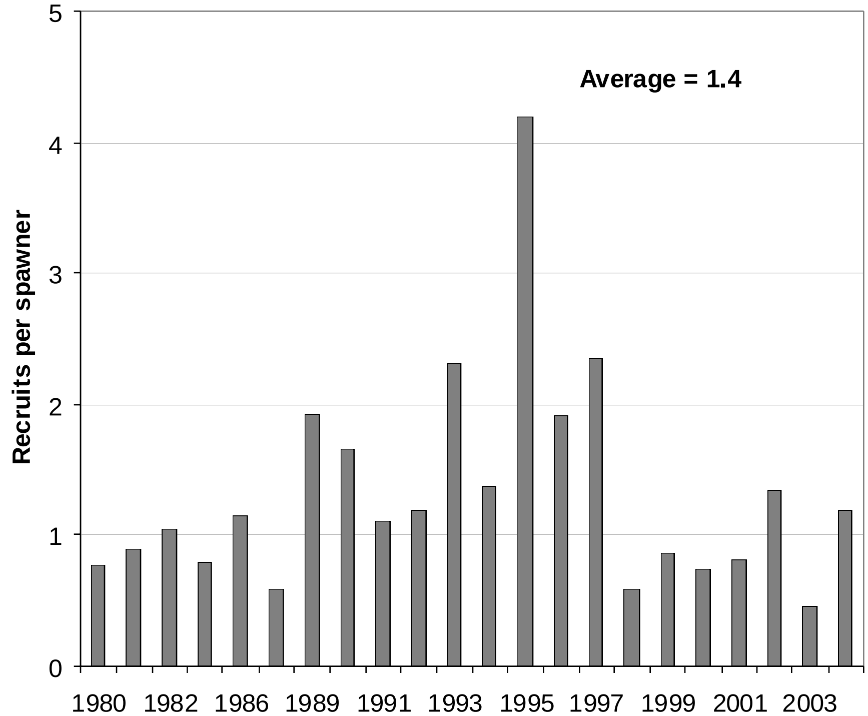


Fig. 8b. Recruit per spawner expressed as number of young-of-the-year males and females (YOY produced per female) from Canadian Campelen spring surveys in NAFO Div. 3NO and Subdiv. 3Ps, 1980-2004.

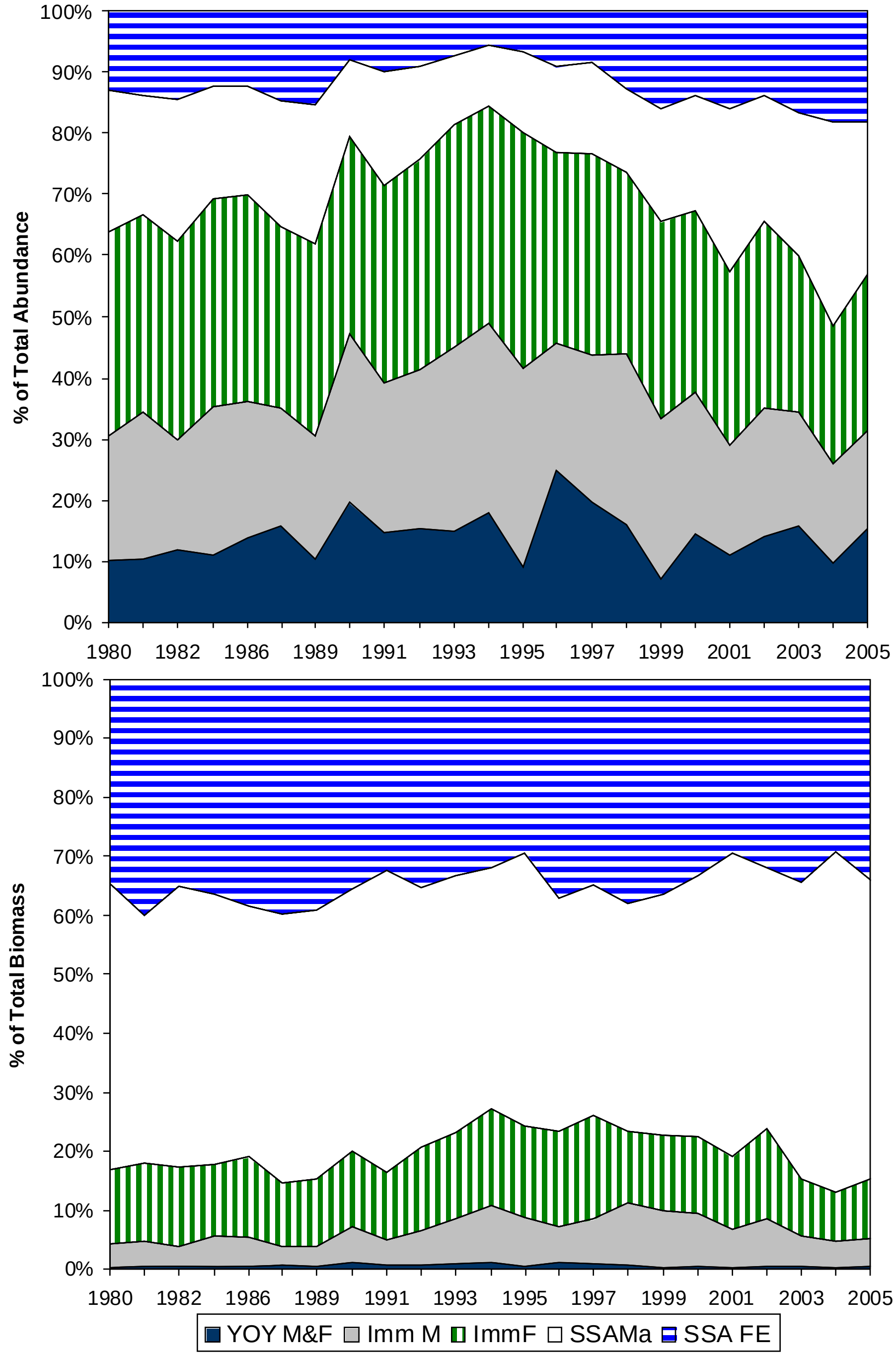


Fig. 9. Proportion of biomass and abundance by stage, 1980-2005.

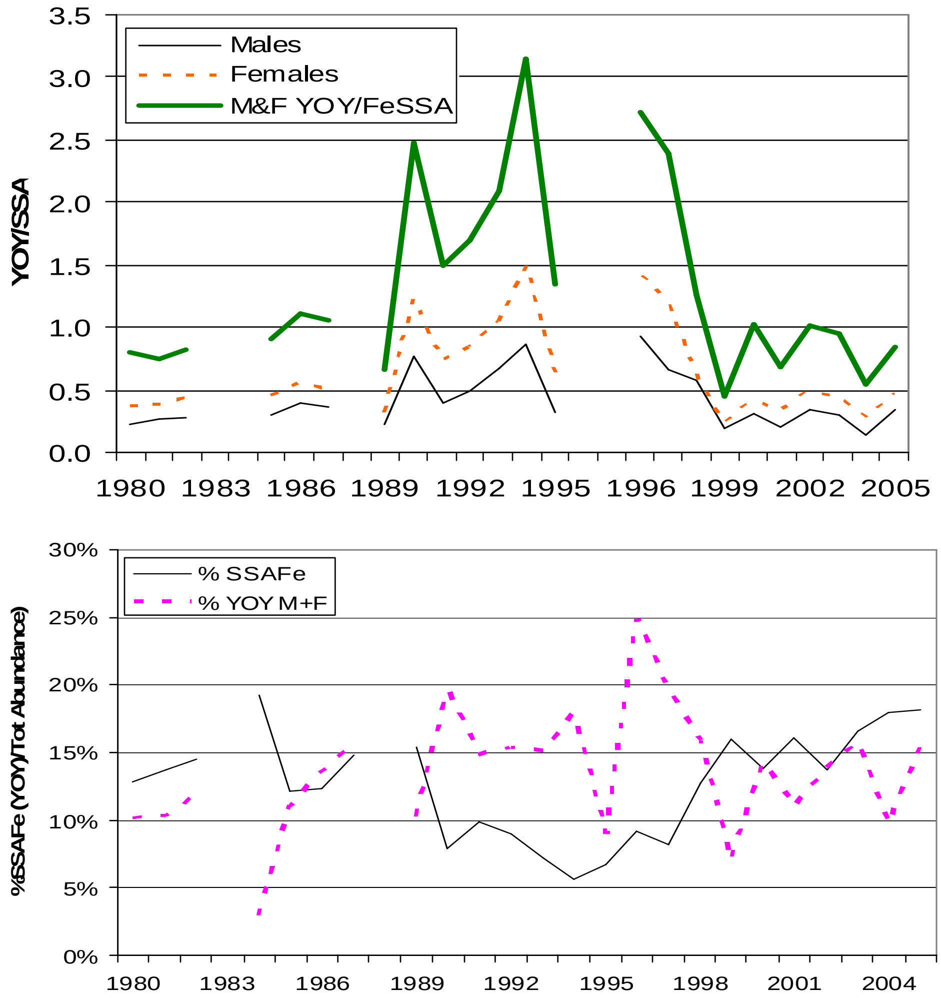


Fig. 10. Relationship between male and female thorny skate young of the year (YOY) and female spawning stock abundance (SSA). Upper Panel: Ratio of YOY (young of the year) to SSA (spawning stock abundance; consisting of mature females), 1980-2005. Lower Panel: relationship of YOY and SSA to total abundance derived from spring research surveys.

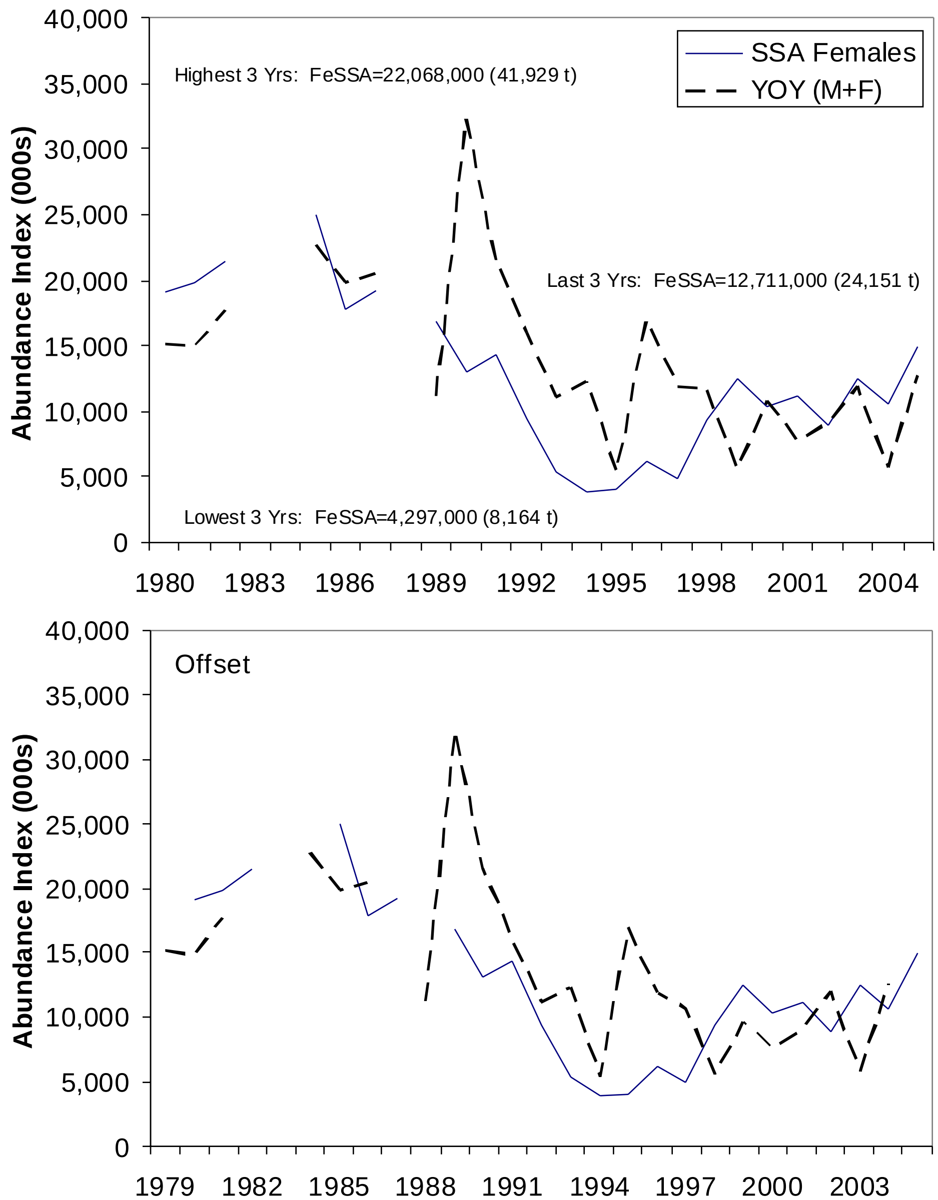


Fig. 11. Recruitment Index (male plus female) and Spawning Stock Abundance (SSA female) Index for thorny skates, 1980-2005. Lower graph shows the YOY offset by one year.

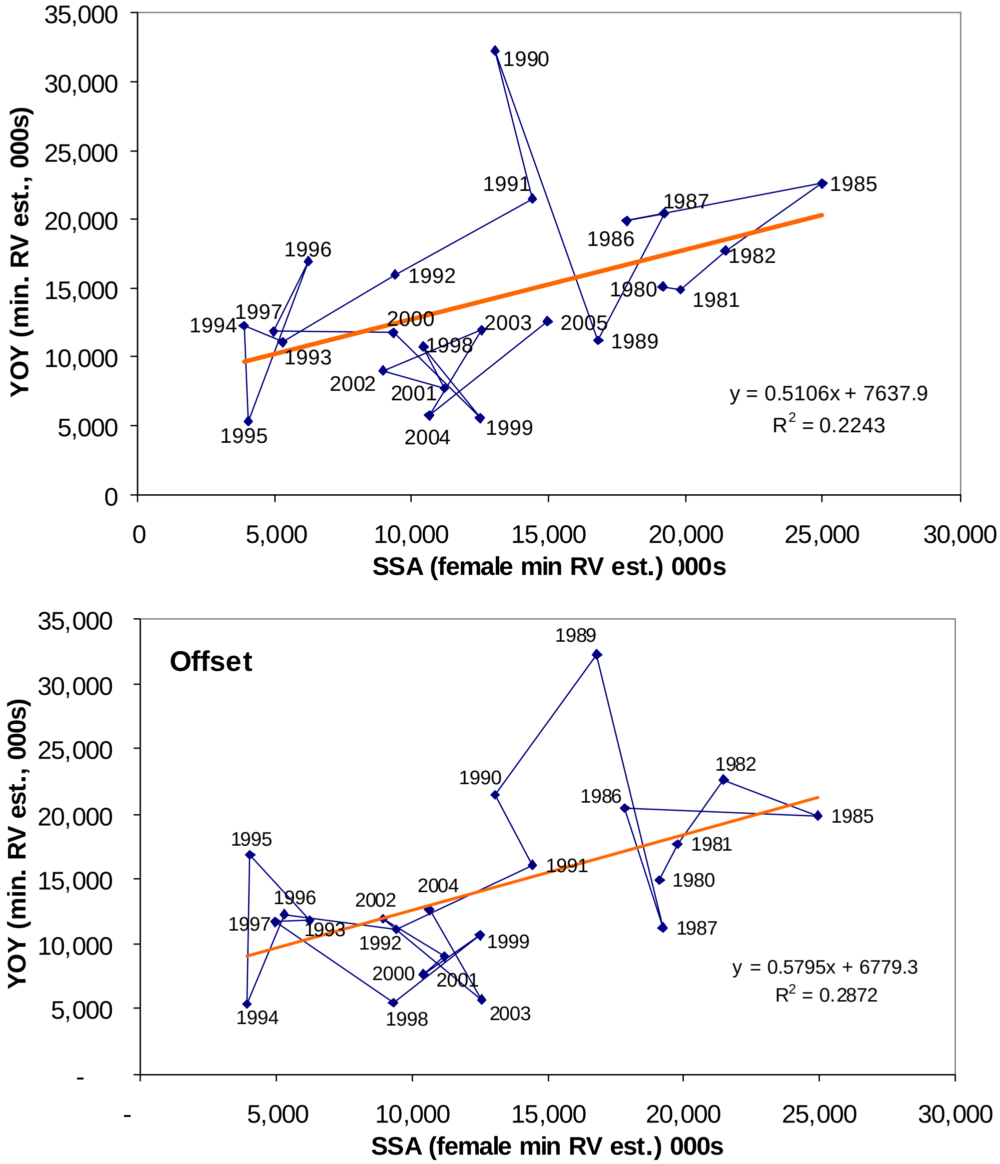
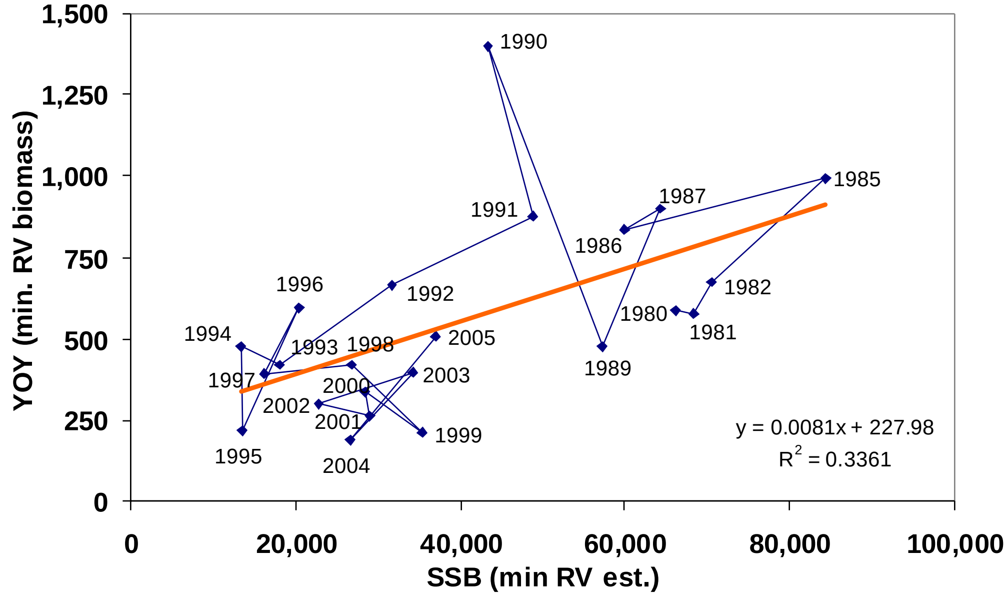


Fig. 12a. Spawning Stock (Female abundance) *versus* Recruit (male plus female) Indices for thorny skates, 1980-2005. Lower graph shows the YOY offset by one year.



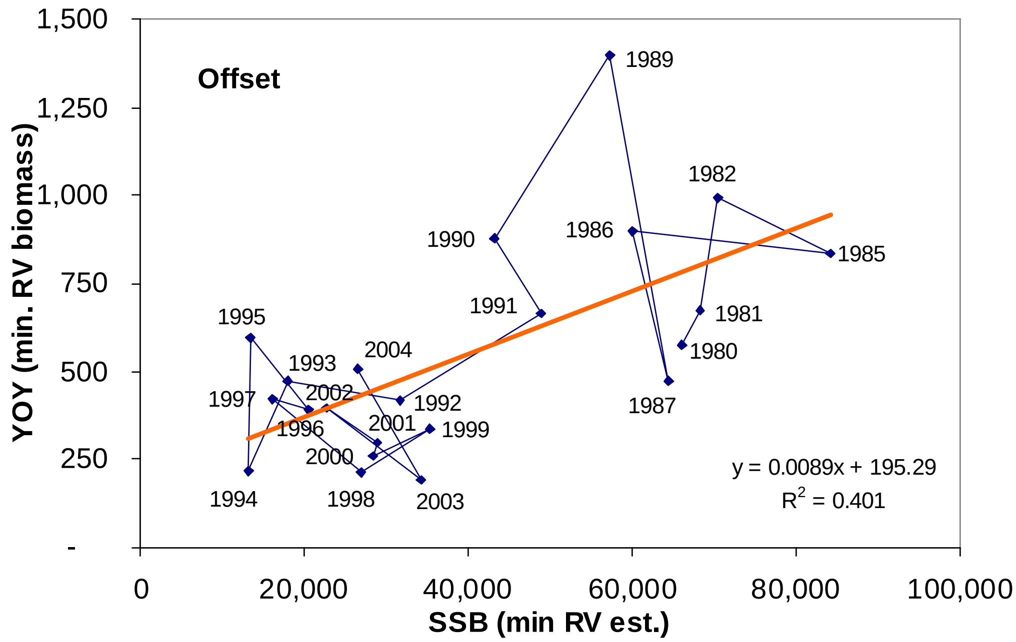


Fig. 12b. Spawning Stock (Female biomass) *versus* Recruit (male plus female YOY biomass) Indices for thorny skates, 1980-2005. Lower graph shows the YOY offset by one year.

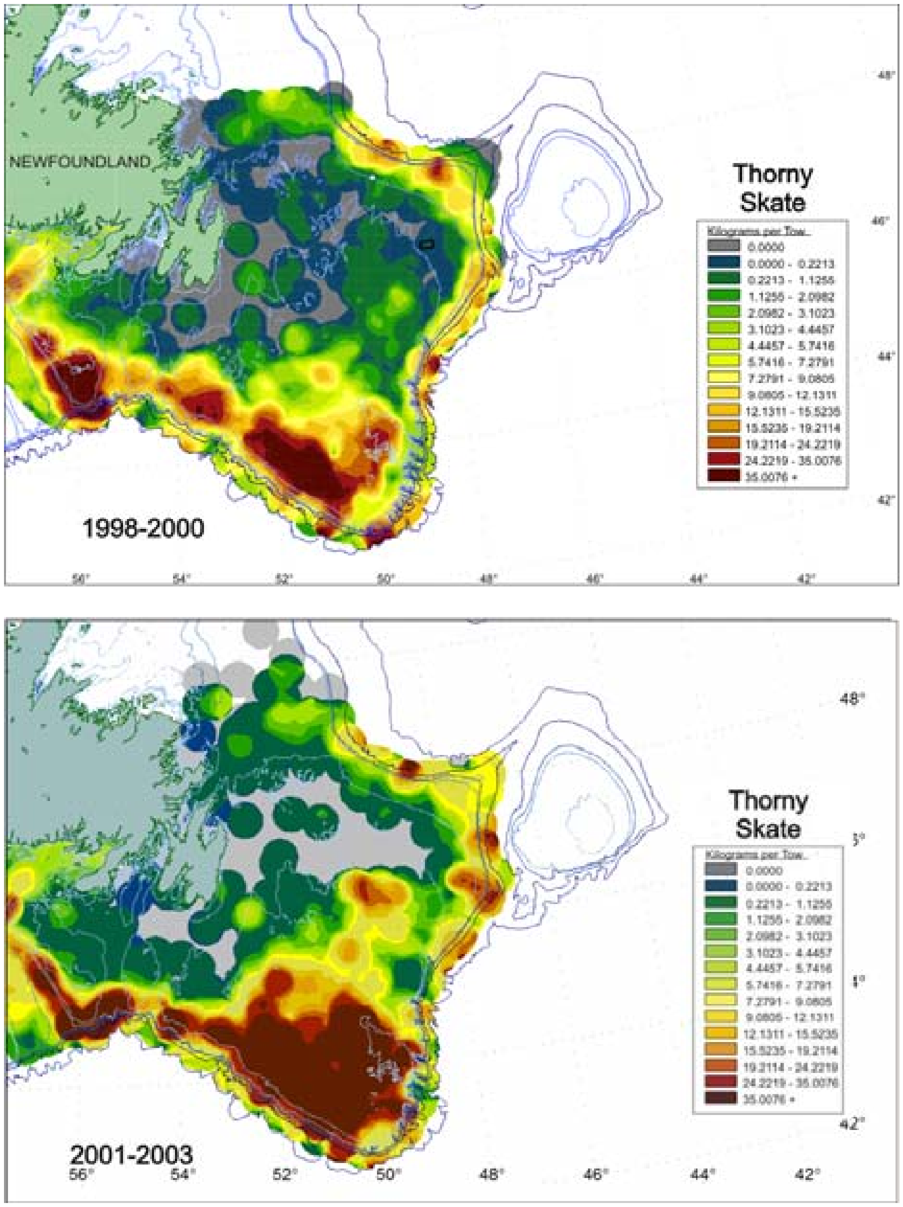


Fig. 13. Distribution of thorny skate on the Grand Banks (NAFO Divisions 3LNOPs), based on **spring** surveys in 1998-2000 and 2001-2003 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.

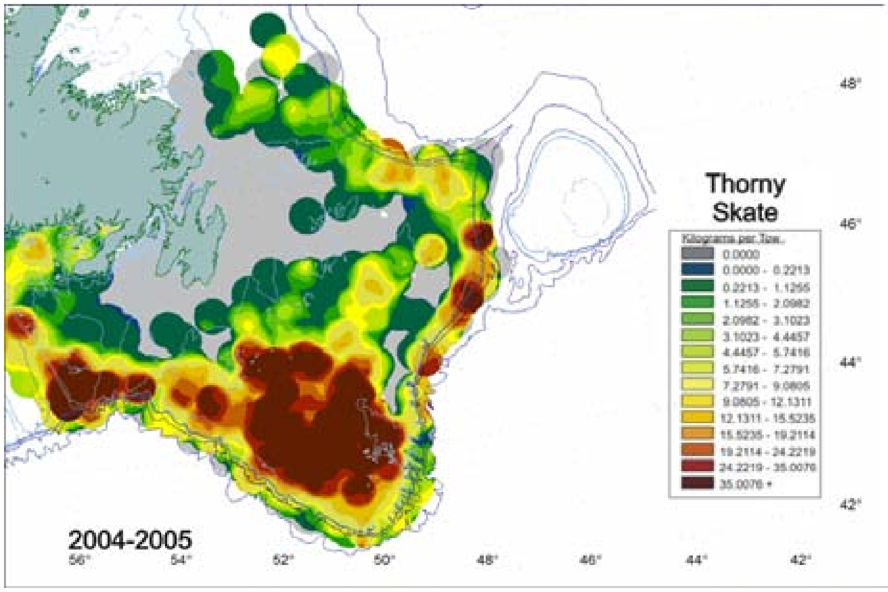
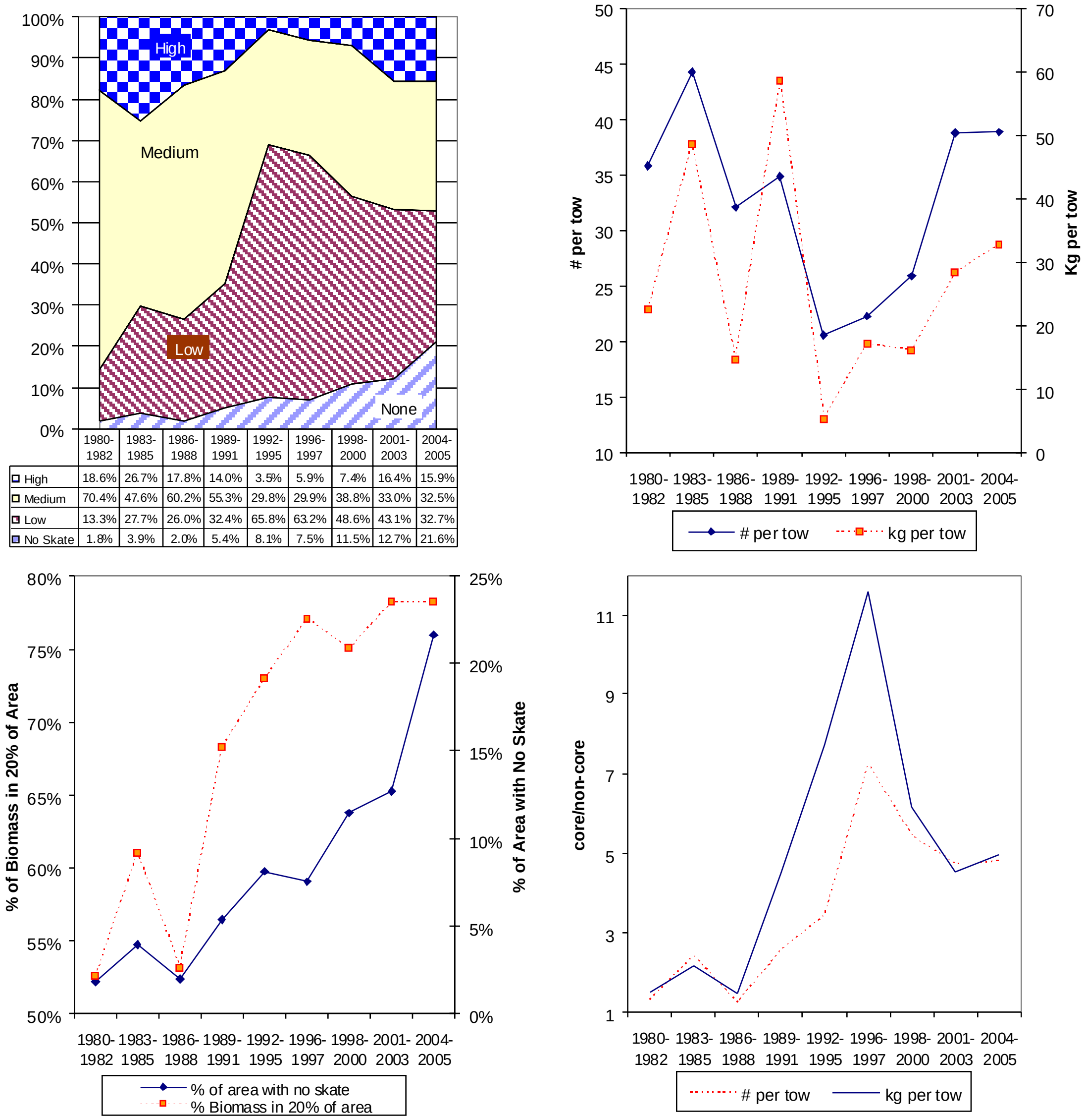


Fig. 13b. Distribution of thorny skate on the Grand Banks (NAFO Div. 3LNOPs), based on **spring** surveys in 2004-2005 (years combined). Green represents low catch rates (in kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas.



	1980-1982	1983-1985	1986-1988	1989-1991	1992-1995	1996-1997	1998-2000	2001-2003	2004-2005
High	18.6%	26.7%	17.8%	14.0%	3.5%	5.9%	7.4%	16.4%	15.9%
Medium	70.4%	47.6%	60.2%	55.3%	29.8%	29.9%	38.8%	33.0%	32.5%
Low	13.3%	27.7%	26.0%	32.4%	65.8%	63.2%	48.6%	43.1%	32.7%
No Skate	1.8%	3.9%	2.0%	5.4%	8.1%	7.5%	11.5%	12.7%	21.6%

Fig. 14. Changes in area of occupancy, based on **spring** survey data, 1980-2005: 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: ratio of density (number and weight per tow) of skate in core/non-core high density areas (core area = locations where skates concentrated when biomass was low).

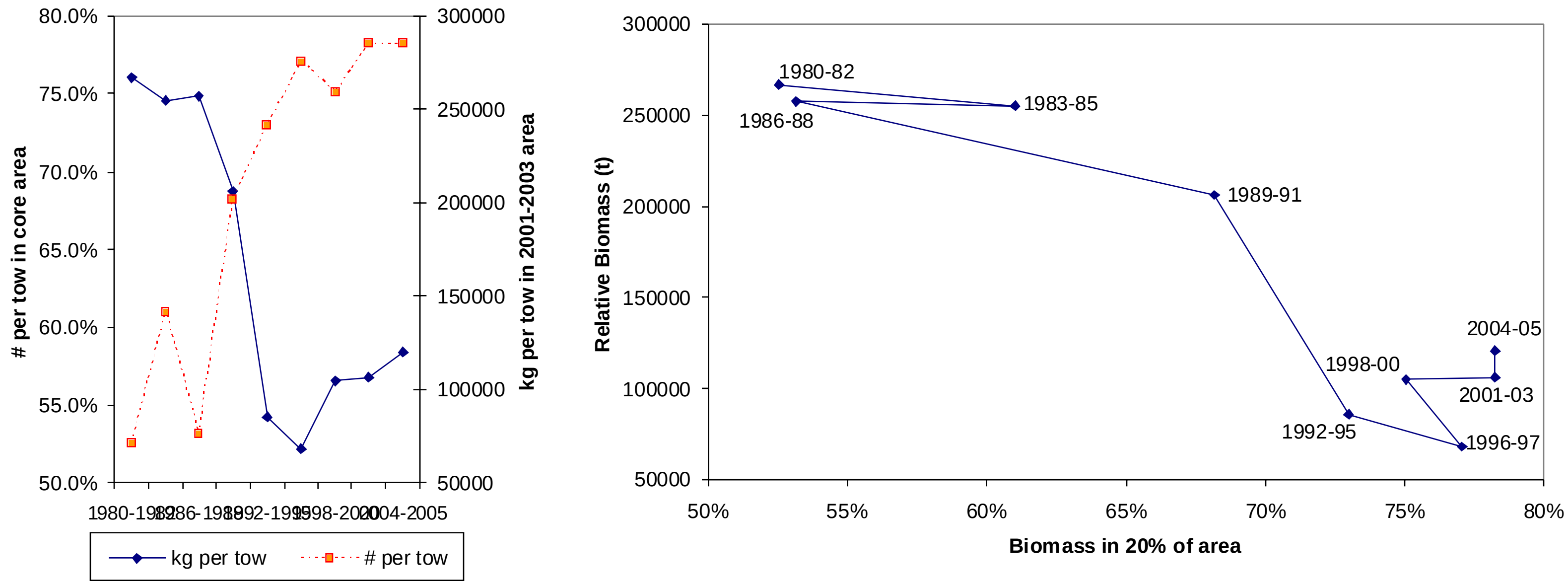


Fig. 15. Changes in area of occupancy, based on **spring** survey data, 1980-2005: Left: Percent of biomass contained within 20% of the total area (dotted line) compared to the survey biomass trajectory. Right: Relative biomass in relation to biomass concentration as a time line.

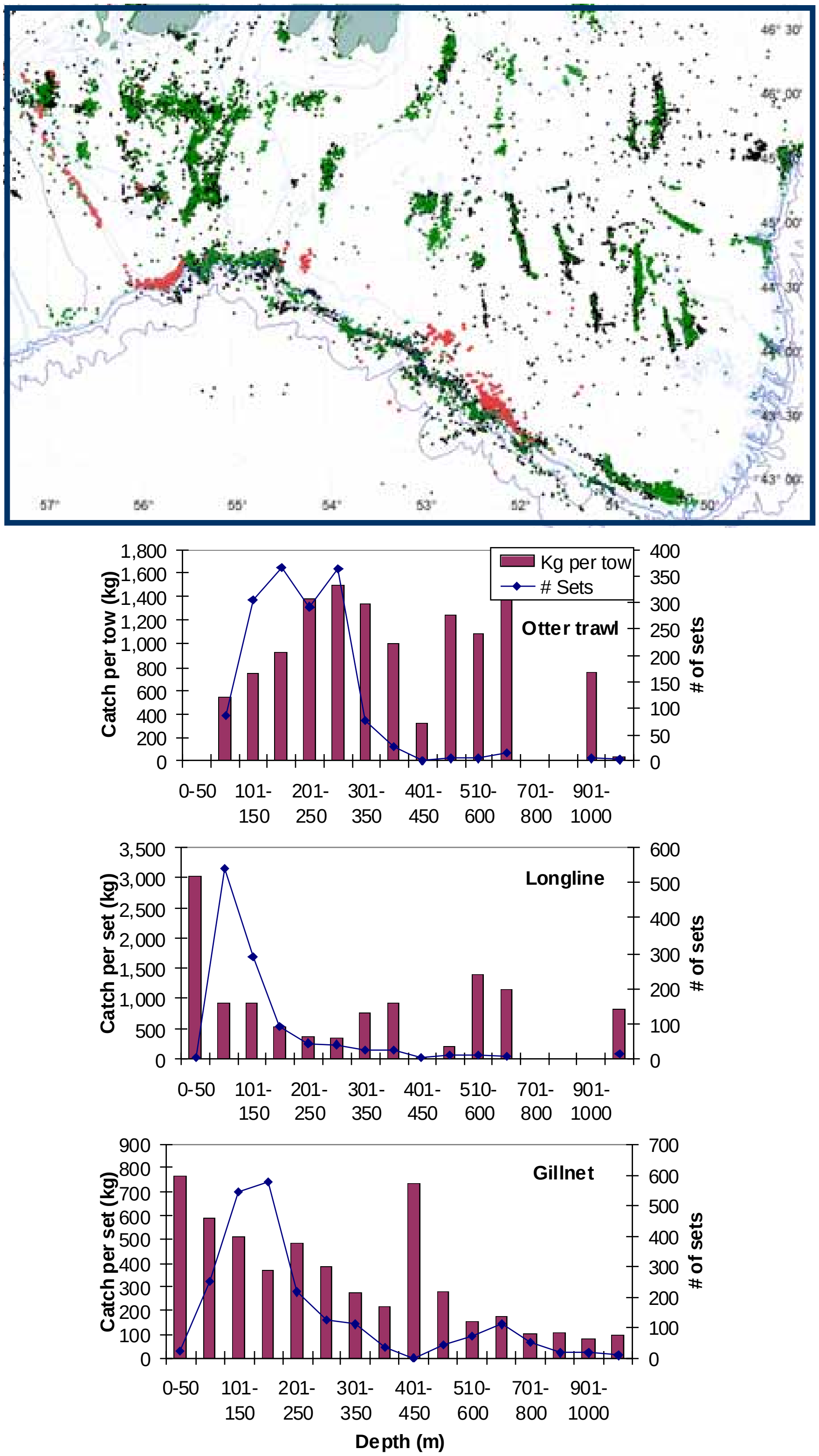


Fig.16a. Distribution of Canadian skate-directed sets for all gear types, 2002-2005. Upper Panel: skate directed locations depicted as red dots (black dots are sets for other directed species). Lower Panels: fishing effort (number of sets) and skate catch per set by depth for each gear type.

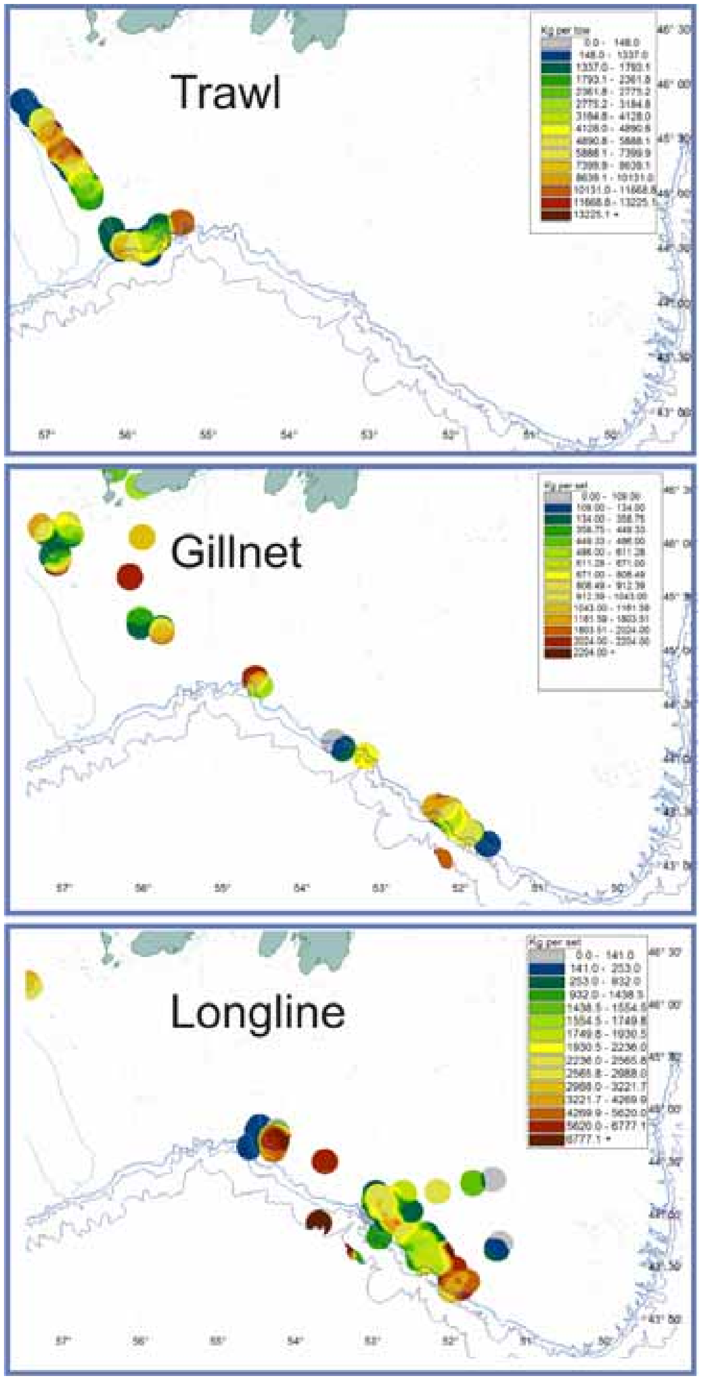


Fig. 16b. Catch per set for the trawl, longline and gillnet fishery for skate, 2004-2005.

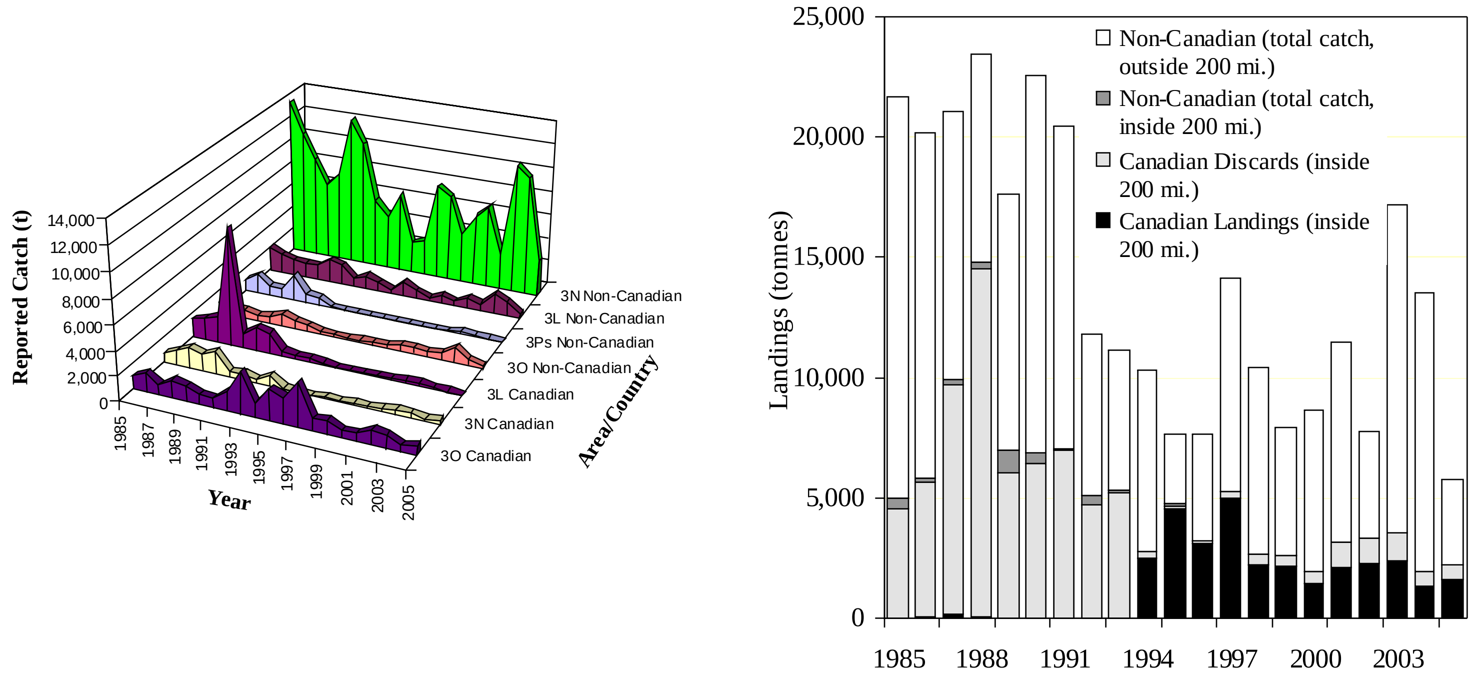


Fig. 17. Reported catches of skate in NAFO Div. 3LNOPs by all countries, 1985-2005. Non-Canadian data for 2004 are preliminary; and 2005 is incomplete. Non-Canadian total catches (outside Canada's 200-mile limit) in 2005 are taken from NAFO letters. Skate data were not speciated; although Canadian Fisheries Observer data indicate that thorny skates comprise 90% of skate catches on the Grand Banks.

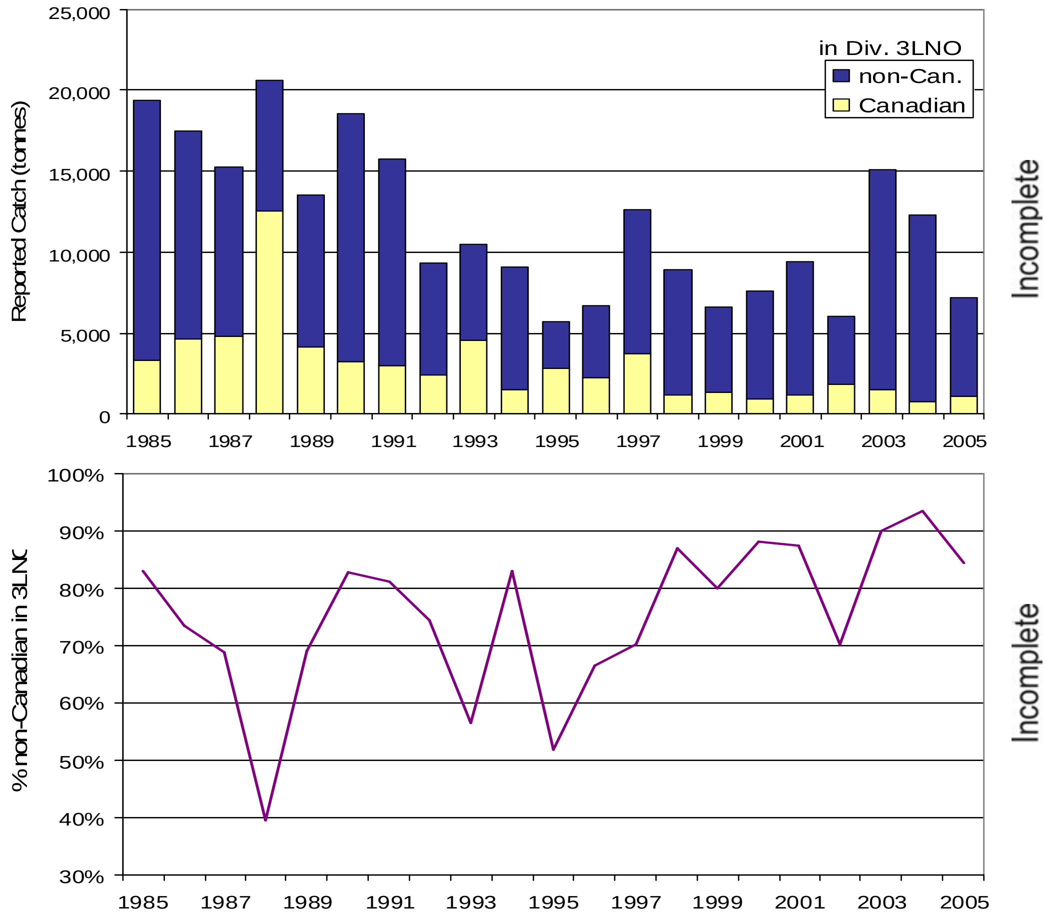


Fig. 18. Reported catches of skate in NAFO Div. 3LNO by all countries, 1985-2005. Non-Canadian data for 2004 are preliminary; and 2005 is incomplete. Non-Canadian total catches (outside Canada's 200-mile limit) in 2005 are taken from NAFO letters. Skate data were not speciated; although Canadian Fisheries Observer data indicate that thorny skates comprise 90% or more of skate catches on the Grand Banks.

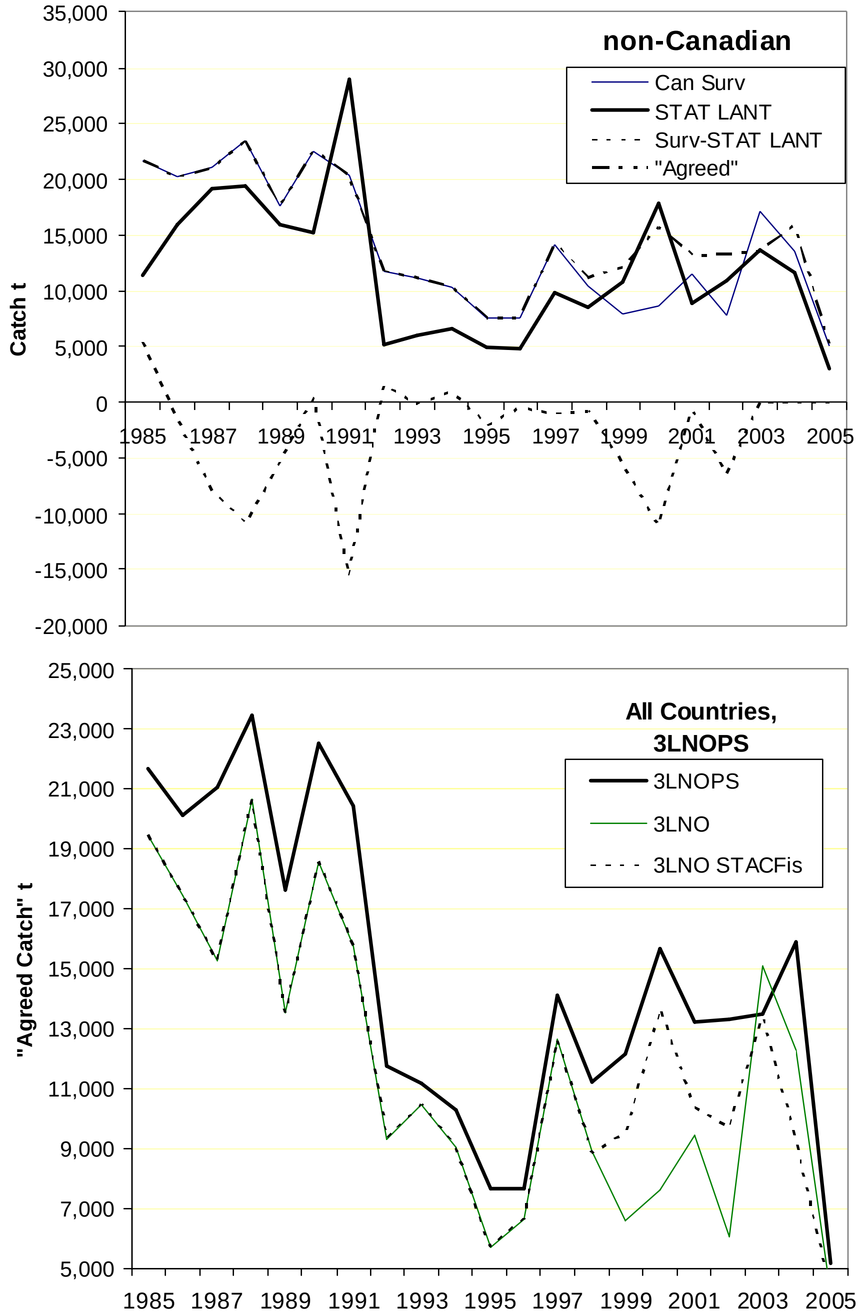
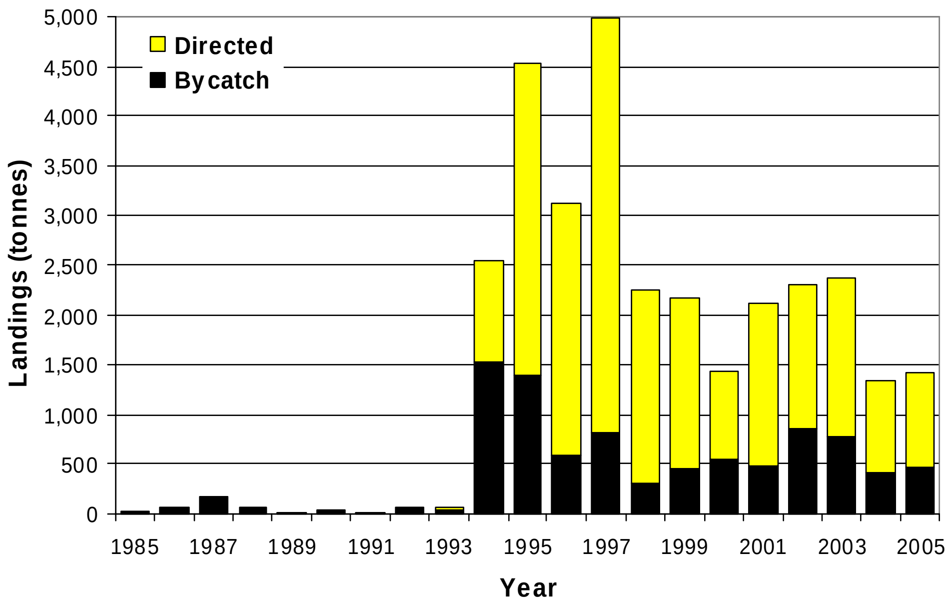
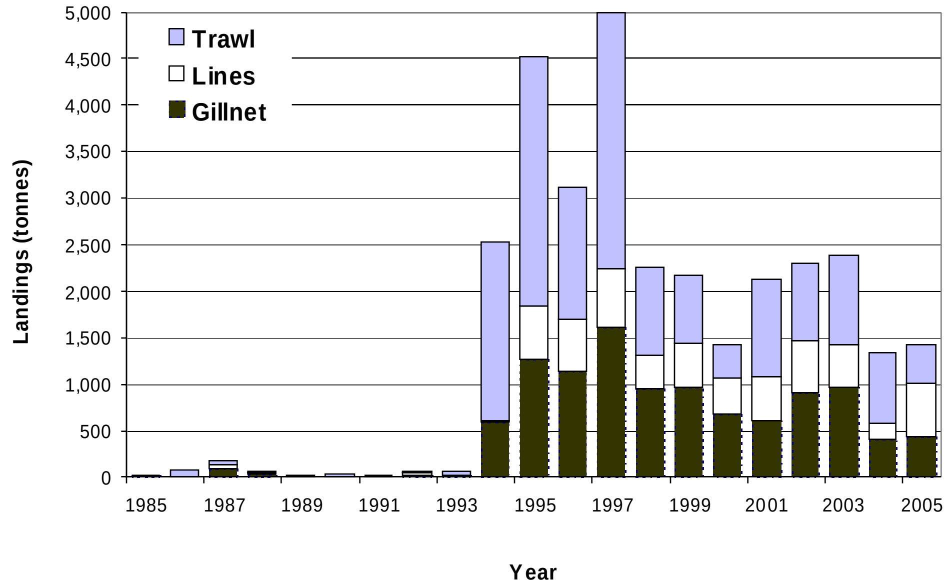


Fig. 19. Reported catches of skate in NAFO Div. 3LNOPs by all countries, 1985-2005. Canadian numbers assume 7 000 tons of discards annually.



	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	8	3	16	445	451	399	973	**2,304**	855	1,449
2003	15	2	7		313	333	439	1,265	**2,374**	774	1,599
2004	15	0	1		212	123	188	799	**1,339**	416	923
2005	11		1		148	518	300	440	**1,417**	460	957

Fig. 20a Directed and non-directed Canadian skate landings in NAFO Div. 3LNOPs, 1985-2005. 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	660	254	156	396	37	799	0	0	**2,303**	914	552	837
2003	552	417	195	252	26	931	0	0	**2,372**	969	447	957
2004	321	93	86	74	10	756	0	0	**1,339**	414	159	766
2005	364	73	91	486	5	399	0	0	**1,417**	437	577	404

Fig.20b . Canadian skate landings in NAFO Div. 3LNOPs by gear type and mode (directed or bycatch), 1985-2005. Data do not include discards at sea.

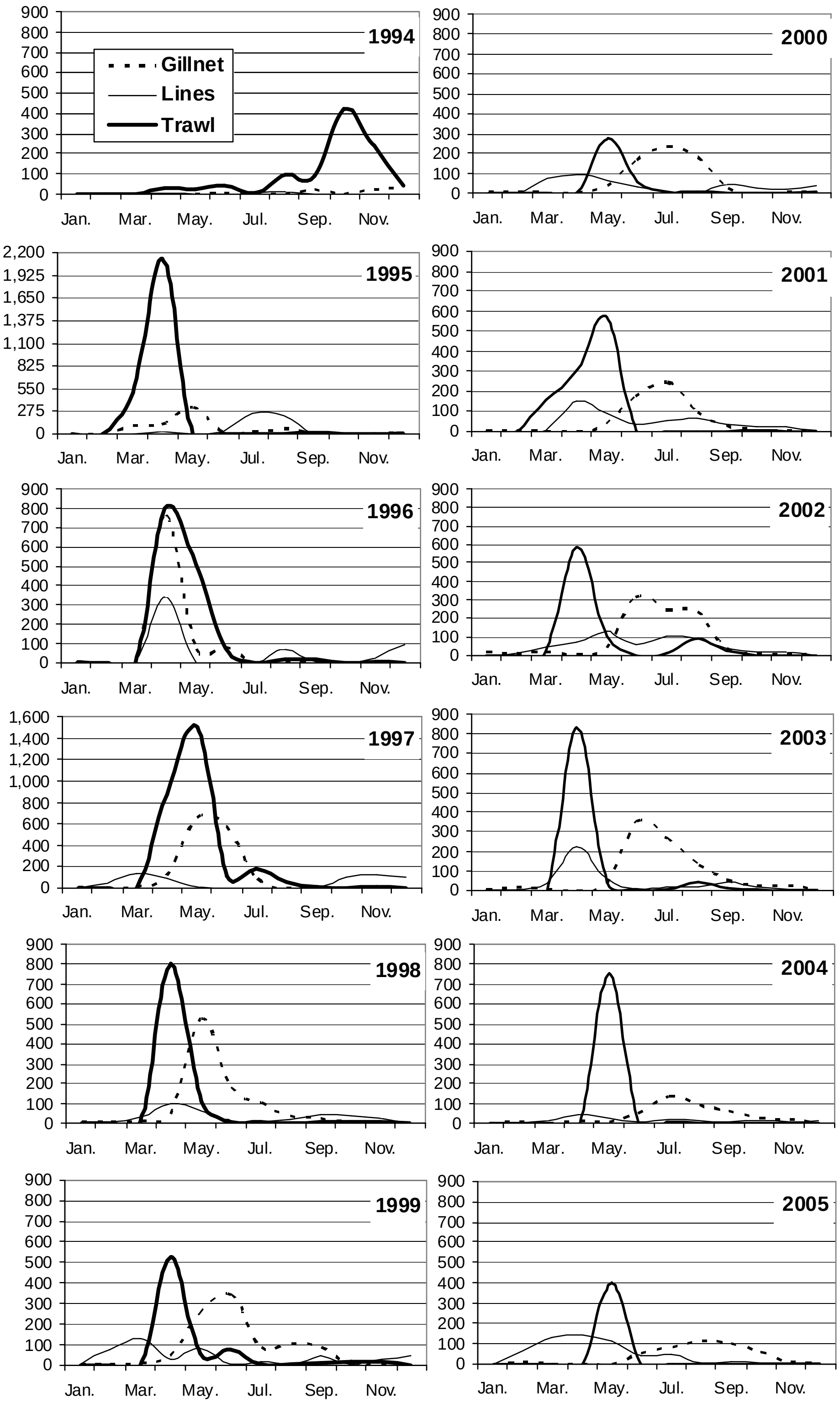


Fig. 21. Monthly Canadian landings of skate in NAFO Div. 3LNOPs, 1994-2005. Landing records for which no month was recorded are excluded.

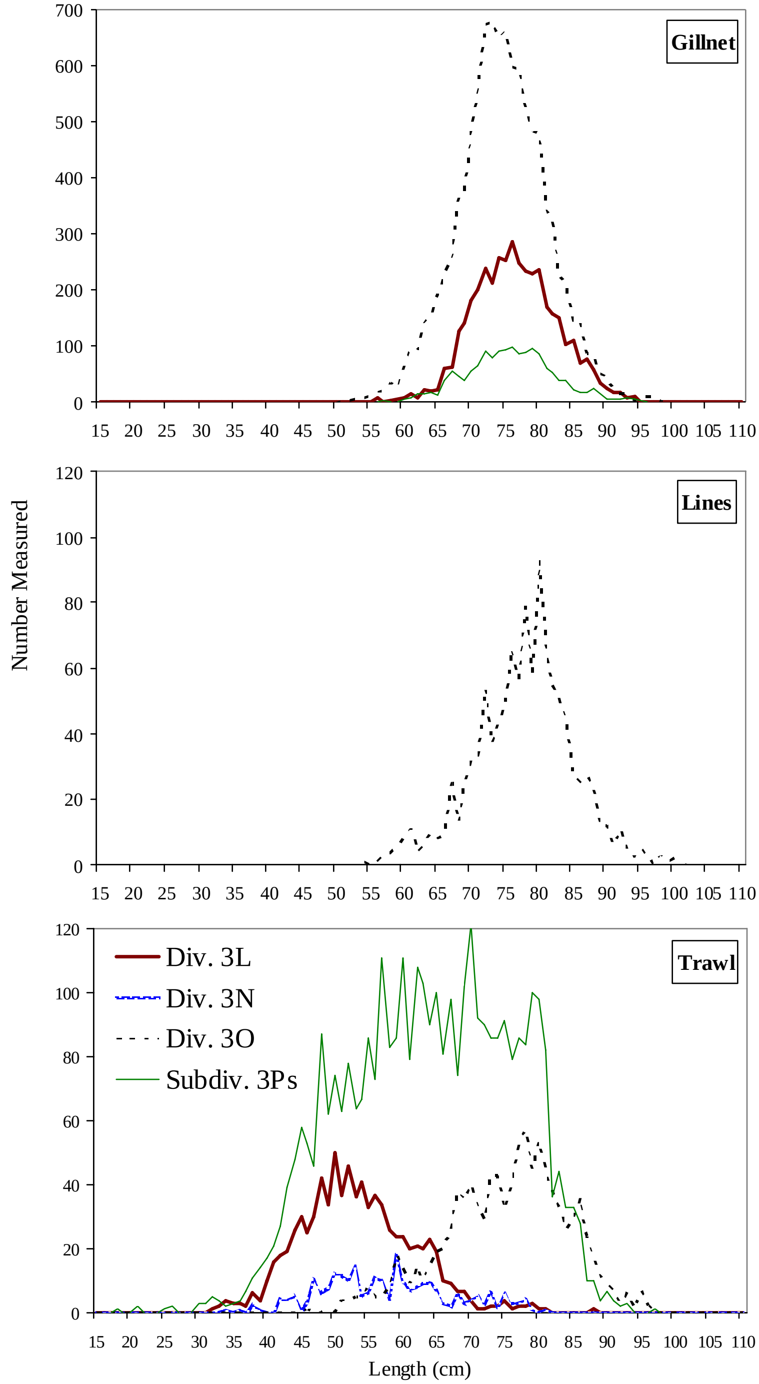


Fig. 22. Length frequencies of Canadian commercial skate catches in NAFO Div. 3LNOPs, 1994-2005. Data are from Canadian Fisheries Observers.

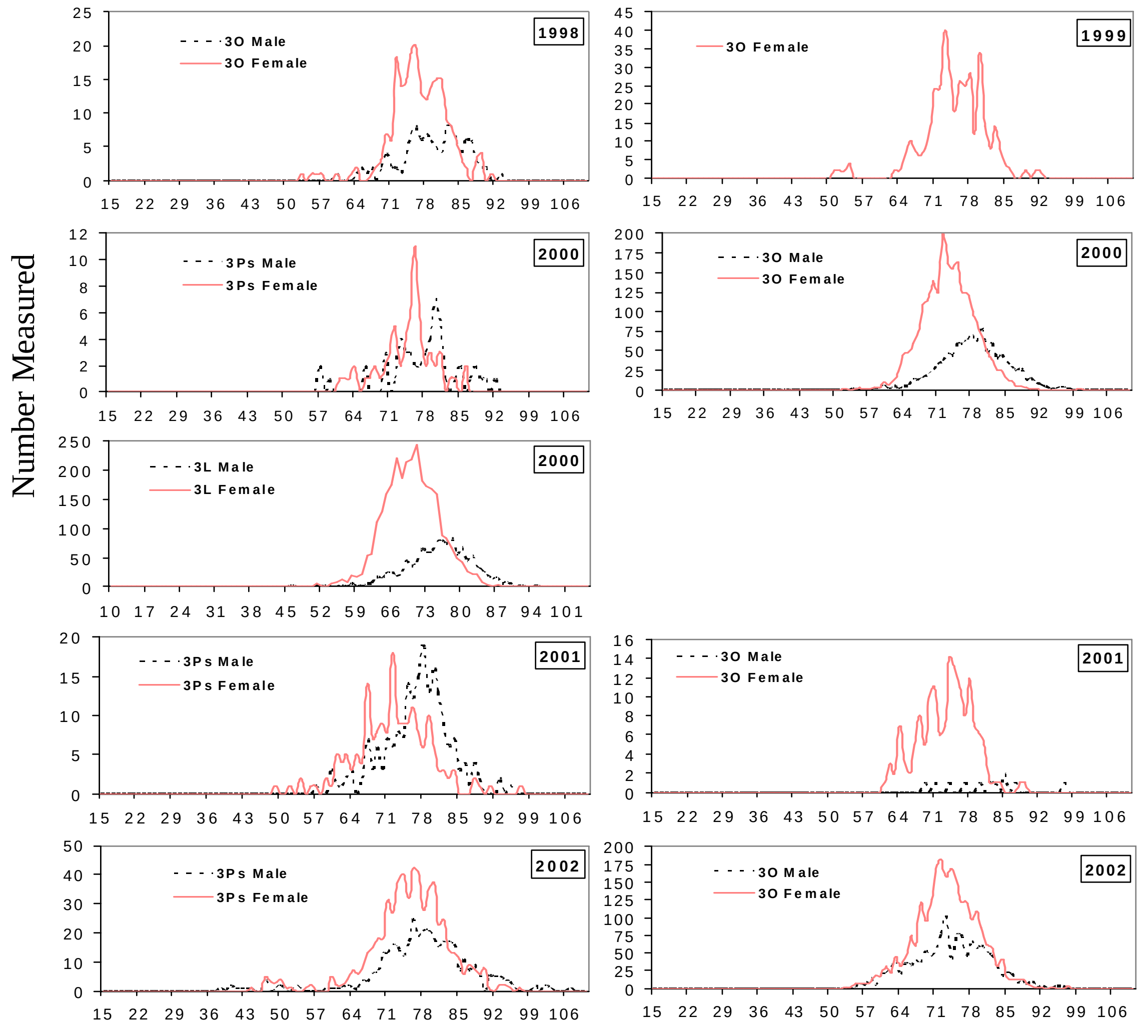


Fig. 23a. Length frequencies of Canadian commercial skate catches for gillnets in NAFO Div. 3LOPs, 1998-2002. X-axis represents lengths of skate in centimeters. Data are from Canadian Fisheries Observers.

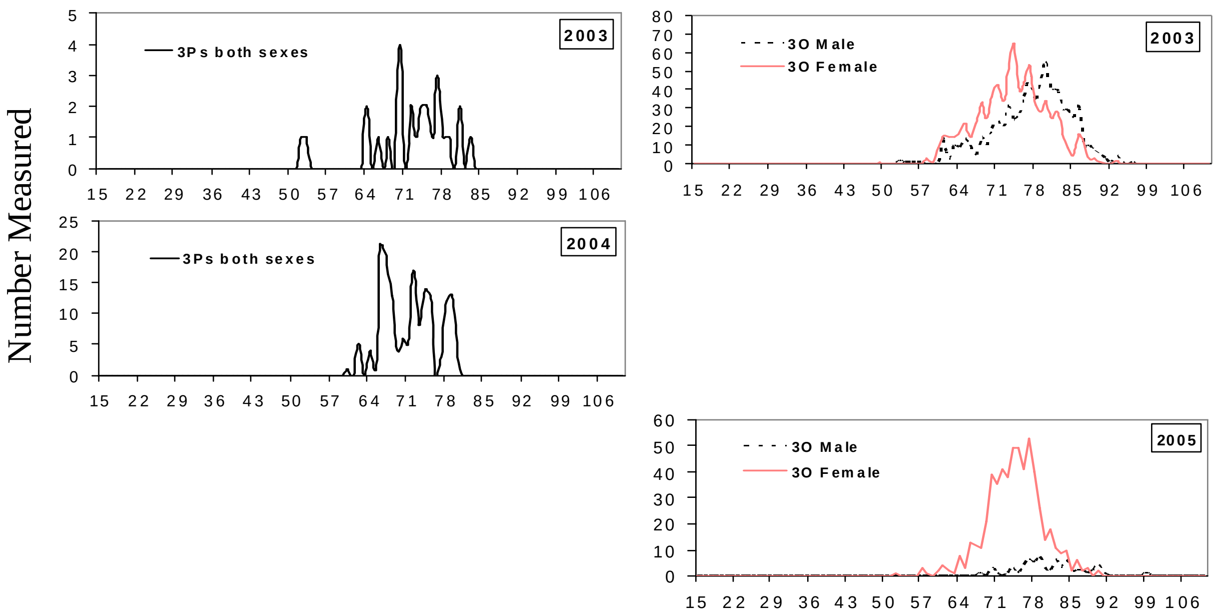


Fig. 23b. Length frequencies of Canadian commercial skate catches for gillnets in NAFO Div. 3OPs, 2003-2005. X-axis represents lengths of skate in centimeters. Data are from Canadian Fisheries Observers.

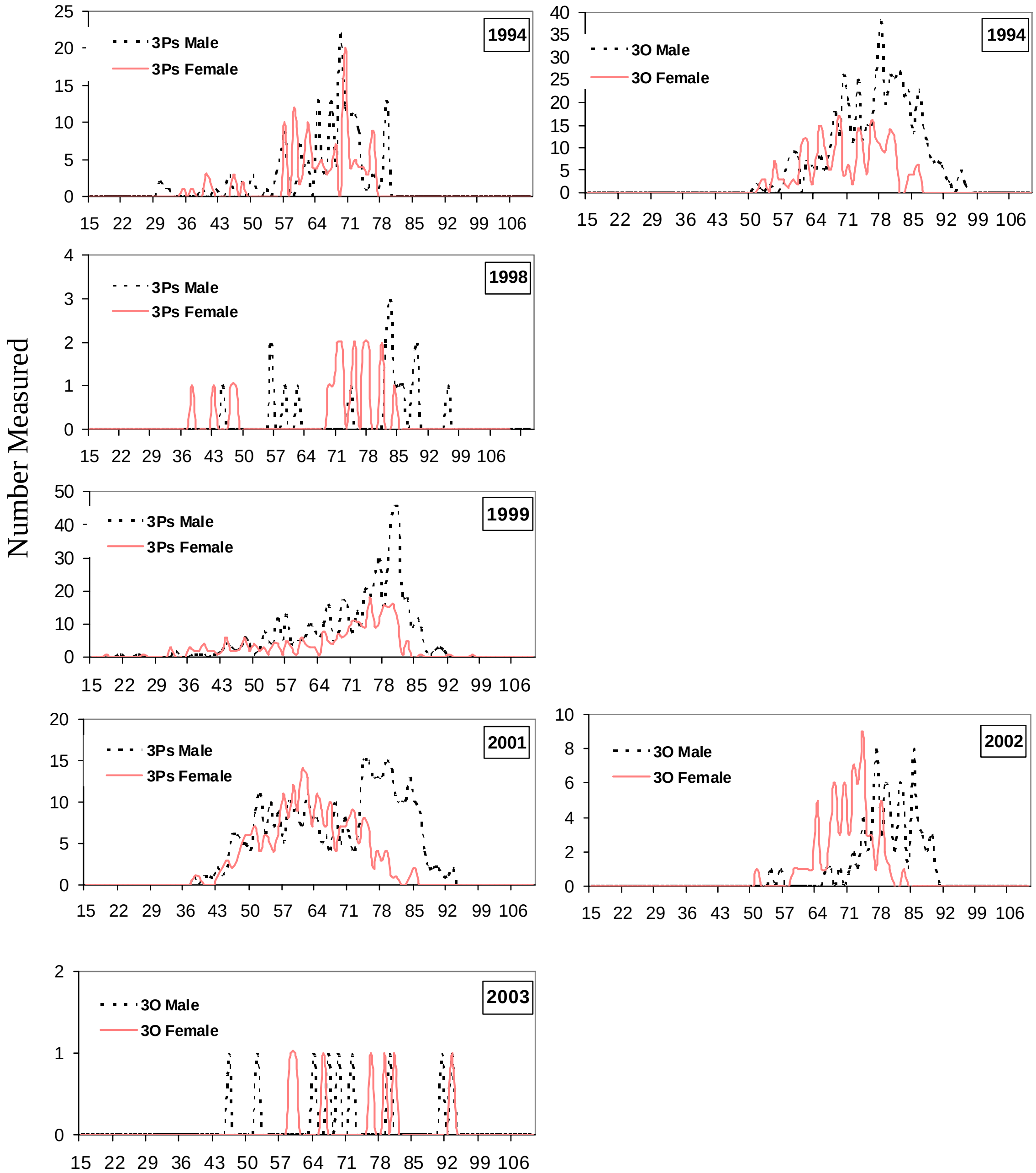


Fig. 23c. Length frequencies of Canadian commercial skate catches for trawls in NAFO Div. 3OPs, 1994-2003. X-axis represents lengths of skate in centimeters. Data are from Canadian Fisheries Observers.

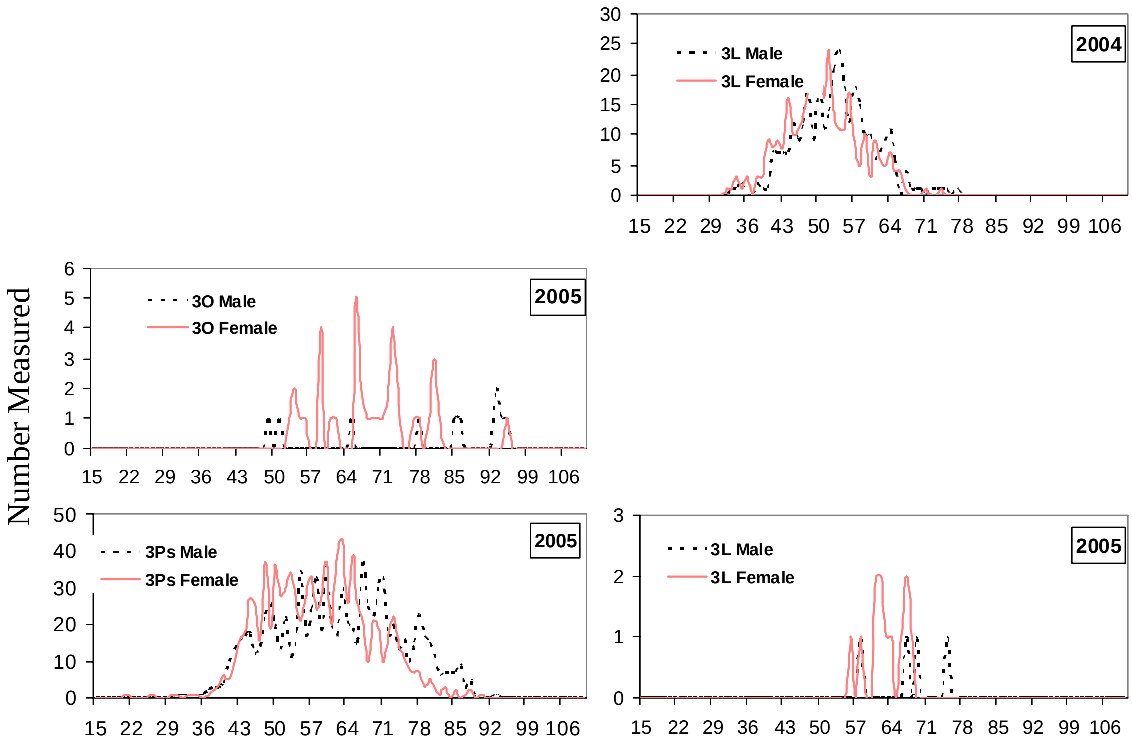


Fig. 23d. Length frequencies of Canadian commercial skate catches for trawls in NAFO Div. 3LOPs, 2004-2005. X-axis represents lengths of skate in centimeters. Data are from Canadian Fisheries Observers.

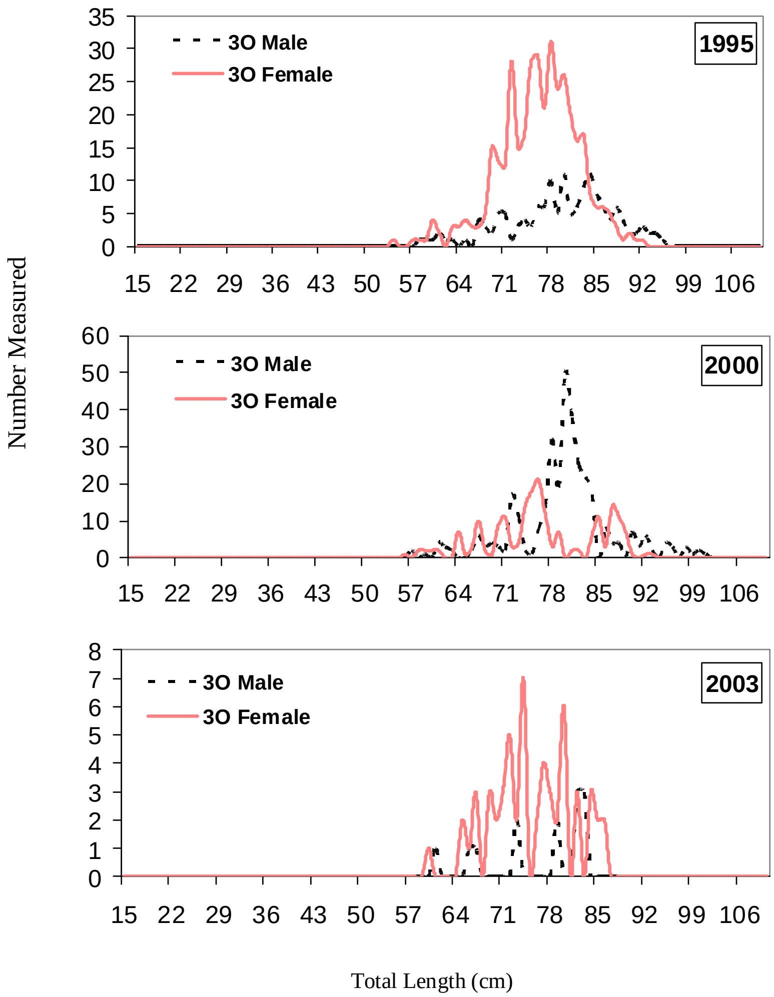


Fig.23e. Length frequencies of Canadian commercial skate catches for lines in NAFO Div. 3O, 1995, 2000 and 2003. Data are from Canadian Fisheries Observers.

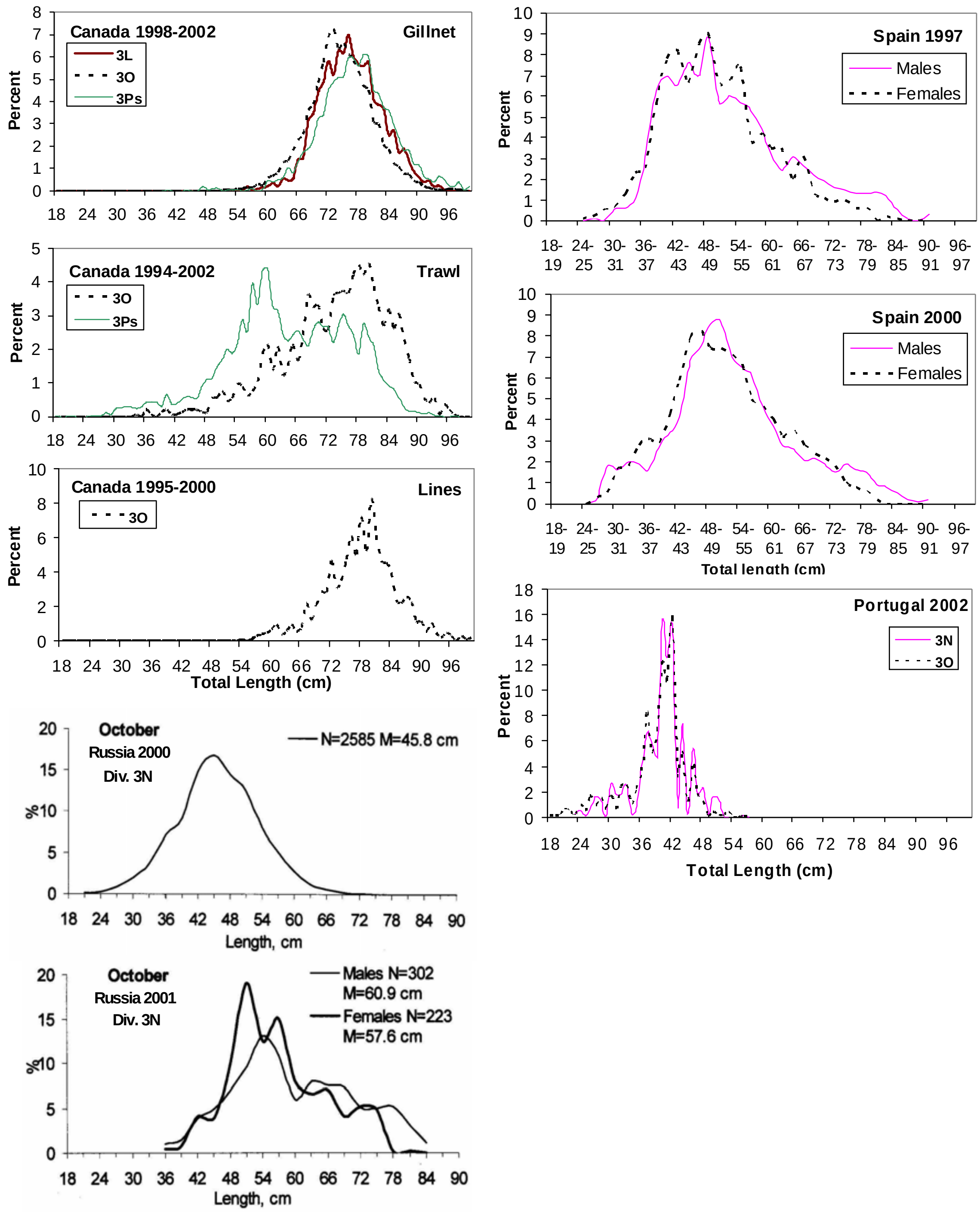


Fig. 23f. Length frequencies of thorny skates in commercial catches (Canadian data from Fishery Observers; Spanish data from del Río and Junquera, 2001; Russian graphs from Vinnichenko *et al.*, 2002; Portuguese data from Vargas *et al.*, 2003).

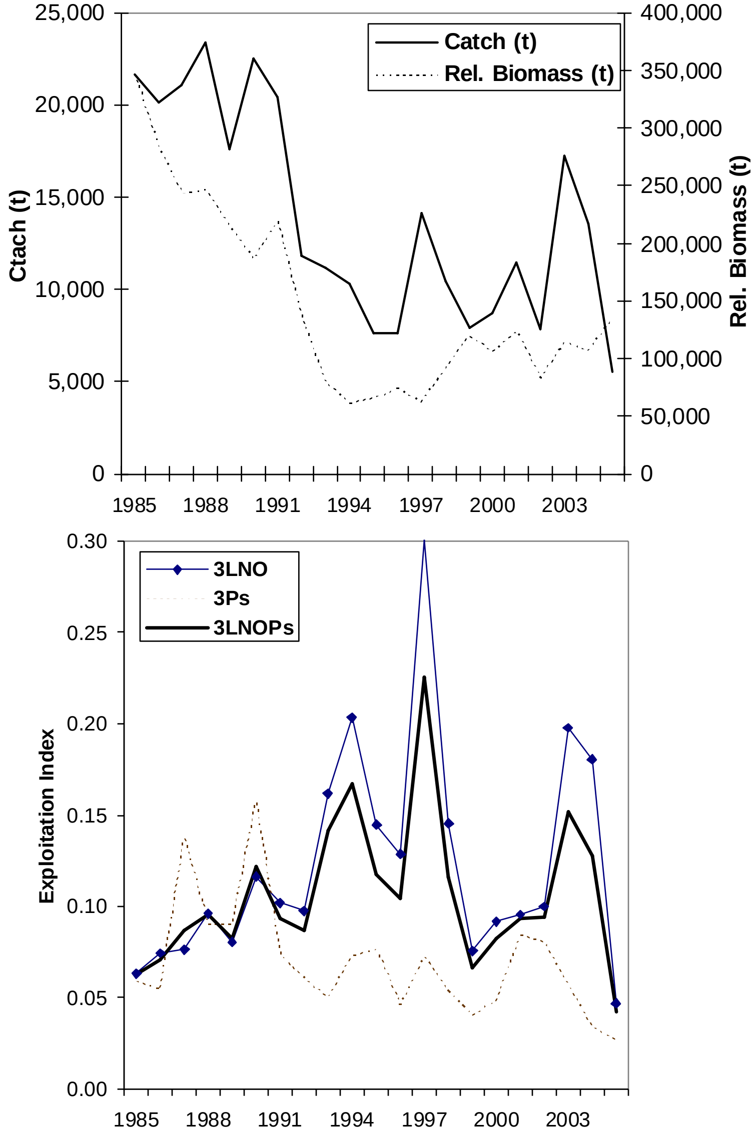


Fig. 24. Upper: Total catch and relative biomass in Div. 3LNOPs. Lower: Exploitation Index (total estimated catch/spring survey biomass index) for skate in Div. 3LNO3Ps, 1985-2005. Spring survey biomass indices converted to Campelen equivalents for 3LNO, 3Ps and 3LNOPs.

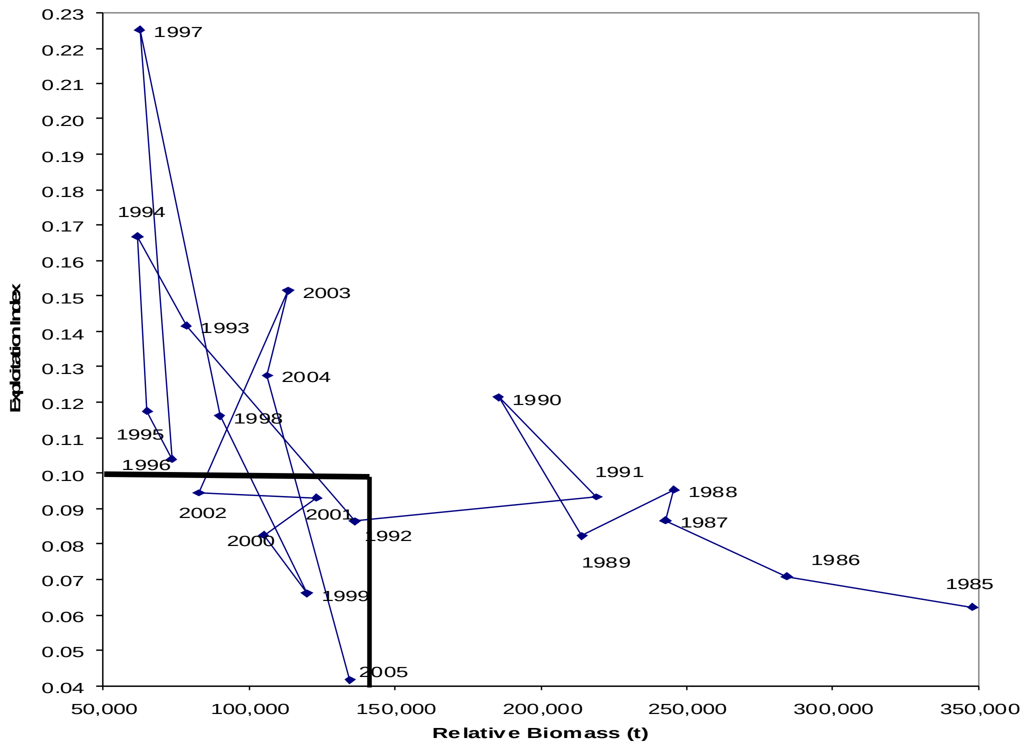


Fig. 25. Relative biomass vs relative *F* trajectory. The thick line shows point of inflection.

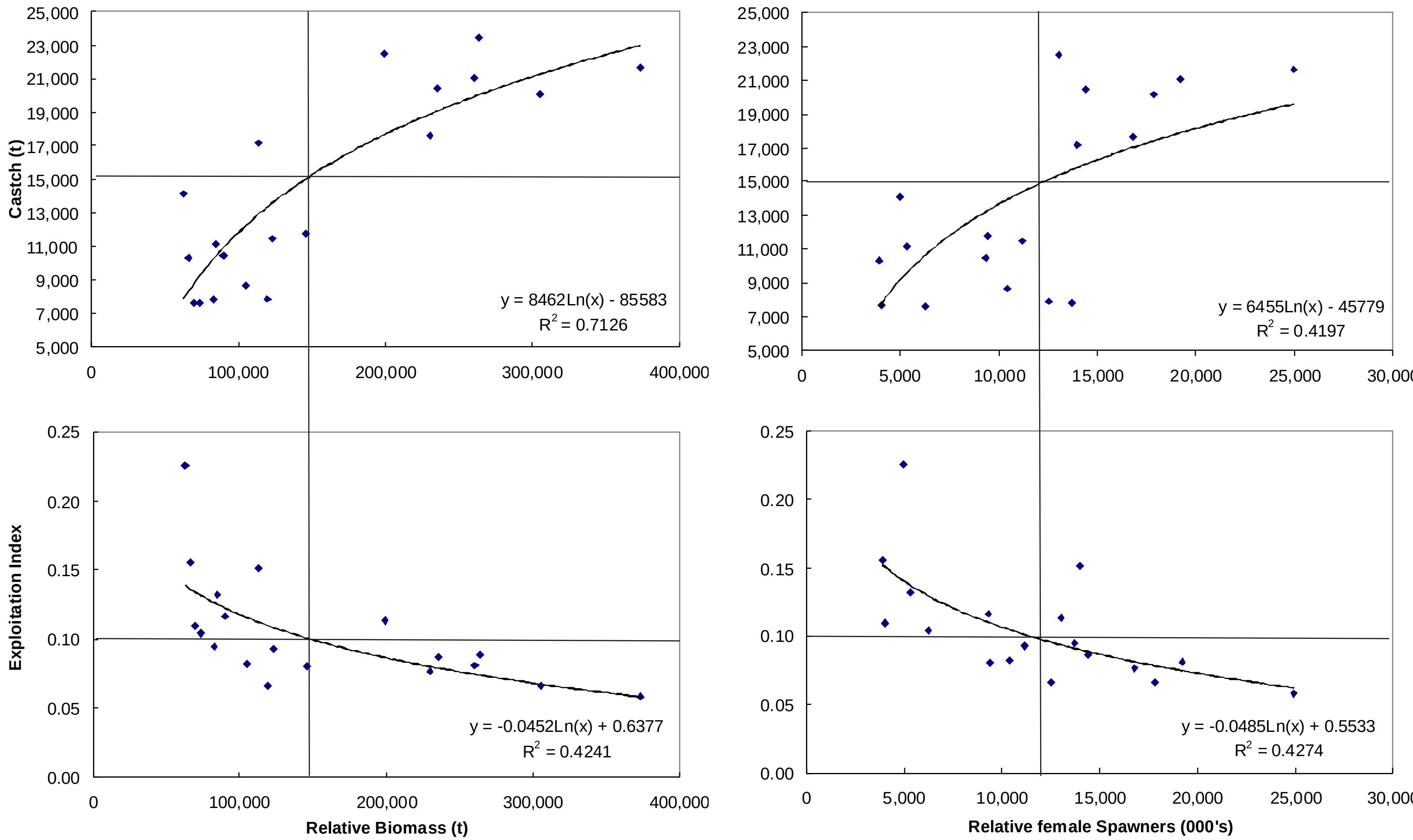


Fig. 26. Relationship between relative spring survey biomass and commercial catch (upper panels), and Exploitation Index (=total estimated catch/spring survey biomass index: lower panels). The X-axes on the left panels are total relative biomass; on the right panels are relative female SSB.

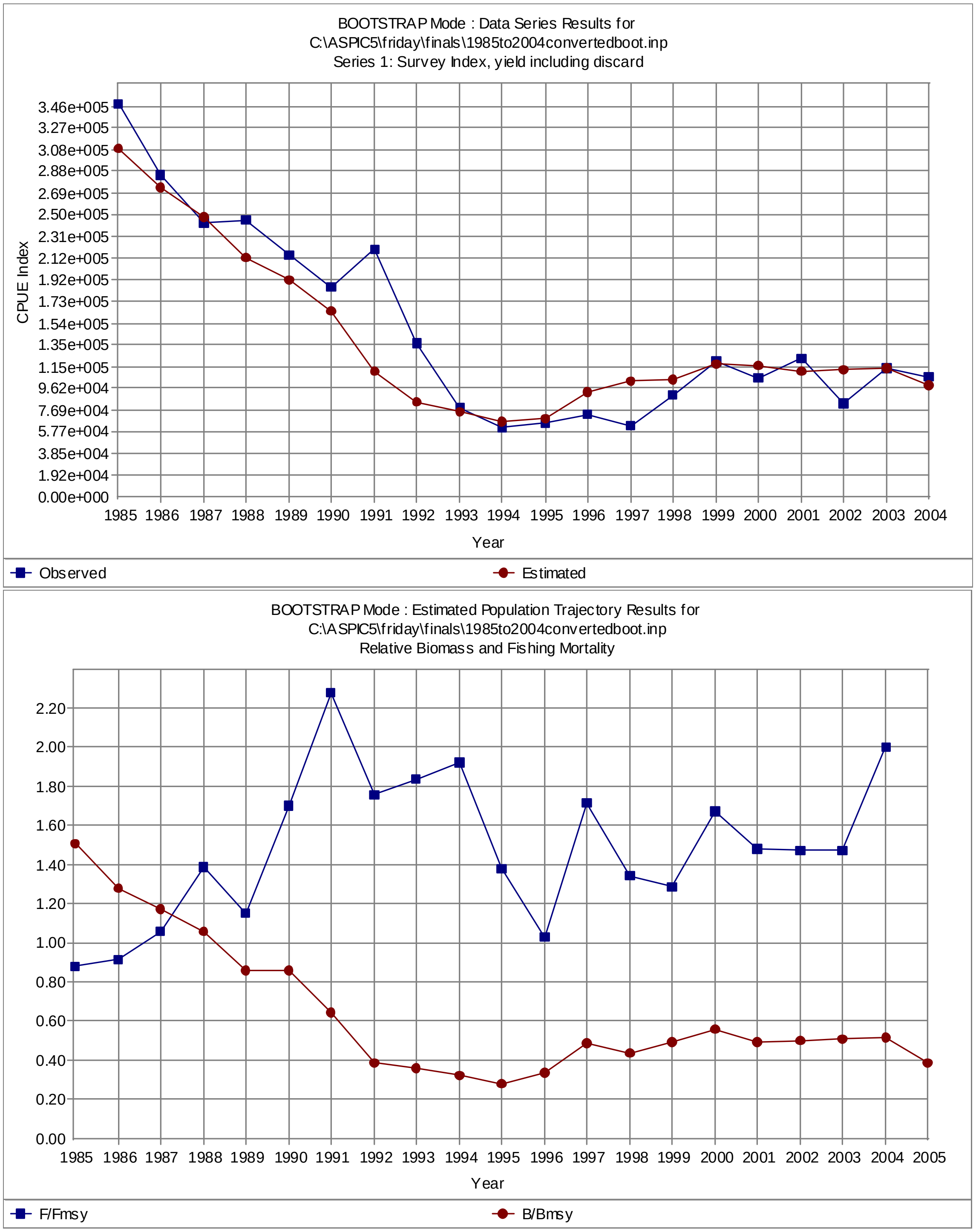


Fig. 27. Results of a non-equilibrium production model (ASPIC, Prager *et al*., 1994). Lower panel: Relative biomass (B/B_{MSY}) and fishing mortality (F/F_{MSY}). Upper panel: Observed survey index and fitted values (relative Biomass x 4). This analysis is based on spring survey data in Div. 3LNOPs Campelen equivalent, 1984-2004 (Run 4).

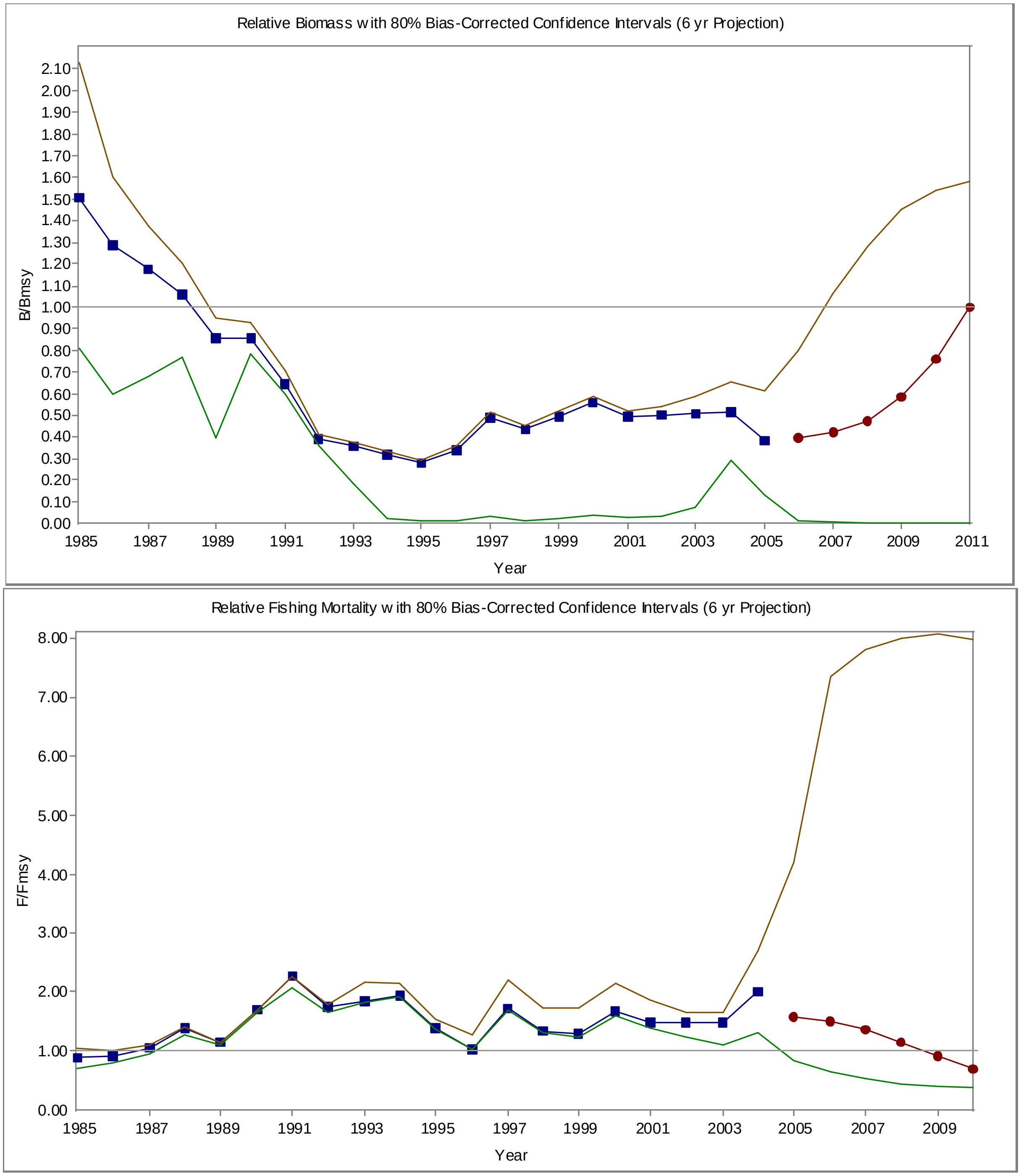


Fig. 28. Trends in *B/Bmsy* (upper panel) and *F/Fmsy* from a 6yr projection of the non-equilibrium production model (ASPIC, Prager *et al*., 1994). The projection is for 6 years using a catch of 11 000 as the predicted yield.

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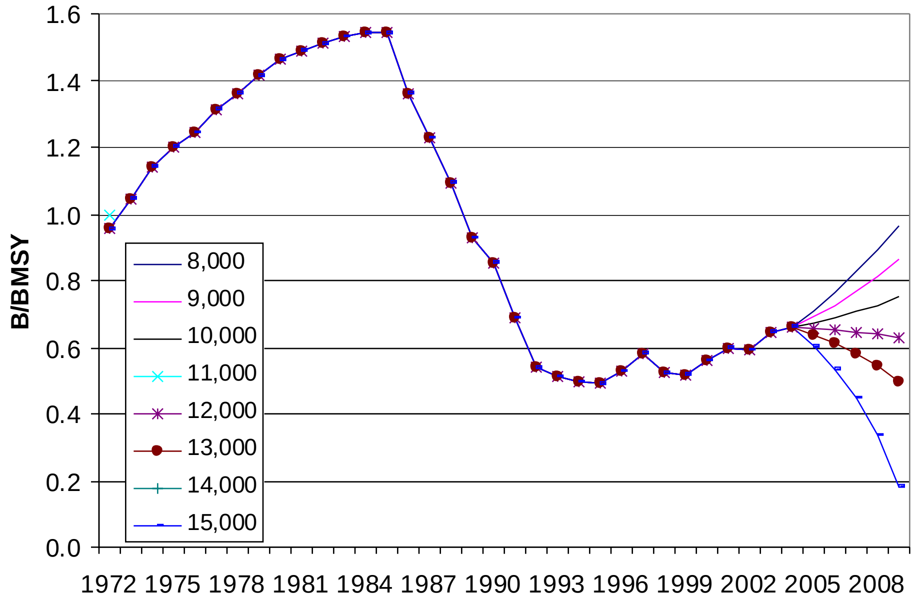


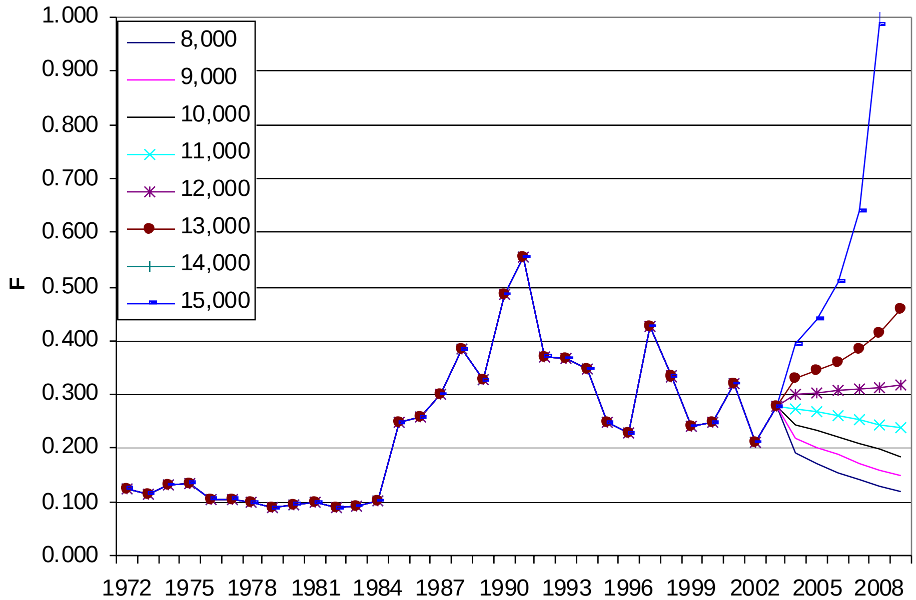
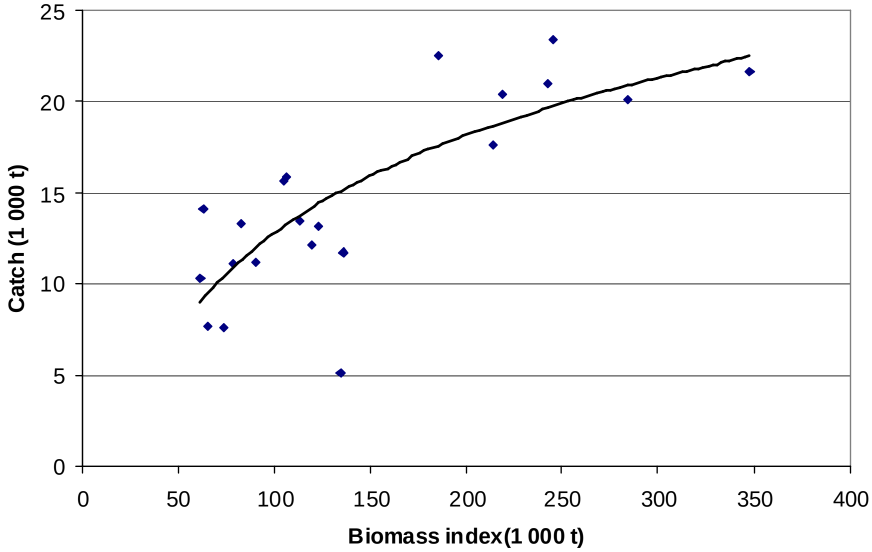


Fig. 29. Results of a non-equilibrium production model (ASPIC, Prager *et al*., 1994). Trends and projections in relative biomass (B/B_{MSY}) (upper panel).and fishing mortality (*F*) (upper panel) and This analysis is based on 32 years of spring survey data standardized to the Campelen series. The projection is for 6 years using the catch in 2003 as the predicted yield.



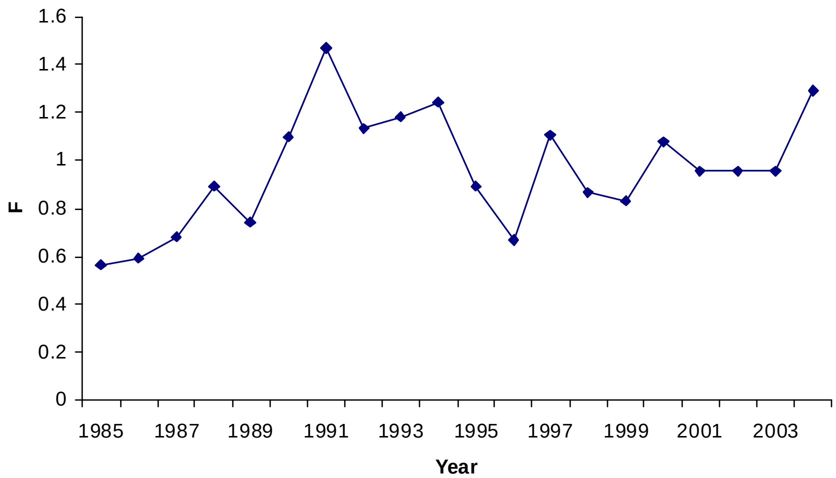


Fig. 30. Upper panel: Catch *vs*. Biomass (input for the ASPIC model). Lower panel: *F* calculated by the ASPIC model.