Fisheries and Oceans / Pêches et Océans

Canadian Stock Assessment Secretariat
Research Document 98/131

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 98/131

The Status of Thorny skate (Raja radiata), a non-traditional species in NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps

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ISSN 1480-4883
Ottawa, 1998

Canada

ABSTRACT

The exploitation of thorny skate has increased in recent years following the decline in the traditional groundfish resources in the waters around Newfoundland. Prior to 1994, skate in Canadian waters were taken only as bycatch, most of which were discarded. However with the establishment of a directed fishery for skate on the southwestern Grand Bank and southern St. Pierre Bank in 1994, domestic landings have averaged about 3,000 t annually. This paper represents the third assessment of this "new" fishery. This evaluation has shown that biomass indices, following a decline to their lowest historic level may have stabilized in recent years. However, a change in survey gear (in the fall of 1995) with different catch characteristics has created a discontinuity in the time series and prevents a comparison between the two periods. Survey data from the fall was examined for the first time. It was found that the spring survey previously used to estimate biomass and abundance may not include a substantial portion of the population. On average, fall survey estimates of biomass were 40% higher. In addition, differences in spring and fall distributions and seasonal change in bycatch rates of skate from Grand Bank slope fisheries suggests that thorny skate migrate toward the shelf edge in the winter, a portion of the population out of the surveyed area. They re-aggregate onto the bank in midsummer and throughout the fall. Analysis of lengths taken during the research surveys have covered a consistent range since 1985 with main modes occurring at 15 to 32 cm and 65 to 83 cm, the latter comprising mature fish. A recent increase in proportion of larger skates in the catches is noted. A spatial analysis of skate size shows a degree of segregation by size, the largest fish tending to aggregate along the southwestern shelf edge with a mix of sizes in the bank aggregation to the north. A comparison of distribution of skate from surveys data with commercial grounds shows that the Canadian fleet fishes about 1/3rd of the area of high concentration of skate in the spring, primarily along the shelf edge where the skate are largest. The Spanish fleet fishes a separate area on the Southeast Shoal outside 200 miles in the fall taking smaller fish. A relationship of both skate density and size with temperature and depth was observed, denser concentrations, in particular larger fish, were associated with warmer, deeper locations.

RÉSUMÉ

L'exploitation de la raie épineuse s'est accrue au cours des dernières années suite à l'appauvrissement des ressources traditionnelles en poisson de fond des eaux de Terre-Neuve. Avant 1994, les captures de raie en eaux canadiennes n'étaient constituées que de prises accidentelles dont la majorité était rejetée. Les débarquements canadiens de raie ont cependant atteint une valeur annuelle moyenne de 3 000 t environ suite à l'instauration, en 1994, d'une pêche dirigée de la raie dans la partie sud-ouest du Grand Banc et la partie sud du banc Saint-Pierre. Le présent document constitue la troisième évaluation de cette « nouvelle » pêche. Il y est montré que les indices de biomasse pourraient s'être stabilisés au cours des dernières années après avoir subi un déclin au niveau historique le plus faible. Par ailleurs, une modification de l'engin utilisé pour les relevés (à l'automne de 1995) et dont les caractéristiques de capture sont différentes a donné lieu à une discontinuité au sein de la série chronologique qui interdit d'effectuer une comparaison entre les deux périodes. Les données des relevés d'automne ont été examinées pour la première fois. Il s'est avéré que le relevé de printemps antérieurement utilisé pour estimer la biomasse et l'abondance pourrait avoir ignoré une partie appréciable de la population. En moyenne, les estimations de biomasse du relevé d'automne étaient de 40 % supérieures. En outre, les écarts entre les distributions de printemps et d'automne et des variations saisonnières des taux des captures accidentelles de raie par les pêches effectuées sur la pente du Grand Banc portent à croire que la raie épineuse migre vers la bordure du plateau en hiver et qu'une partie de la population pourrait donc être à l'extérieur de la zone du relevé. Les raies se regroupent de nouveau sur le banc à la mi-été et au cours de l'automne. L'analyse des longueurs déterminées pendant les relevés de recherche montre l'existence d'une gamme uniforme depuis 1995, les principaux modes se trouvant de 15 à 32 cm et de 65 à 83 cm, ce dernier groupe correspondant aux poissons matures. On a noté récemment une augmentation de la proportion des raies de plus grandes tailles au sein des captures. Une analyse spatiale de la taille des raies montre qu'il y a ségrégation par tailles, les poissons les plus gros ayant tendance à se concentrer le long de la bordure sud-ouest du plateau tandis que la concentration de banc située plus au nord est formée de poissons de tailles différentes. La comparaison de la distribution des raies obtenue des données des relevés avec celle des fonds de pêche commerciale montre que la flottille canadienne exploite le tiers environ de la zone de forte concentration des raies au printemps, surtout le long de la bordure du plateau là où les raies sont les plus grosses. La flottille espagnole exploite une zone distincte située sur le plateau sud-est à l'extérieur de la limite des 200 milles et y capture de plus petits poissons à l'automne. On a décelé un rapport entre la densité et la taille des raies, d'une part, et la température et la profondeur, d'autre part, les concentrations plus denses, notamment de plus gros poissons, étant liées aux zones plus chaudes et plus profondes.

INTRODUCTION

Historically, skate species (*Raja sp.*) were not considered a valuable commodity by the Canadian fleet. Until 1993, any skate taken by Canada were incidental to the catches of other groundfish, and were usually discarded. Most of the reported catches of skate prior to 1994 were attributable to non-Canadian fishing effort outside 200 miles (Fig. 1). However, as a result of increased foreign effort, reported catches increased sharply in 1985 and have been substantial since. Junquera and Paz (1998) noted a shift in Spanish effort to the exploitation of non-regulated species, particularly for skate, in the early 1990's.

A lack of interest in skate by Canada was due to the abundance of more lucrative species and no domestic markets. However, limited amounts of wings were exported to European countries in the 1970's indicating that some skate were landed for commerce in the past. Kulka (1989) reported that in the early to mid-1980's, about 3,000 t of skate were taken annually as bycatch in the Canadian offshore fisheries. Significant amounts of skate landings first appeared in the Canadian statistics in 1993 and 1994 the result of experimental fishing. Since 1995, Canada has directed for skate in a regulated fishery on the Grand Banks (Kulka et *al.* 1996) and the Scotian Shelf (Simon and Frank 1996) inside 200 miles, in addition to the non-regulated fisheries outside 200 miles (Fig. 1).

Commercial skate catches constitute a mix of species. Thorny skate (*R. radiata*) dominates in most areas and comprises more than 95% in the directed fishery on the Grand Banks, although historically, skate bycatches from trawls have contained a more diverse species mix. Kulka et *al.* (1996) noted that offshore trawl bycatches of skate in the mid-1980's from the Northeast Newfoundland Shelf and the Grand Banks comprised about 20% of species other than thorny. Due to its prominence in the catches of the directed fishery, this paper focuses on the status of thorny skate on the Grand Banks in NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps comprising the Grand Bank, Whale Bank, St. Pierre Bank and a series of channels separating them. The area, shown in Fig. 1 is hereafter referred to as 3LNOPs.

Simon and Frank (1995) and (Atkinson, 1995) published the first assessments for skate in NAFO Divisions 4VsW (Scotian Shelf) and 3LNOPs respectively. This paper follows on these and the most recent assessment of the 3LNOPs skates by Kulka et *al.* (1996). It contains a review and update of biological and fishery data necessary for an assessment of the stock. It does not include a virtual population analysis (VPA) for estimating stock size for three reasons: 1) data from research vessel surveys are not age dis-aggregated, 2) biological sampling of commercial catches continues to be inadequate for VPA or most other traditional stock assessment methodologies, and 3) landings for this species are thought to have been consistently under-reported, particularly prior to 1994.

We have chosen to present a comprehensive review of the biological information and abundance indices available from groundfish research surveys from 1985-1997 as well as an analysis of the dynamics of thorny skate distribution. We compare spatial and temporal characteristics of the fishery with the distribution of skate. Reasons for undertaking such an approach are two-fold. Since this is a relatively new fishery, it is particularly important to understand how the allowable catch is being taken in relation to the spatial distribution of the species. In this manner it is possible to identify what particular size groups are being targeted. In the absence of adequate commercial sampling, a demonstration of size dependent spatial distribution from research survey data coupled with commercial fishery catch locations is perhaps the only way to identify what part of the stock is being targeted by the fishery. The consequences of these removals on the stock are considered. It is expected that this work can provide some clues for further refining fishery management aspects. These types of analyses can also serve industry by providing information on distributions that could lead to an improved exploitation strategy while safeguarding important ecological areas. A review of fishery regulations and recent catches (1985-1998) are also provided. Reliability of reported catches is discussed.

Review of the Biology

Thorny skate is a boreal to arctic species distributed in both the eastern and western Atlantic, from Greenland to South Carolina on the western side. Skate distribution in the North Sea has been reported by Shreman and Parin (1994). On the Northeast Newfoundland Shelf, the Grand Banks and the Scotian Shelf, it is widely distributed but most highly aggregated on the southern Grand Bank and eastern Scotian Shelf. (Kulka et *al.* 1996, Simon and Frank 1996). In Canadian waters, it has been taken in a wide range of depths, near shore to as deep as 1700 m in commercial fisheries although it is found at its greatest density along the outer parts of the banks (Kulka et *al.* 1996). In the western Atlantic, thorny skate is found in -1.4 to 14^0 C on both hard and soft bottoms (McEacheran and Musick, 1975).

Thorny skate is either dominant or an important component among about nine skate species within its range. It was the most common species on the Grand Banks and Northeast Newfoundland Shelf, comprising greater than 90% of skates caught in research surveys in these areas. The second most common species from the Grand Banks and areas north, smooth skate (*R. senta*) comprised about 5% of the catch while other species were taken only occasionally. Spinytail (*R. spinicauda*) and Barndoor (*R. laevis*) skate, two deeper water species were also common in commercial offshore catches of the 1980's (Kulka et *al.* 1996). Winter skate, the most common species on the Scotian Shelf (Simon and Frank 1996) is only taken occasionally in survey or commercial gears on the Grand Banks.

Prior to 1991, thorny skate was found to be more widely and continuously distributed than at present (Kulka et *al.* 1996). Moderate to high densities covered much of the Grand Banks and onto the Northeast Newfoundland Shelf as far north as Lat. 50^0. A contraction in the distribution took place in the late 1980's and early 1990's and after 1991, high concentrations were restricted to a much smaller area south of Lat. 47^0. Kulka et *al.* (1996) also noted that male and female size had declined, particularly during the period 1986-1990. These changes were concurrent with the period of spatial contraction and decline of many other groundfish species (Atkinson 1993) and an increase in fishing effort on the Grand Bank, outside 200 miles.

A number of studies were published, mostly in the mid-eighties, on the biology of thorny skate. Topics covered include: migration and abundance (Templeman 1984a), length/weight and morphometrics (Templeman 1984b, 1987a), egg development (Templeman 1982a) and feeding both on the Grand Banks (Rodriguez Marin et *al.* 1994 and Templeman 1982b) and in the Barents and Norwegian Seas (Antipova and Nikiforova 1983, 1990, Berestovskiy 1989a, 1989b.

The exact life span of thorny skate in Newfoundland waters is not known as there has been no attempt to age this species. Preliminary ageing and maturity studies for winter skate on the Scotian Shelf (Simon and Frank 1996) suggests that 50% are sexually mature at lengths of 65-70 cm corresponding to ages of about 6-7 years. Templeman (1987b) showed that thorny skate on the Grand Banks mature at somewhat smaller sizes, between 55-60 cm. Based on the time between tagging and recapture of some thorny skate individuals, it is known that they can live at least 20 years (Templeman 1984a). They deposit between 6 and 40 egg cases a year, each containing a single embryo. Larger skate produce larger eggs, (Templeman 1982, 1987b), however it is not known if egg case size is related to survival rate. Templeman (1987b) reported that male skate in 3LNOPs mature at smaller sizes (68-83 cm) than females (65-74 cm) and size at maturity increases from north to south. Templeman (1984b) reported considerably larger sizes at maturity in 3LNOPs compared to areas north. Based on Templeman's (1987b) data, Atkinson (1995) also noted that female thorny skate in Divisions 3L and 3N (northern part of the Grand Banks) mature at a slightly smaller size than those further south and west in 3O and 3Ps. Limited data suggest that reproduction occurs year round on the Grand Banks.

Stomach analyses suggested that thorny skate feed on a variety of items including both invertebrates and fish (Rodriguez, Marin et *al.* 1994 and Templeman 1982b). Invertebrate food items include marine worms, crabs and whelks. Fish prey, increasingly important in the diet of larger skate includes sculpins, redfish, sand lance and haddock. Significant amounts of offal have been found in the stomachs of skate captured in the vicinity of commercial fishing activity. This and their anatomy (mouth located on the ventral surface) suggests that they are opportunistic bottom feeders. Limited information on predators of thorny skate around Newfoundland shows that they have been recorded as a food item in the diet of seals, sharks and Atlantic halibut.

In spite of the work cited above, much remains to be learned about thorny skate stock structure and life history. This paper in conjunction with the assessment of the current status of the stock focuses on the population and distributional dynamics.

METHODS

Research vessel survey data

Data on skates have routinely been collected during research surveys in waters around Newfoundland. A summary of the stratified-random survey design adopted after 1970 by the Newfoundland region can be found in Doubleday (1981). While survey design has remained constant over the time, strata have been added to the survey area in recent years along with modifications to some of the original strata. An accounting of these modifications can be found in Bishop (1994). Also, there was a change in survey gear after the spring 1995 survey, from Engels 145 to Campelen 1800 bottom trawls. Conversion factors for amounts and sizes of fish caught were derived for the major species but not for skate. Thus, the catch rate data and resulting biomass and abundance indices are at a different scale. This gear change also affected selectivity by fish size. The change in gear is delineated on the various tables by a dashed line and on figures by a vertical bar. Either a CTD, BT, or XBT hydrographic sampling device was used to record bottom temperatures at all tow locations. These data were used to examine the relationship between skate distribution and temperature.

Trawl data from both spring and fall stratified random surveys in Divisions 3LNOPs (3Ps not surveyed in the fall) were used to estimate biomass and abundance and examine trends in average size (biomass/abundance) of the skate from 1985 to 1998. STRAP (Smith and Somerton 1981) was used to estimate biomass and numbers of fish by areal expansion within a series of pre-defined strata related in part to depth. These strata estimates are then added over the survey area. Recently, extra sets, not part of the standard surveys, have been added to some strata as part of a diurnal study. These represent a deviation from the proportional allocation of sets, but do not differ in sampling protocol. The diurnal sets are included in all STRAP estimates.

The surveyed area changed in extent over the years, primarily due to the addition of inshore and deepwater strata. Also, modifications have been made to the boundaries of some of the original strata based on changes reflected in revised hydrographic maps. Biomass, abundance and mean weight indices are provided for two sets of strata. The 'core' estimate uses only strata that have been consistently surveyed over time, while the 'all' estimate includes the new strata as well. Using all strata, the area surveyed in 1996-98 was 294,589 km^2, in 1994-96 was 283,321 km^2 and from 1986-93 was 255,542 km^2 (Bishop 1994).

An estimate of biomass for 1995 to 1997, spring and fall was also calculated using the SPANdex (SPANS index) method (after Kulka et *al.* 1996, methods detailed in Kulka 1998). This method, employing potential mapping (Burke 1997) transforms points to fish density surfaces by placing a circle around each point and averaging the values of all points that fall within the circle.

The circle size selected (38 km diameter) provided the most complete coverage of the survey area, minimizing gaps in the density surface and maximizing spatial resolution. The study area periphery was defined using a 'cookie cut' technique (referred to as a basemap cut in SPANS). This resulted in a density surface bounded on all sides by either land, the 1000 m depth contour or the 3L/3Ps (Sub)division lines . This resulted in a survey area similar in size to the cumulative size of the STRAP strata. However, occasional gaps (resulting in a slightly smaller survey area) still occurred in the density surface when distances between adjacent survey sets exceeded 76 km. Refer to Kulka (1998) for details of the mapping method as it applies to survey and fisheries data. The resulting density map was then post-stratified into 15 classes, each covering approximately the same amount of area. Mean catch rate within each density strata was calculated as described in Kulka (1998).

SPANS was also used to investigate the spatial distribution of thorny skate from research vessel survey data (Campelen sets, 1995 to 1998, spring and fall). For this analysis, the same data were used as for the estimation of biomass/abundance plus additional Campelen sets from special surveys in Div. 3Ps in August. These extra sets were grouped with the fall data. Catch rates (kg per standard tow) for individual sets (point data) were converted to surfaces (classified maps) depicting fish density using potential mapping. For the resulting maps, black areas represent the highest density of skate (highest catch per tow) fading to light grey, the lowest. White areas depict no catch. Density distributions were plotted for the spring (1996 to 1998 combined and separate years) and fall (1995 to 1997 combined and separate years). The strata class bounds (catch per tow legend values) were held constant across years (a single legend for all years) so that varying amounts of each grey shade displayed depicting a density level would vary, reflecting relative changes in density.

Distribution by sex and maturity stage were also investigated using this extended set of survey data. Templeman's (1987a and 1987b) reported on size at maturity and length-weight relationships for thorny skate sampled from 3LNOPs between 1947 and 1972. Generally most skate less than 60 cm were immature while those greater than 60 cm were primarily mature. Using these maturity criteria, Templeman's length/weight regressions were applied to the sexed length frequencies from each set in the survey to obtain catch weights by sex and maturity stage. However, this estimation could only be made for the 65% of survey sets where skate were measured in 1995-1997. Thus, skate length frequencies were not available for all survey sets as used in the distribution analysis. The weights of these two classes of skate from each set were transformed to density surfaces and compared between seasons and sexes. Similarly, bottom temperature maps were created for both the spring and fall period using 15 strata of equal size varying from –1.4 to 5.6+ ^{0} C.

Skate taken during the research cruises were usually identified to species and in approximately 60% of the sets, measures of total length were taken. Since skate catches were usually small, in nearly all cases when length measures were taken, the entire catch was measured. No measures of wing width or maturity stages were done. Length frequencies of catch were plotted by NAFO Division, survey period and year from 1986 to 1997. These length frequencies reflect only the catch of sampled sets. They have not been weighted by strata area or extrapolated to survey abundance estimates.

Fishery data

Information on skate removals in Canadian waters was obtained form three sources. Canadian landings were compiled using statistical records contained within the Zonal Interchange Database (ZIF). Data were summarised by gear, area and month for 1985 to 1997. Discards from domestic fisheries in Canadian waters were calculated by applying the proportion of skate catch to groundfish landings (kept fish, all species) in the observer database to the reported landings of groundfish in ZIF files. These were then summarised by division and year. Also, skate catch (kept plus discards) of foreign vessels in Canadian waters were extracted from fishery observer reports. Observers have been placed on nearly all foreign vessels fishing in Canadian waters.

Foreign catches outside 200 miles reported herein are Canadian surveillance (Conservation and Protection) estimates. Surveillance estimates are used since there has been some concern about the accuracy of the reported foreign (NAFO) catches of skate. Conservation and Protection has suggested that during the 1980's, in some years up to about 60% of the reported skate catches may have actually been misreported catches of other species. Surveillance estimates for 1992 to 1995 were lower than the NAFO reported catches for those years. In subsequent years, Surveillance estimates have exceeded NAFO figures

Since the start of the directed skate fishery in 1994, fishery observers have been deployed to cover approximately 8% of the domestic fishing. Observers collected set by set information on catches as by the methods described in Kulka and Firth (1987). This observer information was used to examine distribution of fishing effort and catch rates. The potential mapping method described above was used to create distribution maps of the observed fishing activity (catch rate over area by gear). Fishing grounds were compared to distribution of skate as determined from research vessel surveys.

Limited samples of wing widths of skate from the catches of the directed fishery were compared to the fish sizes caught in the research surveys.

RESULTS AND DISCUSSION

Biology and Distribution

Spring and fall survey biomass indices derived using the STRAP method are presented in Fig. 2 and 3 and Table 1. In both seasons, biomass and abundance estimates for 'core' and 'all' strata were nearly identical (Table 1a and 1b). The fall series, analysed for the first time does not include data from Subdiv. 3Ps for any year or from Divisions 3N and 3O before 1990. Thus, they are not comparable to the spring results over the entire area and time. Since the fall series was not complete, spring surveys were used to examine biomass and abundance trends.

The spring index shows a declining biomass over the entire area from 1986 to 1994 culminating in the lowest values in the time series. Previously, Kulka et *al.* (1996) had shown that the biomass was in decline from about the late 1970's as reflected by declining (5 year averaged) catch per set from the spring surveys. Unlike earlier years, (i.e. prior to the mid-1980s) when a much larger proportion of skate was found in Div. 3L and northern 3N, most of the biomass is now located in NAFO Divs. 3O and 3Ps. These distributional changes are similar to the spatial contraction experienced by many groundfish species in synchrony with declines in abundance (Atkinson 1993). This decline in biomass could also relate to an increase in fishing effort outside 200 miles on the Grand Bank since 1984. However, an examination of the distribution of the commercial fishery effort found no evidence of disproportionately higher levels of effort in 3K and 3L (Kulka et al. 1996) as would selectively deplete skate in these areas as opposed to farther south. This contends with links between distribution of commercial catches (of cod) and regional stock depletions due to fishing effort hypothesized by Hutchings and Myers (1994) as the primary cause of the decline of that species during a similar period of spatial contraction. As with other Newfoundland groundfish species, it remains unclear what part of this decline in skate stock can be attributed to fishing mortality as opposed to natural mortality related to environmental pressures. Simon and Frank (1996) have shown that thorny skate on the Scotian Shelf has also declined since 1982.

In both spring and fall, the decline in biomass since 1986 was most pronounced to the north in Div. 3L and 3N (Fig.2 and 3). The reduction observed in Div. 3O and Subdiv. 3Ps was less severe and the biomass there appears to have stabilized since about 1993. Considering the high degree of variance associated with the STRAP estimates, it is not possible to judge whether the small differences in the estimates observed between 1993 and 1995 represent actual changes in biomass. As well, the change in gear from Engel to Campelen in the fall of 1995 (time of change illustrated by a dashed line in Table 1) makes it difficult to compare relative biomass between the two periods. Gear conversion factors calculated for the major species (but not for skate) indicated a substantially greater catchability for the Campelen trawl. Applying a catchability conversion factor of 2.2 to skate biomass estimates from Campelen surveys (as was done for cod) would suggest a fairly stable biomass since 1993. However, given the observed behaviour of skate when encountering survey gear (Walsh 1992) it is probable that a conversion factor for skate may be quite different than that for cod.

For comparable years and areas, the spring and fall survey estimates of biomass showed similar trends although fall estimates were consistently higher. The fall survey data, not previously examined may be a better estimator of skate biomass in Divisions 3LNO. The observed differences in biomass between the two periods are considered in the context of seasonal distributional changes described below. Abundance (Fig. 3) follows a somewhat similar pattern between seasons although the decline in numbers seems to extend to 1995. This was due to an increase in average size of skate in recent years coupled with the slight decline in numbers.

Walsh (1992) conducted escapement experiments for Engels gear that looked at skate and three other species on the Grand Bank. He noted that unlike cod, plaice and yellowtail, escapement from nearly all sizes of skate was high. Maximum catching efficiency for thorny skate for sizes above 35 cm was about 40% (typically about 80% or more for large sizes of the other species). For all species tested, Engels gear was observed to be least efficient for capturing skate, particularly larger sizes. Skate of all sizes were observed to escape beneath the footrope. Thus, the estimates of biomass and abundance derived for skate from research surveys must be viewed as minimum values. Similar experiments have not been carried out for Campelen gear. However, a sudden increase (about double) in the estimates of biomass, both spring and fall after the changeover in survey gear suggests that Campelen is more efficient in capturing skate (refer to Fig. 2). Unlike most other groundfish species, there was little change in terms of the size composition between gears (refer to discussion of sizes below).

Biomass was also calculated using the SPANdex method for years where Campelen gear was used. These calculations were useful for examining more detailed spatial aspects of skate density than can be done for STRAP where strata are not necessarily related to fish density. It also allows for the incorporation of summer (August) redfish survey sets that are not part of the standard random stratified series used in STRAP. Table 2 shows the SPANdex indices of biomass and includes details of the calculations by density class. Estimates were not separated by NAFO Division. For the spring (Table 2a), estimated biomass for 1996 and 1997 were nearly identical at just over 90,000 t. These numbers are somewhat higher than the 1996 (73,383 t) and 1997 (62,670 t) spring estimates from STRAP (Fig. 4), despite a slightly smaller survey area (348,000 and 340,000 km^2 for SPANdex vs. 370,000 km^2 for STRAP). For the fall, two estimates were done; one that included the sets done in August in Subdiv. 3Ps on the western side of St. Pierre Bank and in the Laurentian Channel (Table 2b) that were not part of the random stratified survey, and one that excluded these sets (Table 2c). Sets from Div. 4Vn (that appear on the distribution maps) were also excluded from this analysis. The latter estimate, without 3Ps sets was done to make it comparable to STRAP estimates for the same time period. A comparison of STRAP and SPANdex estimates (Fig. 4) shows that the SPANdex estimates were slightly higher for Divs. 3LNO. Including non-standard sets from Subdiv. 3Ps in the Laurentian Channel and the western slope of St. Pierre Bank increased the estimates substantially, ranging from 128,760 t in

1995 to 211,899 t in 1997. These numbers are more than double the spring estimates of STRAP and SPANdex, further evidence that the spring survey underestimates the biomass of skate.

The SPANdex analysis shows that about 75 to 80% (85% for spring 1997) of the biomass was concentrated within 20% of the area in 3LNOPs (Figure 5). Thirty percent of the survey area contained little or no biomass, mostly adjacent to the Avalon Peninsula where bottom temperatures were the coldest (refer to discussion of distribution with respect to temperature below). This degree of aggregation is slightly higher than was calculated for two other species, cod in Divisions 2J3KL (Rose and Kulka 1998 and Kulka 1998) and shrimp on the Labrador Shelf. Similar to skate, in 1983-1988, 64-75% of the cod biomass occurred in 20% of the habitat. In contrast, during the decline of northern cod (1989-1991), hyper-aggregation (87 to 89% in 20% of the area) was observed. This hyper-aggregation did not appear to occur during the decline of the skate. Skate aggregation levels are also similar to the 70 to 80%, post-decline cod aggregation levels and those observed for shrimp in recent years (unpublished data).

Concurrent with the declining biomass of thorny skate, particularly in Divisions 3LN, there has been a steady decline in the average size of skate (Fig. 6 and Table 1). Simon and Frank (1996) reported a similar decline in numbers of larger individuals of thorny skate on the Scotian Shelf (1970 to early 1980's). A reduction in average weight in 3LNOPs was observed in both spring and fall, but was more pronounced in the spring. During the mid to late 1980's, the average weight of skate (spring surveys, all areas) was about 1.75 kg, equivalent to an average total length of about 58 cm and a wingspread of 43 cm (refer to Table 3 after Atkinson 1995 for conversions). In Div. 3O, the average weight fluctuated at around 2 kg until 1993 then dropped to about 1.5 kg thereafter. In 3L, decline in size was greatest from just under 2 kg in the late 1980's to less than 0.5 kg by 1992 (stable thereafter). Size was slightly larger in Div. 3N fluctuating between 0.5 and 1 kg after 1990. The fall sizes in Div. 3L declined steadily but less dramatically from 1.5 kg in 1986, stabilizing at about 0.5 kg after 1992. Since the commencement of surveys in Divs. 3NO in 1990, size in Div. 3O was observed to fluctuate from around 2 kg then 1.5 kg after 1994, similar to what was observed in the spring. In Div. 3N, the fall trend was similar to what was observed in the spring, except that the fish were slightly larger. Recently, in all areas and seasons, size appears to have stabilized or has increased slightly. In the most recent period, 1996-1997, average size in Div 3L was 0.55 kg (total length and wing width of 39 and 29.8 cm or 15.2 and 11.6 in), in Divs. 3NO, 1.15 kg (total length and wing width of 50 and 37 cm or 19.5 and 14.7 in respectively) and 1 kg (total length and wing width of 49 and 36.5 cm or 19.3 and 14.4 in) in Subdiv. 3Ps. The effect of changing from Engels to Campelen gear on most groundfish species was a reduction in average size due to increased catchability of smaller fish for the smaller meshed Campelen gear. As discussed above, this apparently is not the case for skate.

Length composition of thorny skate by year (1986 to 1997) by NAFO Division is presented in Fig. 7a for the spring and Fig. 7b for the fall period. By area, the shapes of the frequencies were generally similar between spring and fall. A large range of sizes were present ranging from about 11 to 101 mm and this range varied little from year to year. There was some inter-annual variation in the mix of sizes. Also, the observed peaks usually but not necessarily match among areas within a given year. For most areas and years, the largest peak occurred between 23 and 29 cm with secondary peak at 15-17 cm, sometimes merging with the 23 to 29 cm mode. A peak of large (mature) fish ranging from about 65 to 83 cm is apparent particularly from 1986 to 1989.

Large fish, until 1990 were also found in Div. 3L. These large fish are nearly absent across all areas in 1992-94 then increasing after 1994. Templeman (1987b) showed an L_{50} maturity (size at 50% maturity) at about 68 cm (2.7 kg) in 3LNOPs for the period 1947-1972. The increase in proportion of fish greater than 65 cm since 1995 points to the re-appearance of mature fish in the population in recent years. Most of these larger fish were located in Div. 3O and Subdiv. 3Ps although some were found in all areas. These larger fish were a more significant part of the catch after 1994 despite the change to Campelen gear that was shown to capture a larger proportion of smaller sizes of some other groundfish species.

Survey set catch weights (1995-1997) for thorny skate were on average 11% greater than those predicted by applying Templeman's (1987a) length-weight relationships derived from 1949-1972 data to current length frequencies. Skate catch weights (based on the regression) were underestimated for both seasons and in all areas. It is not clear whether this is due to a difference in the manner in that the fish weights were derived, changes in gear selectivity (Engels versus Campelen) between the two periods or increased skate weight-at-length. There is no evidence that the fish were weighed differently. Possible weight-at-length changes need to be explored.

A tagging study on the Grand Banks (Templeman 1984) indicated that thorny skate is a primarily a sedentary species and generally does not undergo long migrations. However, Templeman did not attempt to examine seasonal patterns and most of the tagging took place nearshore. Given that there was no directed fishery for skate at the time and no deepwater fisheries in the area (1947-1972), low tag return rates from deep waters are not unexpected. However, in the current study, differences in biomass estimates and distributions between seasons would seem to indicate that some degree of seasonal migration occurs although distances traveled are probably less than 100 km annually. Support for this hypothesis stems from several sources. Fall survey biomass and abundance estimates were usually higher than those for spring. Specifically, in 26 of 28 year∗area combinations, fall estimates were greater than those for spring by an average of 40% (Table 4). Although this could be due to a change in local catchability, it is more likely due to a change in availability, attributable to a seasonal movement of skate outside of the surveyed area. There is no evidence or known biological reason for skate avoiding gear at different rates between spring and fall. A more probable explanation is differences in seasonal distribution.

Fig. 8 (biomass) and Fig. 9 (abundance) clearly show that skate were distributed differently in the spring than in the fall. In the spring, moderate to high concentrations of skates were found to form a nearly continuous band around the periphery of the banks along the outer limits of the surveyed area. This concentration extended from the northern extent of the survey area at the 3L border along the outer Grand Bank across the outer Haddock Channel, Green Bank, Halibut Channel and along the edge of the Laurentian Channel, ending in the Hermitage Channel. The band was most dense and wider along the southwestern slope of the Grand Bank and up into the Laurentian Channel. Compared to the fall, this large (southern) spring concentration was located further west across the 3NO line and into 3Ps (refer also to Fig. 34 that by isolates the areas of highest density of skate). It should be noted that sampling coverage (set locations denoted by dots in reverse gray shade) was thin in the spring along the southwestern edge of the Grand Bank just to the west of the 3NO division line. While it is clear that skate at this location are closer the shelf edge and distributed more to the west of the 3NO border, the exact spring distribution is not clearly defined from the 1995-97 data. A smaller, less dense concentration of skate was also located straddling the line between NAFO Divisions 3L and 3N. Kulka et *al.* 1996 indicated that in earlier years, this concentration of skate in Div. 3L not only comprised larger fish but was distributed over a larger area and at higher densities, representing a greater proportion of the biomass.

In contrast, during the fall survey period, the main body of the skate was distributed more on the bank, inhabiting shallower waters. The concentrations of skate along the shelf edge were diminished while the aggregation on (and westward of) the Southeast Shoal and to a lesser extent, that straddling the 3LN border were larger. This latter aggregation was distributed more to the east and was more dense in the fall (by about 30%) than in the spring. The 3Ps area was not surveyed in the fall. However, survey sets done in August in southern and western 3Ps and across into 4Vn show little or no aggregation of skate along the shelf edge there at that time of year as can be seen in the spring.

Fig. 10a illustrates that in 1995-1997, 65% of the available habitat within the surveyed area fell between 51 to 200 m bottom depth while only 47% (spring) and 52% (fall) of the biomass was located within that depth range (Fig 10c). This was because the skate were denser at greater depths causing more of the biomass to be in deeper waters. There was a significant difference between seasons (Fig. 10b). In the spring, the average density in 500 + m was 25 kg per tow (peaking at 80 kg in 700-800 m). This was 5 times greater than the fall density over the same range of depths. As well, 5 times more of the biomass was located in the deep end of the range (500 m+). Survey sets deeper than 800 m were scarce totaling only 69 sets for the period analysed. However, the 65 deep sets from the fall surveys yielded an average catch rate of 1.9 kg per tow. These catches contrast with the four deep spring sets that averaged 63 kg per tow suggesting that seasonal variation in skate density was greatest in the deepest waters surveyed.

Fig. 11, comparing cumulative area and biomass further illustrates the seasonal differences. This analysis resembles the CDF or cumulative distribution function (Smith and Page 1996) used to compare available habitat with distribution of the species. Whereas in the spring, the biomass line fell below the available area line at all depths less than 700 m indicating preferential occupation of deeper waters, biomass in the fall was more proportionately distributed across available depths. The greatest difference in the fall was at 50-150 m where biomass was disproportionately greater than area. This analysis corroborates the pattern observed in the distribution plots (Fig. 8 and 9) indicating a seasonal variation in skate distribution.

This seasonal variation in the distribution was similar among years but with some annual variations. Fig. 12 and 13 show that the two main concentrations of skate straddle NAFO Division borders shifting in relation to the lines between seasons and years. This suggests that analyses of biomass, abundance and average size by NAFO Division as is done for STRAP may be confounded by distributional dynamics of the skate in relation to divisional borders. Using NAFO divisions to examine biomass trends may not be appropriate. However, stock definitions, including more appropriate spatial boundaries for skate have not yet been defined.

Seasonal patterns observed in the fisheries, particularly deep water effort outside of 200 miles support the hypothesis that skate shifted to deeper waters outside of the surveyed area in the spring. The Canadian fishery taking place primarily during Mar. to Jun. is prosecuted along the shelf edge in deeper (average 165 m) waters. In contrast, information on foreign skate catches from Canadian surveillance reports show that the directed Spanish fishery for skate in August to December, peaking in September is prosecuted in shallow (average 70 m) water on the Southeast Shoal (refer to the section on The Fishery for more details). This corresponds with the period of the fall survey when the fish were found to concentrated on the shelf, in particular on the Southeast Shoal. These observations agree with Junquera and Paz (1998) who reported that the Spanish directed fishery for skate on the southern Grand Bank outside 200 miles (late summer and fall) exploited pre-mating concentrations in shallow waters on the Southeast Shoal.

Also, boarding data from Spanish turbot and grenadier fisheries 1995-97 demonstrate a distinct seasonal variation in the bycatch rates of skate and confirm that skate occur mostly deeper than the surveyed area. These fisheries cover the entire slope outside 200 miles. Compared to Jul.-Nov. (Nov. an intermediate value perhaps indicating the return of the skate to deeper waters), rates on the slope were nearly double during Dec.-Jun. (Fig. 14). This indicates higher concentrations of skate on the slope outside of the survey area at that time of year. Junquera and Paz (1998) also reported that in spring, the Spanish research surveys (primarily in Div. 3N) showed a bimodal pattern of catch at depth. High catch rates were observed at less than 200 m and also at depths greater than 1100 m with much lower values in between, further evidence of a seasonal shift outside of the survey area.

Thus, taken together:

a) the change in spring and fall distributions (similarly noted for thorny skate on the Scotian Shelf by Simon and Frank 1996)
b) higher density and a greater proportion of biomass in deeper waters in the spring
c) the aggregations being 30% more dense in the Canadian fall vs. spring surveys
d) high concentrations located in greater than 1,100 m in Spanish surveys in the spring
e) the estimates of biomass being on average 40% lower in spring than in fall

   and

f) double the bycatch rates of skate in Dec-Jun. vs. Jul.-Nov. in deep slope fisheries (outside the survey area)

suggests that the skate undergo a seasonal migration, including a portion moving outside of the survey area in winter/spring. Skate are in greater proportion on the Grand Banks in the summer/fall, perhaps congregating there to spawn then move off the shelf during the early winter and spring to deeper waters.

The difference between spring and fall biomass also appeared to vary over time. Fig. 15 and Table 4 shows that difference between the spring and fall estimates of biomass increased over the time series particularly between 1992 and 1995. This suggests that the skate may have changed their behaviour with an increasingly greater proportion of skate moving to deeper waters outside the survey area in the spring or that the part of the population that did not migrate became less abundant. As well, the pattern varied between divisions (although divisions may not delineate suitable boundaries for skate as discussed above with regard to distribution). The difference in spring/fall biomass averaged about 20% in Div. 3O vs. about 65% in 3LN suggesting that a smaller proportion of the fish along the southwest part of the Grand Bank (3O) moved into deeper waters compared to the north and eastern portions. This finding is consistent with the distribution map (Fig. 8) showing that the shallowest and most extensive band of high density of fish is located in 3O in the spring. Either the fish in 3O do not move as extensively onto the slope compared to the other parts of the bank or the migration on this part of the shelf is delayed compared to the areas to the north and east. As well, the biomass differences were much more variable in 3O suggesting more variation in the timing of the migration at this location.

There were also significant differences noted in the spatial distribution of average skate size between spring and fall. Fig. 16 shows that during spring, the largest skate averaging 1.8 to 2.6 kg (58 to 64 cm total length) were located on the bank in a band stretching from just south of the Div. 3L line onto the Southeast Shoal. These larger fish were found in moderate to low density concentrations (refer to Fig. 8). Just south of this area, the skate were smaller, about 0.5 to 1.6 kg or 37 to 55 cm total length but these smaller fish are much more densely concentrated. South of that area, on the southwestern slope and up into the Laurentian Channel, the fish are not only larger again at about 2 kg average weight or 60 cm average length but were also densely concentrated. Large fish are also found in a low to moderate concentration over a small area just north of the Avalon Peninsula. In the fall, the average fish size was about 10% larger and most of these larger fish exceeding 3 kg (68 cm) were concentrated along the southwestern slope of the Grand Bank, southern Green Bank and St Pierre Bank in 180+ m. The largest skate in the survey area averaging 3.9 kg (74 cm) were centred at Lat. 53^0 30' along the southwestern slope. This suggests that some large, mature fish may move onto the bank in the fall (when spawning may take place; refer to discussion of size at maturity below).

This area where the largest fish occur is an important fishing ground for the Canadian fleet and the majority of their fishing activity occurs in the spring when these fish are more concentrated in the area. In the area of highest fall concentrations, (from the Southeast Shoal and west) skate were on average about 1.3 to 1.8 kg or 52 to 58 cm. This suggests a mix of mature and immature fish in this area. Size of skate caught in the Spanish directed fishery in this area (outside 200 miles) averaged about 50 cm (from Junquera and Paz 1998). Fish this large were caught even though the mesh in the trawls used to capture these fish (usually less than 200 mm) was smaller than the 300 mm mesh employed by the Canadian fleet.

A comparison of the distribution of males with females indicated a great deal of similarity between the sexes during both spring and fall (Fig. 17). The overlap was almost complete in the spring. However, in the fall, there was a concentration of females centered at $51^0$30' N 44^0 W that was not observed for the males. Otherwise the fall distributions were similar. Maturity stages of skate have not been recorded since the 1970's (Templeman 1987b). A comparison of density distribution maps of skates greater than 60 cm (primarily mature individuals) and less than or equal to 60 cm (immature) by season indicates that the two groups tended to overlap extensively in the spring, less so in the fall (Fig 18, maps of mature and immature fish were scaled differently because of the considerable difference in relative density between the two components). In the fall, the concentration located in southern Div. 3L comprised almost exclusively immature fish. Historically however, this was not the case. Figure 6 indicates that the fish in 3L in the late 1980's were on average much larger (mature fish) as well as being more densely aggregated and extensively distributed. Also, in the fall, immature fish tended to be concentrated on the bank straddling the 200 mile line while mature fish were closer to the edge of the shelf. Thus mature fish tended to distribute deeper in the fall. In summary males and females tended to overlap extensively, mature vs. immature fish less so.

Water masses on the Grand Banks are a mix of cold, low salinity waters that are transported into the area by the Labrador Current. Spring and fall bottom temperature distributions are similar (Fig.19) but in the fall, temperatures are about 0.5^0 C warmer averaged over the entire area. Over the inner portion of the continental slope at depths of 200+ m, comparatively warmer (and saline) conditions occur particularly along the western edge of the Grand Banks and up into the Laurentian Channel where temperatures average in the 3 to 5^0 C range. The warm slope water extends furthest onto the shelf along the southwestern edge of the Grand Bank and the southern St. Pierre Bank. A warm area also occurs on the shelf over the Southeast Shoal (30-80 m) and in the Laurentian Channel where temperatures above 4^0 C can be found. The coldest areas where temperatures are less than 0^0 C are found in the waters surrounding the Avalon Peninsula both spring and fall, although more extensively in the spring. Annual plots show similar patterns from year to year with some variation in extent of warm and cold areas (Fig. 20 and 21). One anomaly is the warm area directly south of the Avalon Peninsula in 1997. However, this is consistently an area of low skate densities.

Given that skate spend most of their time on bottom, the bottom temperatures used in this analysis are the ambient conditions for skate. Fig 22, panel A shows that the extent of the available habitat (area within temperature strata) varied between spring and fall. In the spring, cold areas were more extensive, particularly in the -0.54 to 0.24^0 C range. The inner portion of 3Ps was not sampled in the fall, in part explaining the reduced area of cold water shown in Fig. 21 for the fall. Also in the fall, there was a larger extent of water warmer than 5^0 C, this around the periphery of the bank and on the Southeast Shoal (Fig. 19).

The distribution of thorny skate in relation to bottom temperature indicates that they were not distributed proportionately across available habitat. While skate are widely distributed over the Grand Banks (Fig. 8), the densest aggregations are found on the warmer parts of the banks, more so in the fall. Panel B shows that no skate were found in waters below 0^0 C at any time of the year. In the fall, density peaked in the 1.07 to 2.94^0 C range while in the spring, skate were most densely aggregated in the 4.44 to 5.27^0 C range, near the maximum available temperature. In terms of biomass, the pattern was similar. Fig. 22, comparing panels A and C shows that in the fall (and spring) respectively, bottom temperatures between 0.24 and 2.94^0 C occurred over 66 (42)% of the surveyed area but contained 40 (46)% of the biomass. In the warmest waters, above 4.44^0 C, fall (spring) area amounted to 22 (11)% but contained 22 (41)% of the biomass.

Fig. 23, comparing cumulative area and biomass in relation to ambient temperature (resembling the Smith and Page 1996 CDF technique) further illustrates the seasonal differences. Neither spring or fall distributions of skate were thermal neutral. Whereas in the spring, percent of biomass fell well below percent of the available area over almost the entire range of temperatures indicating a strong association with the warmest waters, biomass in the fall was proportionately distributed across in temperatures exceeding 2.37^0 C. Thus, skate differentially distribute in warmer waters on the Grand Banks, more so in the spring. Whether the skate are differentially selecting warmer habitat between spring and fall or the differences relate more to the migration to deeper (also warmer) waters is unclear. Non-random distribution with respect to temperature habitat may be an indicator of other changing environmental factors that influence the distribution of skate.

Fig. 24 also indicates a relationship between average skate size and bottom temperature. The pattern was consistent between spring and fall. Smaller (immature) skate sizes, between 0.5 and 1.5 kg (37-55 cm total length) tended to be associated with temperatures less than 3^0 C. Larger (a mix of mature and immature) skates averaging between 1.5 and 2.6 kg (55 to 64 cm), particularly in the fall when larger skates tended to be found in 4.5 to 5.5^0 bottom temperatures, the warmest locations on the Grand Banks. Whether this constituted a preference for warmer temperatures (that coincided with deeper areas) is unclear.

The Fishery

From the time of the extension of jurisdiction to 1984, skate landings reported to NAFO averaged 5000 t. Since that time, catches have increased dramatically. This was due in part to the emergence of a directed foreign fishery outside 200 miles in 1985, and more recently to the introduction of a directed skate fishery in Canadian waters starting in 1994. This latter introduction was mostly the result of moratoria imposed on traditional groundfish fisheries, coupled with the recognition that skate were marketable and concentrations appeared sufficient to support a viable fishery. This was thought particularly likely since the foreign fleet outside 200 miles was successfully directing for skate. As well, skate had always been a major bycatch component in domestic water fisheries. Consequently, markets were established while a directed fishery was developed (see Atkinson 1995 and Kulka 1996 for a more complete discussion on the development of this fishery).

Although poorly represented in the landings statistics, skate were caught in Canadian waters of 3LNOPs previous to 1994. Kulka (1982, 1984, 1985 and 1986) reported that skates consistently comprised the greatest non-commercial bycatch in the Newfoundland offshore trawl fisheries, averaging 3,000-4,000 t during the early 1980's. Skate was sometimes the dominant bycatch of Grand Bank fisheries for plaice, cod, redfish and yellowtail, although nearly all of this incidental catch was discarded at sea. As a result, landing statistics for skate in Canadian waters prior to 1994 represent only a fraction of the actual catch. For this assessment, an effort was made to quantify these other catches to better estimate fishing mortality. Consequently, catch estimates are presented for these non-directed discards (using observer data and groundfish catch landings), as well as for foreign skate catch inside 200 miles (observer data) and outside 200 miles (C&P surveillance estimates). The results of these analyses are presented in Fig. 25, broken out by fishing sector and NAFO Division.

Skate catches since 1985 can be grouped into two periods: 1985-1991 when total catch ranged from 16,000 to 23,000 t and 1992-1996 when catches dropped to under 12,000 t declining to less than 7,000 in 1996. Total catch in 1997 was similar to that of 1992. Catches outside 200 miles accounted for an average of 60% of the annual catch (all years). Canadian landings inside 200 miles that represented less than 1% of the total catch prior to 1994 have since averaged from 1/4 to 1/2 of the total landings in subsequent years. As well, discards that were common in the pre-directed fishery period are presently negligible. Foreign bycatches inside 200 miles that averaged 11% of the total during the pre-directed fishery period (peaking at 30 % in 1993) were less than 2% in subsequent years. In terms of areas fished, catches in Canadian waters occurred primarily in 3L and 3Ps prior to 1992 (bycatch), but have shifted to 3O as well as 3Ps in recent years since the start of the directed fishery. Catches outside 200 miles occurred primarily in 3N (Fig. 25).

Given the limited knowledge of biology of skate (refer to Review of the Biology section above), prudent management measures, including catch limitations spread out by area were implemented in 1995. Atkinson (1995) reported on earlier suggestions by industry for an unrestricted skate fishery around Newfoundland, similar to the current regime outside the Canadian 200 mile limit. However, because of concerns about the sustainability of the resource in relation to stock biomass and reproductive capacity, the more conservative approach was adopted. Although only limited scientific information was available at the time, it was used as the basis for setting a TAC for 1995. Catch limits were set based on 20% of the average trawlable biomass for research surveys for 1991-1993. Catch quotas were separated between two bank areas, the Grand Banks (Divisions 3LNO) and St. Pierre Bank (Subdiv. 3Ps) in an attempt to spread out fishing effort. This resulted in a TAC of 5,000 t for 3LNO and 1,000 t for 3Ps for 1995. In 1995 and 1996, for Canada, skate were regulated by a TAC of 6,000t and 2,000t divided respectively between 3LNO and 3Ps.

However, taking into consideration the large foreign catches outside 200 miles, removals were considerably higher than the targeted 20% of the minimum trawlable biomass. Similarly, catches (combined foreign and domestic) continue to exceed levels considered prudent when the 1997 TAC was set. In 1997, the quota was reduced to 3,000 t, split 15% for 3LN, 50% for 3O and 35% for 3Ps. However it is important to note that domestic catches alone have not exceeded the TAC in any year.

In 1997, the allocation by gear was set at 45.8% for mobile (otter trawl) and 54.2% for fixed gear (comprising gillnets and longlines). Fixed gear fisheries were restricted to the inshore sector (vessels less than 65 ft), while mobile gear fisheries could be carried out either inshore or offshore. Minimum allowable mesh size for otter trawls was set at 300 mm in the codend and 250 mm in the remainder of the trawl for mobile gear > 65 ft. For fixed gear (gillnet), minimum mesh size was set at 12 in. outside 12 nmi. and 10 ½ in. inside for vessels > 65 ft. For vessels <65 ft. using fixed gear, fishing seasons were set for Aug. 1 to Dec. 31 outside 12 nmi. and Apr. 1 to Dec. 31 inside. Seasons for vessels <100 ft. using mobile gear were set for Apr. 1-Dec. 31 while vessels >100 ft. with mobile gear or vessels >65 ft. with fixed gear were able to fish year round. Maximum allowable bycatch in other fisheries was set at 5%. Domestic fishery policies and regulatory measures for 1997 are summarized in Table 5.

Although maximum allowable bycatch in other fisheries was set at 5%, statistics show that about 40% of the skate landings (Canadian fishery, inside 200 miles only) were classified as bycatch (Fig. 26). Much of this occurred in mixed fisheries for halibut, redfish, monkfish and white hake Table 6 lists Canadian landings by gear and month. Landings in the first year of the domestic fishery prior to the implementation of quotas were reported to be 3,747 t, primarily from trawl directed and mixed fisheries in Div. 3O and Subdiv. 3Ps (Fig. 27). Landings increased slightly in 1996 then dropped to about ½ in 1996 and 1997. Gillnet landings comprised the other major component. The resultant landings are seasonal (Fig. 28) occurring primarily between March and June for all gears except in 1994, the first year of the fishery when trawling was concentrated in the fall.

In contrast, the fishery prosecuted by foreign fleets outside of the 200 mile limit remain unregulated. Otter trawls are the primary gear used to direct for skate in this fishery. Unregulated mesh sizes used are considerably smaller than the 300 mm employed by the mobile Canadian fleet inside 200 miles, usually less than 200 mm, often as small as 150 mm. Boarding data were used to identify incidental skate catch in the turbot, plaice and redfish foreign directed fisheries taking place along the shelf edge outside 200 miles. Duran and Paz (1997) reported skate as the most common bycatch in the Spanish trawl fishery for turbot in NAFO Divs.3N and 3O in 1991-1994. Boarding data confirms this to be the case.

A spatial representation of the foreign and domestic fisheries is presented in Figs. 29 through 33. Fig. 29, panel A shows the location of observed Canadian fishing sets by gear for 1993 to 1998 (to date) combined. Much of the activity occurred in a band about 50 km long centred near the dividing line between Div. 3O and Subdiv. 3Ps. In contrast, panel B shows that the foreign effort (Spanish log data collected during boardings from 1995-1997) occurred on the tail of the Grand Bank and also along the entire eastern shelf edge outside 200 miles. That portion on the bank where catch rates were highest was mainly a directed fishery for skate. This on-shelf effort took place primarily from June to December (Fig. 30) at the time when the research surveys showed that skate were aggregated on the Southeast Shoal partly outside the 200 mile limit. Here the catch rates were observed to average 555 kg per hour (based on daily catches collected from boardings and assuming a 20 hour per day fishing effort). This matches closely with the 452-618 kg per hour catch rate reported by Junquera and Paz (1998) for the directed skate fishery in Div. 3N. On the other hand, the activity along the shelf edge, spread throughout the year was directed at other species, primarily turbot. Bycatch rates of skate in this area were much lower averaging 59 kg per hour.

Figures 31, 32 and 33 show distribution of fishing effort and catch rates for the domestic and foreign otter trawl and domestic longline and gillnet fisheries. The Canadian otter trawl effort occurred in both Div. 3O and Subdiv. 3Ps near the dividing line. Although most of the reported catches were from the spring (Mar. to Jun. as opposed to the foreign activity on the tail mostly after May), otter trawl catch rates as recorded by fishery observers at 730 kg per hour were about the same, spring and fall (Table 7). For longlines, the activity was more spread out in the spring and catch rates were generally lower at 180 kg per 1000 hooks. Best catches were achieved at the mouth of Haddock Channel in the fall. Some skate were also taken at the mouth of St. Mary's bay. Gillnet catches, primarily from Div. 3O in the spring were highest near the 3O/3Ps line. Catch rates for this gear averaged 2,500 kg per 100 nets. All gear activity was prosecuted in a fairly narrow range of depths averaging 140m. Both spring and fall research surveys indicated that the skate along the southwestern edge of the bank (where they were fished by Canada) were more densely aggregated at depths greater than what was fished (refer to Fig. 10). Spring density of skate was lowest between 100 and 200 m and peaked at 700-800 m. Gear limitations may have effectively restricted effort to shallower waters.

Research survey sets (skate catch rates) were superimposed on commercial otter trawl fishing grounds. From this analysis, it was determined that a mean (survey) weight per tow of about 30 kg (120 kg per hour) correspond with areas where commercial catch rates averaged about 700-800 kg per hour (refer to Table 7). This suggested that the commercial trawls were about 6.25 times more efficient than Campelen survey gear for catching skate. The research vessel density plots (Fig. 34) were then re-scaled to show only areas with commercial potential (i.e. where catch per tow was greater than 15 kg, equivalent to greater than 325 kg per hour for commercial gear, near the lower bound of the range of catch rates). Fishing sets are superimposed to show correspondence between actual and potential fishing areas. The observed fishing grounds covering 16,000 km^2 were about $1/3^{rd}$ of the potential areas that covered about 45,000 km^2. Foreign effort location outside 200 miles in Div. 3N corresponded closely with the distribution of skate. In Div. 3Ps Canadian activity corresponded with the areas of highest concentration although high concentrations along the edge of the Laurentian Channel just north of the fishing grounds were not observed to be fished.. On the other hand, Canadian activity did not match with the areas of highest concentration in Div. 3O. The fishery in this area was concentrated near the 3O/3Ps dividing line while the most dense spring (and fall) concentrations of skate were located about 150-200 km further to the east.

Based on market conditions, the minimum acceptable size (wing width) is about 46 cm (18 inches). Atkinson (1995) noted that in 3LN, about 50% maturity is reached at about 46 cm (18 inches) wing width, but in 3OPs the width at 50% maturity is about 56 cm (22 inches). A limited number of measurements of wing width done by fishery observers shows that the mesh size used selected skate of a large enough size for the market and the fishing grounds corresponded with areas identified from the research surveys where skate were largest. The size in directed catches from 3O and 3Ps ranged from 50 to 95 cm (average 77.2) in 1995 and 35 to 95 cm (average 69.4) in 1996 (Fig. 35). There were no commercial data available for 1997.

CONCLUSION AND PROGNOSIS

In managing a commercially exploited species, it is important to have some knowledge of the reproductive biology, spatial distribution (and how the catch is being taken in relation to the distribution), stock structure, and the nature of commercial catches in terms of amounts, size and age. Earlier studies provided information on some of these topics but were based on sampling done decades ago. They demonstrated substantial differences in size at maturity (one indictor of stock structure) between 3LNOPs versus areas to the north. Differences within 3LNOPs are less than clear. Analyses of distribution (this study with data from recent years) indicates that a single concentration on southern Grand Banks that straddles the 3N and 3O and the 3O and 3Ps divisional borders shifting seasonally in relation to the lines between and years. Whether this concentration of fish constitutes part of a larger stock, a single stock or several stocks remains unclear. The distribution dynamics and some of the earlier morphometric studies suggest a single stock.

No new information on stock structure aside from description of the distribution has been presented in this paper but what is clear from the current work is that the NAFO division boundaries are not appropriate for defining management units for thorny skate. Analyses of biomass, abundance and average size done by NAFO Division as is the case for STRAP are confounded by the seasonal distributional dynamics of skate in relation to divisional borders, making it difficult to judge inter-annual trends in biomass (when analysed by division). Stock definition, including determination of spatial boundaries remains to be done.

Past work showed that starting in the late 1970's, thorny skate declined earlier and at a greater rate to the north. The decline accelerated in the early 1990's. The current study showed that for the last few years, after reaching its lowest level in all areas, the biomass still shows no sign of recovery through 1997. Although it was always a common bycatch in offshore fisheries, prior to the mid-1980's, there was no directed fishing effort for skate. The majority of the bycatch originated from the Grand Banks in the area where the skate concentrations have persisted, not the areas to the north where the decline was most extreme. As with numerous other species, what proportion of the decline is attributable to changes in fishing mortality vs. environmental influences remains uncertain.

Fall survey data was analysed here for the first time. Compared to the spring surveys and with information from the fisheries fall surveys revealed seasonal differences in distribution, suggesting a small scale migration. The skate are distributed more onto the shelf in summer/fall than in winter/spring. Because of the migration, the spring survey, used to estimate minimum trawlable biomass does not account for the entire population but the fall surveys, while accounting for a greater proportion of the stock in 3LNO cannot be used to formulate an index because they do not include Subdiv. 3Ps. The relative spring fall biomass estimates suggest that a portion of the skate (about 40% on average) move outside of the survey area after the fall survey, not returning until after the survey the following spring. In addition escapement studies show that skate have a lower catchability than some other groundfish species. As a result, an exploitation rate based on spring biomass estimates is likely artificially high. However, in determining an appropriate level of exploitation for thorny skate, this must be balanced by the knowledge that the biomass index has declined to its lowest historical level (as yet showing no sign of recovery). The average total catch for 1996-97 was 8,930 t, which represents approximately 13% of the average spring survey estimate for the same period. This constitutes a substantial reduction from the 20% exploitation rate set in 1995. However, if there was change in catchability due to the change in survey gear in the fall of 1995 as appears to be the case then a comparison of exploitation rates between periods is not valid.

It has been stated that skate have a low reproductive capacity due to low egg production. Although skates are not as fecund compared to say cod, it does not immediately follow that they have lower reproductive capacity: newly hatched skate have a much higher survival probability. A more appropriate comparison (were it available) would be the number of juveniles produced per female per year. It may be that the effective yield per recruit is not greatly different from more fecund species. Further investigation of this matter is required.

It is important to understand how the species is being exploited in relation to its spatial distribution. In the absence of adequate sampling of commercial lengths, a demonstration of size dependent spatial distribution from research survey data coupled with commercial fishery catch locations identified what part of the stock and what sizes were being targeted by the fishery. This work provided some clues for further refining fishery management aspects. It was determined that although the TAC was allocated among several areas, the Canadian fishery continues to be concentrated in an area straddling the 3O and 3Ps division line along the shelf edge, particularly in the spring where the largest fish tended to aggregate. The foreign fishery, using smaller meshed gear concentrated on smaller fish that aggregated on the Southeast Shoal in the fall.

Deficiencies

There remain a number of important limitations to our knowledge of skates in the waters around Newfoundland. We lack information on such things as growth rates and age of maturity and details of the age structure of the population(s). No ageing of this species has been attempted thus age dis-aggregated analyses are not possible. Biological sampling of the commercial catches continues to be inadequate and information on the commercial catches is restricted to gross removals of weight. There are uncertainties in the reported landings, although this study tried to present a better accounting of the catches. For these reasons, available data are not suitable for analysis by traditional stock assessment methodologies. As well, much of the previous baseline biological work such as food and feeding, stock structure, morphology and reproduction were based on decades old data. Ageing, up to date maturity and stock structure studies would enhance our knowledge of the current status of thorny skate in 3LNOPs. Tagging work concentrating on the offshore concentrations would lead to a better understanding of the mechanism of it's migration. A program of sampling of the commercial catches should be initiated to define removals by size and possibly by age.

Prognosis

Assuming that skates are a renewable resource, one would expect some evidence of renewal, some sign that skates that are caught are replaced by fresh stock. Aside from perhaps of an increase in proportion of mature fish in the surveys in recent years and an apparent increase in weight at length (compared to 1949-72 data), such evidence of recovery is lacking. Considering the historical decline in biomass of skate to its lowest level, the lack of comparable data for recent years on current stock status (due to the change in survey gear), the uncertainty about the stock(s) ability to rebuild in the absence of information on juvenile survival, and an unregulated fishery outside 200 miles, an increase in harvest levels would not be considered prudent. Given the limited knowledge of stock structure of skate, spreading the catch out by area is appropriate. Dwelling on the bottom, skates tend to be sedentary (except during a seasonal migration). For this reason, local concentrations can be depleted. On the other hand, escapement of this species at all sizes seems to be high affording some protection against local depletion. Given the uncertainties, management on a scale finer than Division might be prudent. Still, in the absence of detailed data on stock structure, a first cautious approach would be continued allocation among divisions to facilitate dispersion of effort. The biomass proportions in the 1996-97 spring survey were: 22% in Divisions 3LN, 47% in Div. 3O and 31% in Subdiv. 3Ps.

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Table 1a. Biomass, abundance and mean weight of thorny skate from spring research vessel surveys, 1986-1998. Surveys were conducted with an Engels trawl (1986- fall 1995) and Campelen (spring 1996- 1998). Estimates are given separately for "core" strata (those covered in all surveys) and "all" strata (includes new deep water and inshore strata added in recent years).

Biomass (tonnes)

	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All Divisions	
Year	Core	All	Core	All	Core	All	Core	All	Core	All
1986	27,506		43,435		18,360		18,790		108,091	
1987	32,298		23,833		20,081		16,022		92,234	
1988	27,616		19,561		34,399		11,808		93,384	
1989	28,855		19,347		15,816		17,430		81,448	
1990	17,839		18,693		24,388		9,553		70,473	
1991	8,739		11,388		38,978		24,226		83,331	
1992	4,703		9,074		22,807		15,234		51,818	
1993	3,365		7,303		13,824		6,400		30,892	
1994	1,468	1,543	3,998	4,013	11,368	11,368	6,495	6,511	23,329	23,435
1995	1,102	1,109	1,112	1,112	12,726	12,726	9,644	9,812	24,584	24,759
1996	4,993	4,993	11,010	11,010	35,529	35,529	21,251	21,851	72,783	73,383
1997	3,969	3,969	9,703	9,703	28,293	28,293	19,545	20,705	61,510	62,670
1998	6,023	6,023	13,186	13,186	39,422	39,422	28,034	29,262	86,666	87,893

Abundance (thousands)

	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All Divisions	
Year	Core	All	Core	All	Core	All	Core	All	Core	All
1986	21,170		22,063		8,733		14,939		66,905	
1987	16,178		13,859		14,066		11,617		55,720	
1988	14,475		10,940		17,765		7,869		51,049	
1989	16,673		12,409		7,305		10,687		47,074	
1990	18,156		29,610		16,578		8,820		73,164	
1991	14,372		18,408		14,543		20,766		68,089	
1992	15,486		8,531		14,697		8,889		47,603	
1993	11,473		7,053		6,208		8,917		33,651	
1994	6,519	6,611	7,237	7,258	7,895	7,895	7,904	7,943	29,555	29,707
1995	3,851	3,867	2,900	2,900	11,067	11,067	7,724	8,055	25,542	25,889
1996	10,418	10,418	10,636	10,636	22,731	22,731	25,222	25,591	69,007	69,376
1997	6,804	6,804	13,554	13,554	25,635	25,635	17,606	18,379	63,599	64,372
1998	8,008	8,008	10,140	10,140	30,511	30,511	22,198	23,185	70,857	71,844

Mean Weight (kg)

	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All Divisions	
Year	Core	All	Core	All	Core	All	Core	All	Core	All
1986	1.30		1.97		2.10		1.26		1.62	
1987	2.00		1.72		1.43		1.38		1.66	
1988	1.91		1.79		1.94		1.50		1.83	
1989	1.73		1.56		2.17		1.63		1.73	
1990	0.98		0.63		1.47		1.08		0.96	
1991	0.61		0.62		2.68		1.17		1.22	
1992	0.30		1.06		1.55		1.71		1.09	
1993	0.29		1.04		2.23		0.72		0.92	
1994	0.23	0.23	0.55	0.55	1.44	1.44	0.82	0.82	0.79	0.79
1995	0.29	0.29	0.38	0.38	1.15	1.15	1.25	1.22	0.96	0.96
1996	0.48	0.48	1.04	1.04	1.56	1.56	0.84	0.85	1.05	1.06
1997	0.58	0.58	0.72	0.72	1.10	1.10	1.11	1.13	0.97	0.97
1998	0.75	0.75	1.30	1.30	1.29	1.29	1.26	1.26	1.22	1.22

Table 1b. Biomass, abundance and mean weight of thorny skate from fall research vessel surveys, 1986-1997. Surveys were conducted with an Engels trawl (1986-1994) and Campelen (1995-1998). Estimates are given separately for "core" strata (those covered in all surveys) and "all" strata (includes deep water, and inshore strata added in recent years).

Biomass (tonnes)

	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All Divisions	
Year	Core	All	Core	All	Core	All	Core	All	Core	All
1986	44,555								44,555	
1987	34,584								34,584	
1988	42,484								42,484	
1989	26,723								26,723	
1990	37,632		26,559		38,384				102,575	
1991	20,730		40,929		29,735				91,394	
1992	15,862		20,858		16,686				53,406	
1993	9,487		13,987		25,313				48,787	
1994	6,379	6,379	20,059	20,059	12,570	12,570			39,008	39,008
1995	11,299	11,299	40,775	40,775	44,653	44,653			96,727	96,727
1996	13,716	14,459	28,629	28,629	36,969	36,969			79,314	80,057
1997	7,320	7,534	43,075	43,075	58,160	58,160			108,555	108,769
1998										

Abundance (thousands)

	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All Divisions	
Year	Core	All	Core	All	Core	All	Core	All	Core	All
1986	31,167								31,167	
1987	33,421								33,421	
1988	35,799								35,799	
1989	31,733								31,733	
1990	48,247		18,122		21,980				88,349	
1991	30,403		25,260		12,264				67,927	
1992	38,867		13,989		10,196				63,052	
1993	25,414		12,840		17,100				55,354	
1994	18,263	18,263	20,720	20,720	12,706	12,706			51,689	51,689
1995	23,284	23,284	37,322	37,322	30,582	30,582			91,188	91,188
1996	22,995	23,483	22,694	16,614	45,145	45,145			90,834	85,242
1997	13,323	13,448	30,540	37,601	50,047	50,047			93,910	101,096
1998										

Mean weight (kg)

	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All Divisions	
Year	Core	All	Core	All	Core	All	Core	All	Core	All
1986	1.43								1.43	
1987	1.03								1.03	
1988	1.19								1.19	
1989	0.84								0.84	
1990	0.78		1.47		1.75				1.16	
1991	0.68		1.62		2.42				1.35	
1992	0.41		1.49		1.64				0.85	
1993	0.37		1.09		1.48				0.88	
1994	0.35		0.97		0.99				0.75	
1995	0.49		1.09		1.46				1.06	
1996	0.60		1.26		0.82				0.87	
1997	0.55		1.41		1.16				1.16	
1998										

Table 2a - Skate SPANdex index of abundance from spring research vessel surveys in NAFO Divisions 3L, 3N, 3O and 3P using Campelan gear. Engel gear was used for most of the 1995 survey and these data are not included.

Spring 1996

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1	22	25,362	0.0	0	0	0.0	0.00%	100.00%	100.00%
2	32	23,534	0.1	90,647	91	0.2	0.10%	100.00%	94.86%
3	27	25,896	0.2	188,408	188	0.4	0.20%	99.90%	87.94%
4	26	23,031	0.4	394,267	394	0.6	0.43%	99.70%	80.32%
5	27	20,996	0.6	548,130	548	0.7	0.60%	99.27%	73.55%
6	38	24,426	1.0	1,034,916	1,035	1.0	1.13%	98.67%	67.38%
7	26	21,033	1.4	1,269,223	1,269	1.8	1.38%	97.55%	60.20%
8	35	24,634	1.3	1,349,467	1,349	1.5	1.47%	96.17%	54.02%
9	33	22,869	3.0	2,926,415	2,926	2.8	3.18%	94.70%	46.77%
10	29	21,207	2.6	2,377,924	2,378	2.5	2.59%	91.52%	40.05%
11	32	21,933	3.5	3,285,365	3,285	3.9	3.57%	88.93%	33.82%
12	37	21,552	6.0	5,497,324	5,497	7.1	5.98%	85.36%	27.37%
13	34	23,131	10.8	10,641,929	10,642	10.0	11.57%	79.38%	21.03%
14	38	21,966	16.0	15,069,609	15,070	15.2	16.39%	67.81%	14.23%
15	27	26,441	41.8	47,289,828	47,290	28.9	51.42%	51.42%	7.77%
Sum	463	**348,011**	5.91	**91,963,452**	***91,963***	5.09	**100.00%**	0	0

Spring 1997

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1		0	0.0	0	0	0.0	0.00%	100.00%	100.00%
2	43	49,863	0.0	0	0	0.0	0.00%	100.00%	100.00%
3	23	21,893	0.0	37,479	37	0.1	0.04%	100.00%	85.34%
4	22	21,299	0.2	164,078	164	0.3	0.18%	99.96%	78.90%
5	31	21,121	0.3	225,981	226	0.5	0.25%	99.78%	72.64%
6	32	21,758	0.3	260,732	261	0.4	0.29%	99.53%	66.43%
7	39	27,372	0.7	843,445	843	0.9	0.93%	99.24%	60.04%
8	28	26,664	1.5	1,666,079	1,666	1.7	1.83%	98.32%	51.99%
9	21	24,885	1.8	1,906,374	1,906	1.6	2.09%	96.49%	44.15%
10	25	22,164	1.9	1,783,296	1,783	2.5	1.96%	94.40%	36.84%
11	26	24,490	4.1	4,286,764	4,287	2.9	4.70%	92.44%	30.32%
12	20	23,594	6.6	6,674,527	6,675	6.2	7.32%	87.74%	23.12%
13	43	18,098	9.9	7,668,020	7,668	12.1	8.42%	80.41%	16.18%
14	31	16,469	16.4	11,580,366	11,580	16.5	12.71%	72.00%	10.86%
15	29	20,479	61.6	54,024,264	54,024	107.0	59.29%	59.29%	6.02%
Sum	413	340,149	7.02	**91,121,406**	***91,121***	10.18	**100.00%**	0	0

Table 2b - Skate SPANdex index of abundance from fall research vessel surveys in NAFO Divisions 3L, 3N, 3O and 3P. Estimates include sets in NAFO Div. 3P along the Laurentian Channel side that are not part of the regular fall survey.

Fall 1995

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1	21	25,051	0.0	0	0	0.0	0.00%	100.00%	100.00%
2	26	24,750	0.1	105,924	106	0.2	0.08%	100.00%	92.45%
3	29	25,256	0.4	421,548	422	0.4	0.33%	99.92%	85.00%
4	28	27,236	1.0	1,142,318	1,142	1.0	0.89%	99.59%	77.39%
5	26	23,974	0.9	943,943	944	1.1	0.73%	98.70%	69.19%
6	27	23,519	1.4	1,419,239	1,419	1.7	1.10%	97.97%	61.96%
7	35	23,979	2.5	2,606,647	2,607	2.8	2.02%	96.87%	54.88%
8	21	22,660	3.5	3,384,565	3,385	3.5	2.63%	94.84%	47.65%
9	33	19,122	5.8	4,713,823	4,714	5.1	3.66%	92.21%	40.83%
10	28	19,138	7.9	6,437,787	6,438	7.5	5.00%	88.55%	35.07%
11	35	18,356	9.6	7,541,657	7,542	8.3	5.86%	83.55%	29.30%
12	31	18,781	15.5	12,458,561	12,459	17.8	9.68%	77.70%	23.77%
13	29	21,666	23.5	21,762,527	21,763	19.9	16.90%	68.02%	18.12%
14	30	22,070	30.0	28,364,501	28,365	22.2	22.03%	51.12%	11.59%
15	26	16,402	53.4	37,456,752	37,457	43.5	29.09%	29.09%	4.94%
Sum	425	**331,960**	10.36	**128,759,791**	***128,760***	9.00	**100.00%**	0	0

Fall 1996

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1	63	70,703	0.0	0	0	0.0	0.00%	100.00%	100.00%
2	12	15,869	0.2	162,997	163	0.3	0.09%	100.00%	77.29%
3	26	18,188	0.4	334,712	335	0.6	0.18%	99.91%	72.19%
4	13	17,996	0.5	354,284	354	0.5	0.19%	99.73%	66.35%
5	23	15,482	0.8	556,575	557	1.6	0.30%	99.54%	60.57%
6	22	15,076	2.3	1,509,800	1,510	2.7	0.81%	99.25%	55.60%
7	15	16,624	2.8	1,977,870	1,978	2.7	1.06%	98.44%	50.76%
8	28	15,866	4.3	2,933,382	2,933	3.9	1.57%	97.38%	45.42%
9	22	15,412	6.4	4,234,591	4,235	5.9	2.26%	95.82%	40.32%
10	13	17,855	10.3	7,863,080	7,863	5.9	4.20%	93.55%	35.37%
11	22	18,795	12.8	10,312,117	10,312	9.0	5.51%	89.35%	29.63%
12	12	19,451	17.5	14,592,891	14,593	13.8	7.80%	83.84%	23.60%
13	24	18,885	23.4	18,936,807	18,937	17.2	10.12%	76.04%	17.35%
14	24	15,960	31.4	21,420,343	21,420	23.0	11.45%	65.92%	11.28%
15	16	19,168	124.2	101,910,932	101,911	261.1	54.47%	54.47%	6.16%
Sum	335	**311,330**	15.83	**187,100,383**	***187,100***	23.21	**100.00%**	0	0

Fall 1997

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1	34	47,973	0.0	0	0	0.0	0.00%	100.00%	100.00%
2	30	16,261	0.0	27,837	28	0.1	0.01%	100.00%	84.94%
3	18	21,289	0.2	136,667	137	0.2	0.06%	99.99%	79.84%
4	22	19,365	0.8	663,017	663	1.0	0.31%	99.92%	73.15%
5	21	20,863	1.3	1,187,534	1,188	1.9	0.56%	99.61%	67.08%
6	28	17,347	2.4	1,744,656	1,745	2.7	0.82%	99.05%	60.53%
7	33	17,518	4.0	2,991,403	2,991	4.4	1.41%	98.23%	55.08%
8	34	15,746	4.5	3,059,452	3,059	5.2	1.44%	96.81%	49.58%
9	25	21,080	7.0	6,288,121	6,288	5.4	2.97%	95.37%	44.64%
10	21	19,737	9.4	7,914,769	7,915	8.8	3.74%	92.40%	38.02%
11	27	18,893	10.9	8,797,258	8,797	9.6	4.15%	88.67%	31.83%
12	21	19,511	19.4	16,216,094	16,216	18.1	7.65%	84.52%	25.90%
13	29	16,852	31.1	22,415,578	22,416	30.5	10.58%	76.86%	19.77%
14	24	20,291	44.6	38,765,476	38,765	33.3	18.29%	66.28%	14.48%
15	16	25,844	91.9	101,690,813	101,691	100.9	47.99%	47.99%	8.11%
Sum	383	**318,570**	15.17	**211,898,673**	***211,899***	14.80	**100.00%**	0	0

Table 2c - SPANdex index of abundance from fall research vessel surveys in NAFO Divisions 3L, 3N, 3O and 3P. Estimates do not include sets in Subdiv. 3Ps.

Fall 1995

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1	33	32035	0.0	13,710	14	0.0	0.01%	100.00%	100.00%
2	21	18640	0.2	183,481	183	0.3	0.17%	99.99%	88.59%
3	24	20444	0.4	323,732	324	0.4	0.30%	99.82%	81.95%
4	22	20867	1.0	901,984	902	0.9	0.83%	99.52%	74.67%
5	19	20125	1.0	861,298	861	1.1	0.79%	98.69%	67.23%
6	21	21892	1.3	1,199,259	1,199	1.4	1.11%	97.89%	60.07%
7	25	18780	1.9	1,535,135	1,535	2.2	1.42%	96.79%	52.27%
8	23	17013	4.2	3,058,072	3,058	4.3	2.82%	95.37%	45.58%
9	23	15470	5.4	3,542,106	3,542	4.4	3.27%	92.55%	39.52%
10	19	16622	7.1	5,072,129	5,072	5.8	4.68%	89.28%	34.01%
11	26	13899	10.9	6,459,975	6,460	8.6	5.96%	84.60%	28.09%
12	22	15687	16.2	10,869,366	10,869	16.7	10.03%	78.63%	23.14%
13	23	18224	23.6	18,414,383	18,414	20.7	16.99%	68.60%	17.55%
14	29	16551	29.4	20,811,027	20,811	20.9	19.21%	51.61%	11.06%
15	23	14494	56.6	35,109,300	35,109	44.6	32.40%	32.40%	5.16%
Sum	353	280,743	10.61	108,354,958	108,355	8.82	100.00%	0	0

Fall 1996

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1	51	64,204	0.0	0	0	0.0	0.00%	100.00%	100.00%
2	12	5,339	0.0	2,285	2	0.0	0.00%	100.00%	75.55%
3	5	5,374	0.1	16,100	16	0.1	0.02%	100.00%	73.52%
4	3	5,060	0.4	75,794	76	0.3	0.09%	99.98%	71.47%
5	4	6,169	0.4	95,046	95	0.5	0.12%	99.88%	69.55%
6	16	8,657	0.2	81,509	82	0.4	0.10%	99.76%	67.20%
7	20	22,433	0.6	566,444	566	0.6	0.71%	99.66%	63.90%
8	24	17,126	0.9	644,995	645	1.5	0.80%	98.96%	55.36%
9	7	5,394	2.1	482,475	482	2.6	0.60%	98.15%	48.84%
10	16	10,700	2.0	915,865	916	2.7	1.14%	97.55%	46.78%
11	32	25,513	3.2	3,537,725	3,538	3.3	4.41%	96.41%	42.71%
12	22	14,958	7.3	4,698,801	4,699	5.5	5.86%	92.00%	32.99%
13	3	6,303	9.3	2,516,787	2,517	0.4	3.14%	86.14%	27.30%
14	10	15,714	10.5	7,027,818	7,028	6.1	8.76%	83.01%	24.90%
15	48	49,669	28.0	59,562,242	59,562	22.0	74.25%	74.25%	18.91%
Sum	273	262,613	4.33	80,223,885	80,224	3.07	100.00%	0	0

Fall 1997

Density Class	Set Count	3LNOP Area	Mean Kg per tow	Biomass kg	Biomass t	Stdev	% of Biomass	Cumulative Biomass	% of Area
1	54	57,823	0.0	24,747	25	0.0	0.02%	100.00%	100.00%
2	21	15,603	0.1	80,132	80	0.2	0.06%	99.98%	78.07%
3	11	16,100	0.5	330,738	331	0.7	0.25%	99.92%	72.16%
4	22	14,766	0.7	423,404	423	1.0	0.33%	99.66%	66.05%
5	15	16,627	1.8	1,252,403	1,252	2.1	0.96%	99.34%	60.45%
6	20	11,579	1.4	708,638	709	2.0	0.55%	98.37%	54.15%
7	21	15,710	3.5	2,380,109	2,380	3.3	1.83%	97.83%	49.76%
8	35	10,689	3.8	1,756,652	1,757	4.6	1.35%	95.99%	43.80%
9	24	13,484	5.7	3,260,504	3,261	5.4	2.51%	94.64%	39.75%
10	16	14,865	8.1	5,134,001	5,134	6.1	3.95%	92.13%	34.64%
11	17	14,527	10.2	6,353,958	6,354	10.2	4.89%	88.18%	29.00%
12	18	14,597	14.8	9,264,506	9,265	14.8	7.14%	83.28%	23.49%
13	17	14,279	31.4	19,207,006	19,207	23.0	14.79%	76.15%	17.96%
14	18	14,688	43.5	27,313,033	27,313	29.1	21.04%	61.35%	12.54%
15	13	18,389	66.5	52,335,604	52,336	51.2	40.31%	40.31%	6.97%
Sum	322	263,726	12.80	129,825,435	129,825	10.24	100.00%	0	0

Table 3 - Length, weight and wing width relationships for skate in Divs. 3LNO and Subdiv. 3Ps.

Total Length		Wing Width		Average
(cm)	(in)	(cm)	(in)	Weight (kg)
10	3.94	7.48	2.94	0.01
13	5.12	9.72	3.83	0.02
16	6.30	11.96	4.71	0.04
19	7.48	14.20	5.59	0.06
22	8.66	16.45	6.47	0.09
25	9.84	18.69	7.36	0.14
28	11.02	20.93	8.24	0.20
31	12.20	23.17	9.12	0.27
34	13.39	25.42	10.01	0.36
37	14.57	27.66	10.89	0.46
40	15.75	29.90	11.77	0.58
43	16.93	32.14	12.65	0.73
46	18.11	34.39	13.54	0.90
49	19.29	36.63	14.42	1.09
52	20.47	38.87	15.30	1.30
55	21.65	41.11	16.19	1.55
58	22.83	43.36	17.07	1.82
61	24.02	45.60	17.95	2.12
64	25.20	47.84	18.83	2.57
67	26.38	50.08	19.72	2.92
70	27.56	52.33	20.60	3.30
73	28.74	54.57	21.48	3.71
76	29.92	56.81	22.37	4.15
79	31.10	59.05	23.25	4.63
82	32.28	61.30	24.13	5.14
85	33.46	63.54	25.01	5.68
88	34.65	65.78	25.90	6.26
91	35.83	68.02	26.78	6.88
94	37.01	70.27	27.66	7.54
97	38.19	72.51	28.55	8.23
100	39.37	74.75	29.43	8.97
103	40.55	76.99	30.31	9.75
106	41.73	79.24	31.19	9.96
109	42.91	81.48	32.08	
112	44.09	83.72	32.96	
115	45.28	85.96	33.84	

Table 4 - Percent difference between spring and fall estimates of biomass, abundance and mean size by area and year.

Biomass (tonnes)

	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All Division
Year	core	all	core	all	core	all	core	all	core
1986	38.27%								38.27%
1987	6.61%								6.61%
1988	35.00%								35.00%
1989	-7.98%								-7.98%
1990	52.60%		29.62%		36.46%				39.56%
1991	57.84%		72.18%		-31.08%				32.98%
1992	70.35%		56.50%		-36.68%				30.05%
1993	64.53%		47.79%		45.39%				52.57%
1994	76.99%	75.81%	80.07%	79.99%	9.56%	9.56%			55.33%
1995	90.25%	90.18%	97.27%	97.27%	71.50%	71.50%			86.33%
1996	63.60%	65.47%	61.54%	61.54%	3.90%	3.90%			43.32%
1997	45.78%	47.32%	77.47%	77.47%	51.35%	51.35%			58.46%
1998									
Avg.	49.49%	69.70%	65.30%	79.07%	18.80%	34.08%			39.21%
90-98	65.24%	69.70%	65.30%	79.07%	18.80%	34.08%			

Abundance (thousands)

Year	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All
1986	32.08%								32.08%
1987	51.59%								51.59%
1988	59.57%								59.57%
1989	47.46%								47.46%
1990	62.37%		-63.39%		24.58%				7.85%
1991	52.73%		27.13%		-18.58%				20.42%
1992	60.16%		39.02%		-44.14%				18.34%
1993	54.86%		45.07%		63.70%				54.54%
1994	64.30%	63.80%	65.07%	64.97%	37.86%	37.86%			55.65%
1995	83.46%	83.39%	92.23%	92.23%	63.81%	63.81%			79.82%
1996	54.69%	55.64%	53.13%	35.98%	49.65%	49.65%			49.79%
1997	48.93%	49.41%	55.62%	63.95%	48.78%	48.78%			52.58%
1998									
Avg.	56.02%	63.06%	39.23%	64.28%	28.21%	50.03%			44.14%
90-98	60.19%	63.06%	39.23%	64.28%	28.21%	50.03%			

Mean Weight (kg)

Year	Div. 3L		Div. 3N		Div. 3O		Div. 3P		All
1986	9.11%								9.11%
1987	-92.93%								-92.93%
1988	-60.76%								-60.76%
1989	-105.51%								-105.51%
1990	-25.97%		56.92%		15.76%				15.57%
1991	10.82%		61.82%		-10.54%				20.70%
1992	25.59%		28.66%		5.18%				19.81%
1993	21.43%		4.95%		-50.43%				-8.02%
1994	35.53%		42.94%		-45.55%				10.97%
1995	41.03%		64.90%		21.25%				42.39%
1996	19.65%		17.94%		-90.87%				-17.76%
1997	-6.17%		49.24%		5.03%				16.03%
1998									
Avg.	-10.68%		40.92%		-18.77%				-12.53%
90-98	15.24%		40.92%		-18.77%				

Table 5. Fishery regulations and quota allocations for thorny skate in NAFO divisions 3L, 3N, 3O and 3Ps in 1997.

Gear Type	**Vessel Size**	**Sector**	**Season**	**Gear Restrictions**	**Adjustments/reason**	**TAC**
Fixed Gear	<35'	Inshore	Inside 12 nautical miles-Aug. 1-Dec. 31 Outside 12 nautical miles-April1-Dec. 31	GN Inside 12 nautical miles-min mesh 10.5" Outside 12 nautical miles - min mesh 12"	3Ps closed May 28 due to high bycatch levels 3LN outside 12 nmi closed July 12 due to high bycatch	3L-100 3Ps-250
Fixed Gear	35-64'	Inshore	Same as above	Same as above	3Ps closed May 28 due to high bycatch levels	3LN-150 3O-575 3Ps-250
Fixed Gear	65'-100'	Inshore	Jan. 1- Dec. 31	GN min mesh size 12"		3LN-50 3O-150 3Ps-100
Mobile Gear	<65'	Inshore	April 1- Dec. 31	GN min mesh size 300mm for codend 254 for rest of trawl	3Ps closed May 4 – quota filled	For all mobile gear 3LN-150 3O-775 3Ps-450
Mobile Gear	65'-100'	Inshore	April 1- Dec. 31	GN min mesh size 300mm for codend 250 for rest of trawl	As above	As above
Mobile Gear	>100'	Offshore	Jan. 1- Dec. 31	GN min mesh size 300mm for codend 250 for rest of trawl	As above	As above

Table 6. Domestic landings of thorny skate in NAFO divisions 3LNOP, by gear type and month 1985-1997.

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	17
	1986	0	0	0	0	0	0	0	0	0	0	0	0	1
	1987	0	0	0	0	0	0	1	0	0	0	0	0	131
	1988	0	0	0	0	17	0	0	1	0	0	0	0	44
	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	8
	1992	0	0	0	0	0	0	0	0	0	0	0	0	15
	1993	0	0	0	1	1	0	4	0	0	2	0	0	15
	1994	0	0	0	0	1	14	9	0	35	0	34	49	728
	1995	2	7	101	108	335	15	37	62	10	7	0	8	585
	1996	0	1	14	445	65	58	1	6	4	1	2	4	188
	1997	7	1	10	57	337	315	47	3	0	0	0	0	145
Lines	1985	0	0	0	0	0	0	0	0	0	0	0	0	13
	1987	0	0	0	0	0	0	0	0	0	0	0	0	67
	1988	0	0	0	16	0	0	0	0	0	0	0	0	1
	1990	0	0	0	0	1	0	0	0	0	0	0	0	0
	1991	0	0	0	0	13	0	0	0	0	0	0	0	0
	1992	0	0	0	0	0	0	1	22	9	1	0	0	18
	1993	0	0	0	1	4	1	0	3	0	0	0	0	13
	1994	0	0	0	8	0	0	9	14	0	0	0	0	4
	1995	0	0	2	33	5	32	248	214	2	0	0	39	0
	1996	13	0	8	199	0	0	1	44	3	3	22	47	0
	1997	0	31	85	67	5	1	0	0	8	50	71	54	32
Trawl	1986	0	0	0	1	0	0	0	0	0	0	0	0	85
	1987	0	0	0	0	0	0	0	0	0	0	0	0	42
	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	2	3	0	0	0	0	1	0	0	2
	1992	6	0	0	0	0	0	0	0	0	0	0	0	0
	1993	0	0	0	0	3	29	0	9	0	1	1	2	0
	1994	0	0	0	50	34	64	7	138	130	609	354	64	1,387
	1995	0	0	504	2,120	0	0	0	0	21	7	0	0	22
	1996	0	0	0	401	254	35	0	10	16	2	4	2	0
	1997	0	1	0	385	739	105	185	60	17	1	7	0	0

Table 7 - Observed summary statistics for the observed domestic skate fishery, 1993-1998.

Otter trawl Observed Fishery

		t/hour				Catch (t)					Depth (m)			
Month	Sets	MIN	MAX	MEAN	STDDEV	SUM	MIN	MAX	MEAN	STDDEV	MIN	MAX	MEAN	STDDEV
4	114	0.01	2.25	0.77	0.51	235.24	0.01	5.20	2.06	1.10	79	360	156	74
5	31	0.00	2.13	0.82	0.61	68.12	0.01	4.25	2.20	1.30	99	183	124	24
7	28	0.00	1.90	0.74	0.53	68.87	0.00	7.10	2.46	1.81	159	179	168	4
8	25	0.03	2.14	1.19	0.56	86.38	0.06	7.50	3.46	1.76	53	170	162	22
9	70	0.00	2.12	0.49	0.57	110.96	0.00	6.35	1.59	1.80	46	302	117	42
10	69	0.00	6.10	0.72	0.76	216.01	0.00	25.00	3.13	3.03	91	126	109	7
All	337	0.00	6.10	0.73	0.62	785.58	0.00	25.00	2.33	2.00	46	360	137	53

Gillnet Observed Fishery

		t/100 nets				Catch (t)					Depth (m)			
Month	Sets	MIN	MAX	MEAN	STDDEV	SUM	MIN	MAX	MEAN	STDDEV	MIN	MAX	MEAN	STDDEV
4	34	1.50	24.08	5.19	3.96	44.11	0.38	6.02	1.30	0.99	128	179	138	10
5	66	0.03	12.96	1.67	2.39	24.16	0.01	3.50	0.37	0.49	110	329	168	50
6	2	0.12	0.20	0.16	0.04	0.08	0.03	0.05	0.04	0.01	229	261	245	16
8	18	0.43	2.64	0.92	0.45	1.94	0.03	0.79	0.11	0.18	15	59	26	14
All	120	0.03	24.08	2.53	3.24	70.29	0.01	6.02	0.59	0.79	15	329	139	63

Longline Observed Fishery

		t/1000 hooks				Catch (t)					Depth (m)			
Month	Sets	MIN	MAX	MEAN	STDDEV	SUM	MIN	MAX	MEAN	STDDEV	MIN	MAX	MEAN	STDDEV
3	68	0.00	0.03	0.01	0.01	10.18	0.00	0.58	0.15	0.14	91	823	125	92
4	95	0.00	0.05	0.01	0.01	6.68	0.00	0.47	0.07	0.11	82	402	196	70
5	36	0.00	0.61	0.26	0.17	25.38	0.00	1.36	0.70	0.41	112	177	136	18
8	4	0.02	0.04	0.03	0.01	0.14	0.02	0.05	0.03	0.01	311	358	335	24
9	44	0.00	0.25	0.07	0.06	4.32	0.00	0.36	0.10	0.09	33	369	94	103
10	44	0.03	1.76	0.86	0.46	74.19	0.01	3.52	1.69	0.88	37	113	97	16
All	291	0.00	1.76	0.18	0.35	120.89	0.00	3.52	0.42	0.69	33	823	143	86

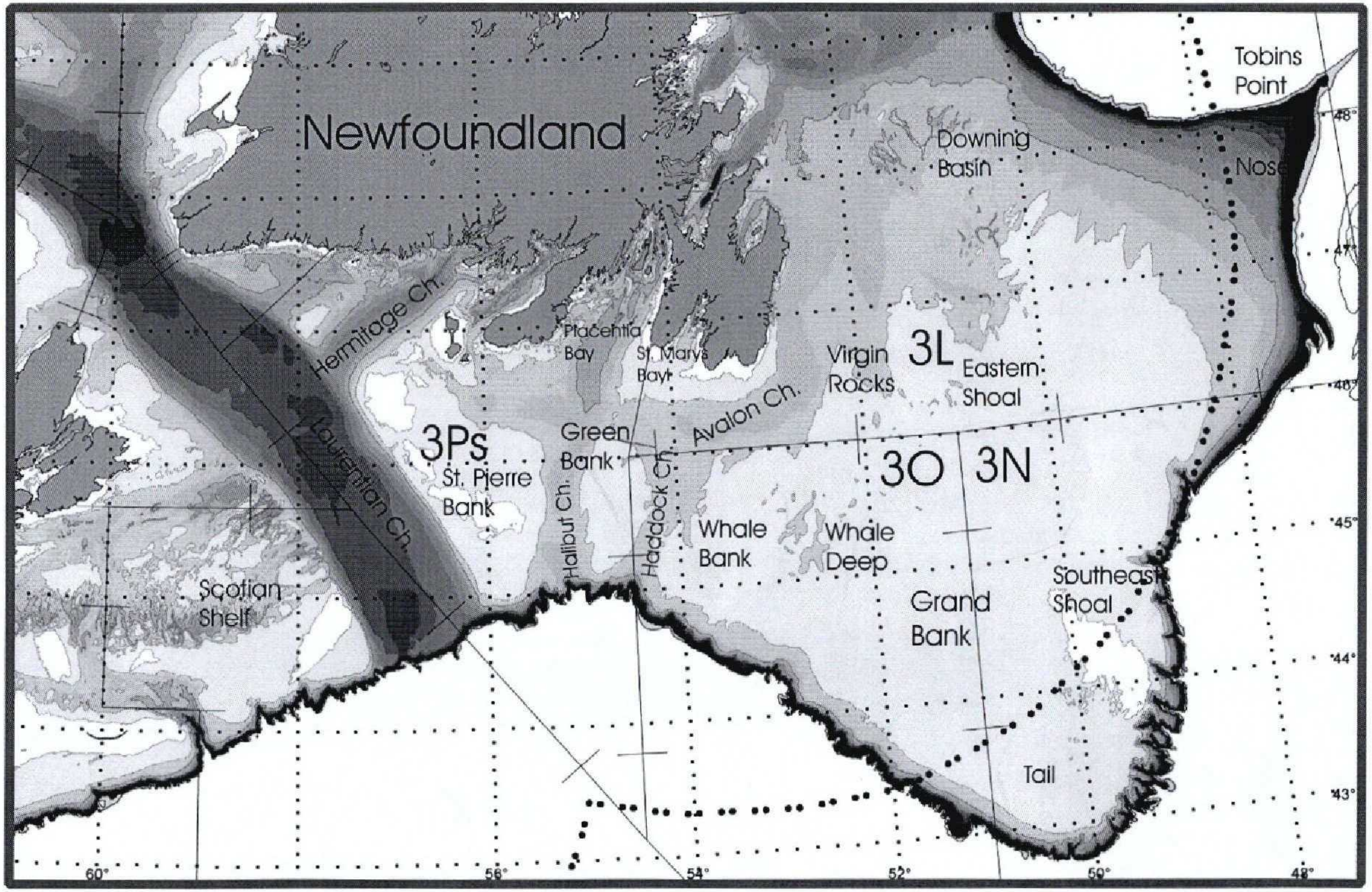


Figure 1- Study area for thorny skate showing NAFO Divisions, the 200 mile limit, specific locations and bathymetry (0 to 450 m by 50 m then 500 to 1000 m by 100 m).

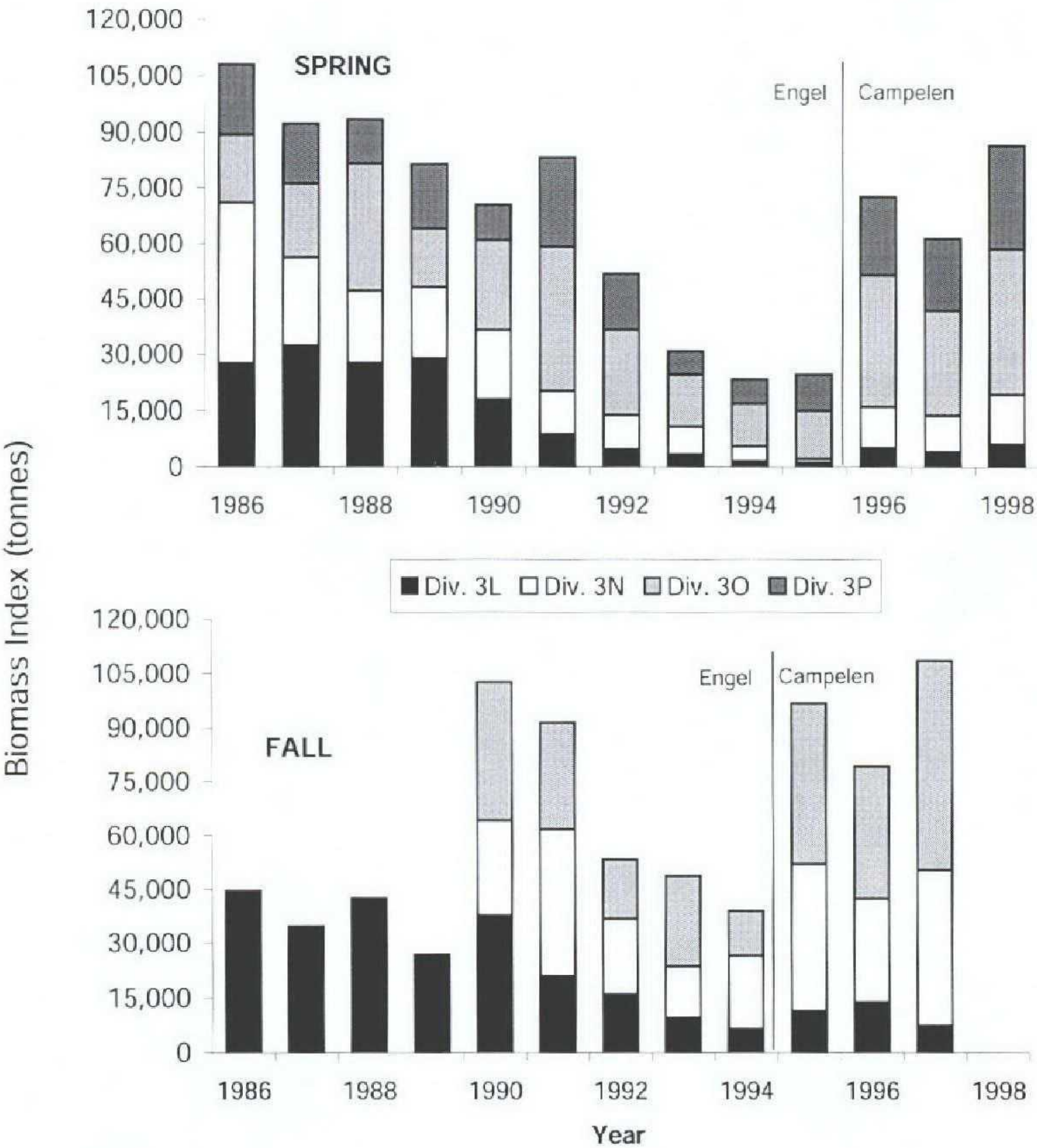


Figure 2. Spring and fall research survey biomass indices for thorny skate in NAFO divisions 3L, 3N, 3O and subdivision 3Ps, 1986-1998. Data for 1998 are incomplete.

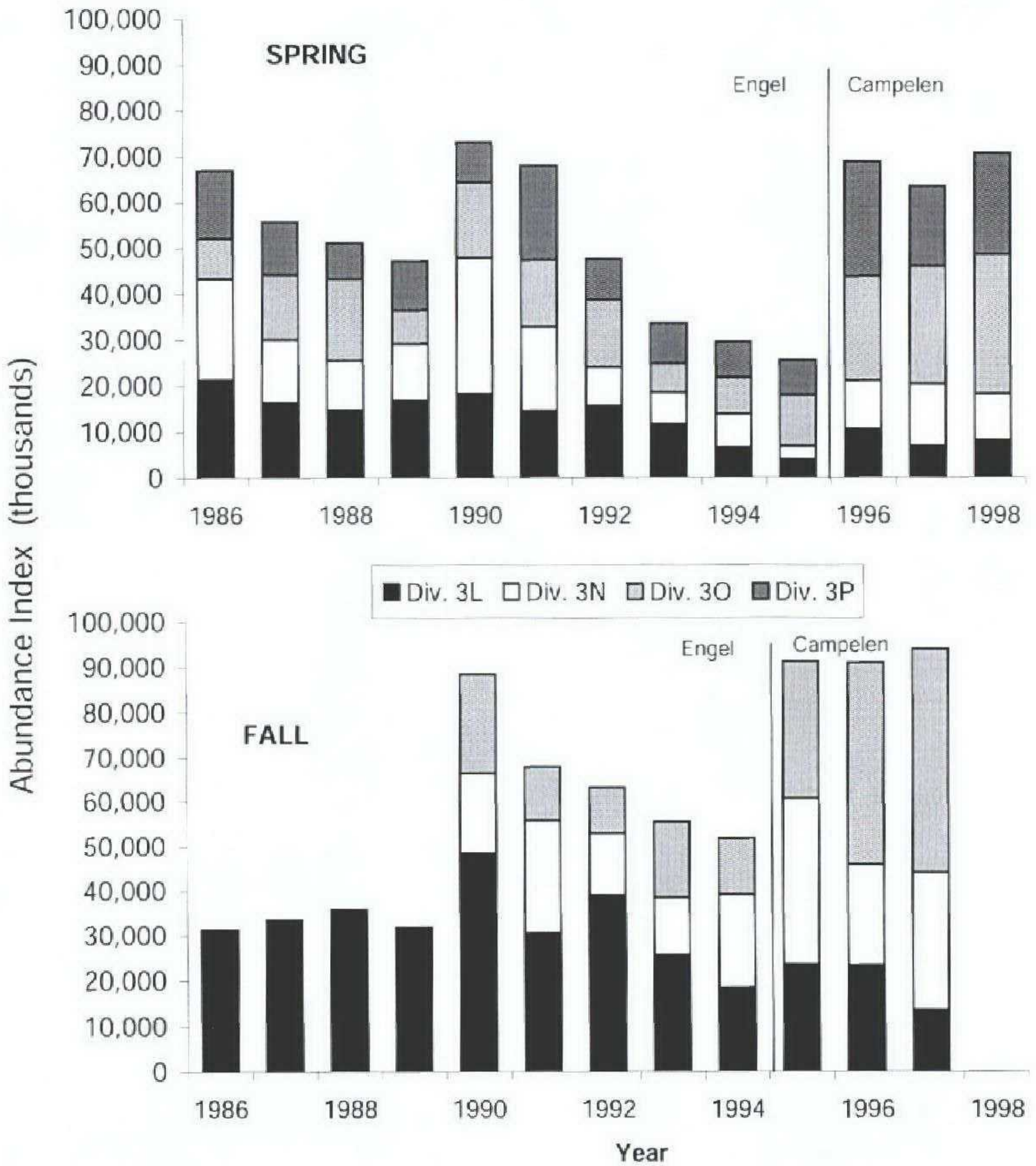


Figure 3. Spring and fall research survey abundance indices for thorny skate in NAFO divisions 3L, 3N, 3O and subdivision 3Ps, 1986-1998. Data for 1998 are incomplete.

Year	SPANdex Fall (t)	Strap Fall	SPANdex Spring	Strap Spring	
1995	108,355	96,727		24,584	*(Engel)*
1996	80,224	79,314	91,963	73,383	
1997	129,825	108,555	91,121	62,670	
(Includes Laur Ch sets) 1995	128,760				
(Includes Laur Ch sets) 1996	187,100				
(Includes Laur Ch sets) 1997	211,899				

Change between Years	SPANdex Fall	Strap Fall	SPANdex Spring	Strap Spring
1995				
1996	-25.96%	-18.00%		198.50%
1997	61.83%	36.87%	-0.92%	-14.60%

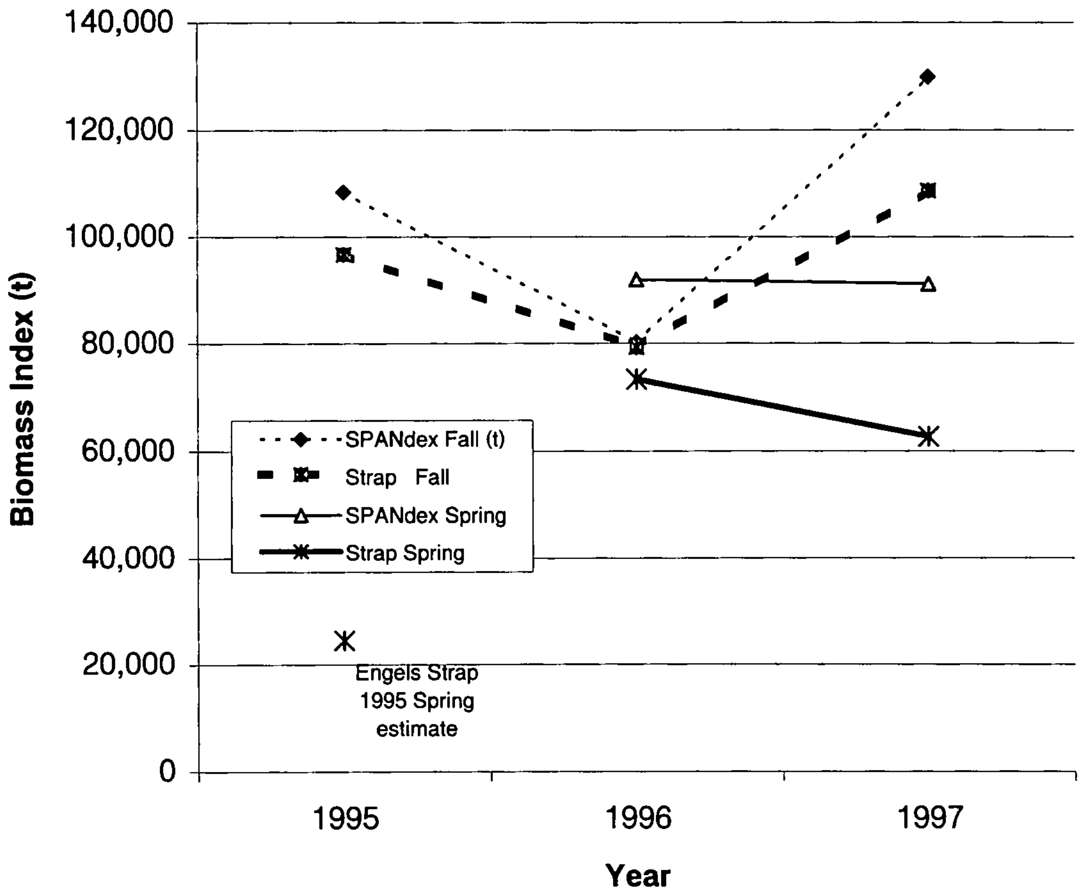


Figure 4 - A comparison of biomass indices for skate from spring and fall surveys, 1995-1997. The upper table shows estimates (tonnes) from standard surveys and estimates incuding sets from 3P. The lower table shows percent changes between years.

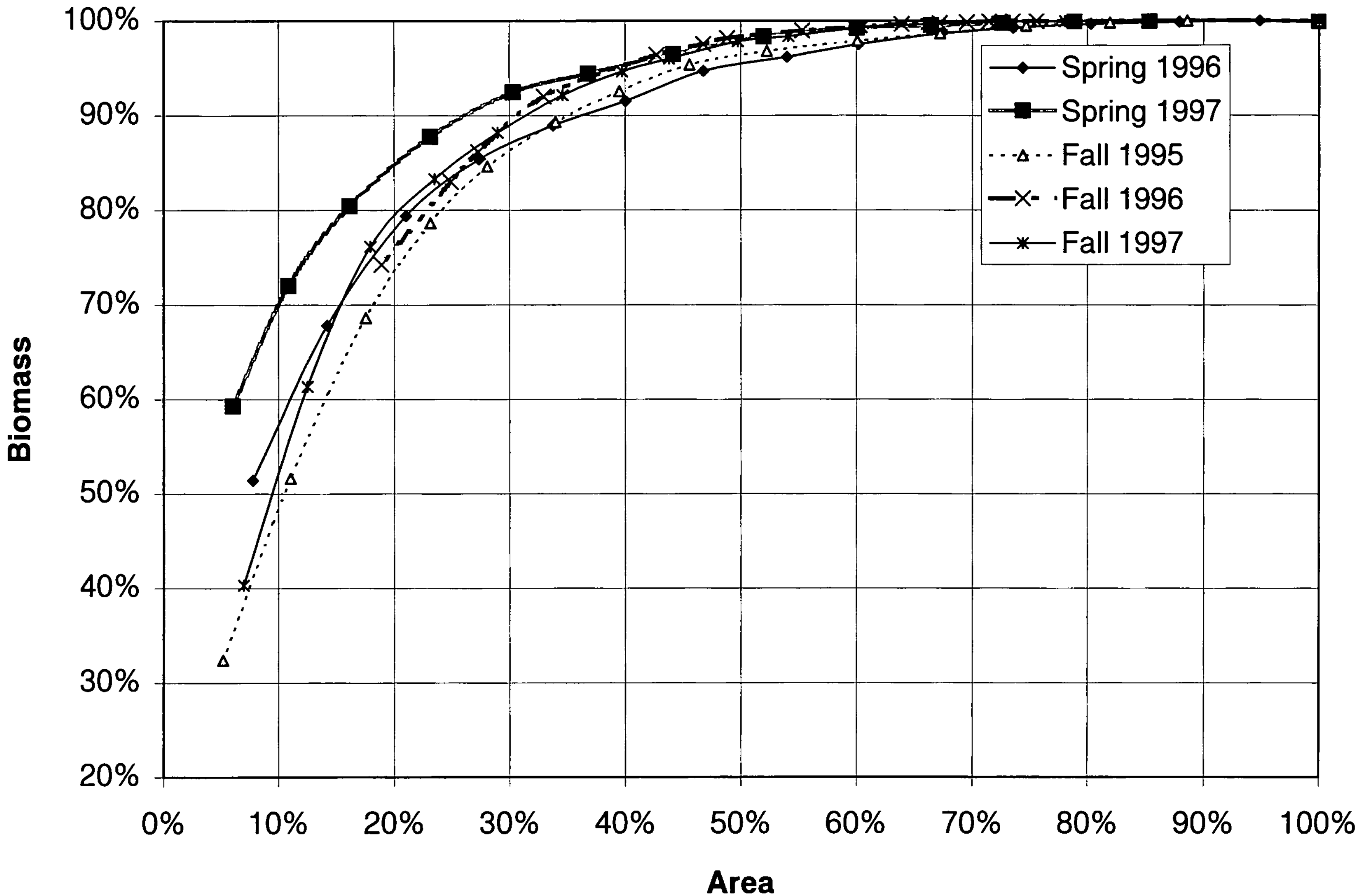


Figure 5 - Percent of biomass as a function of percent of area from SPANdex calculations for spring and fall surveys using Campelen gear.

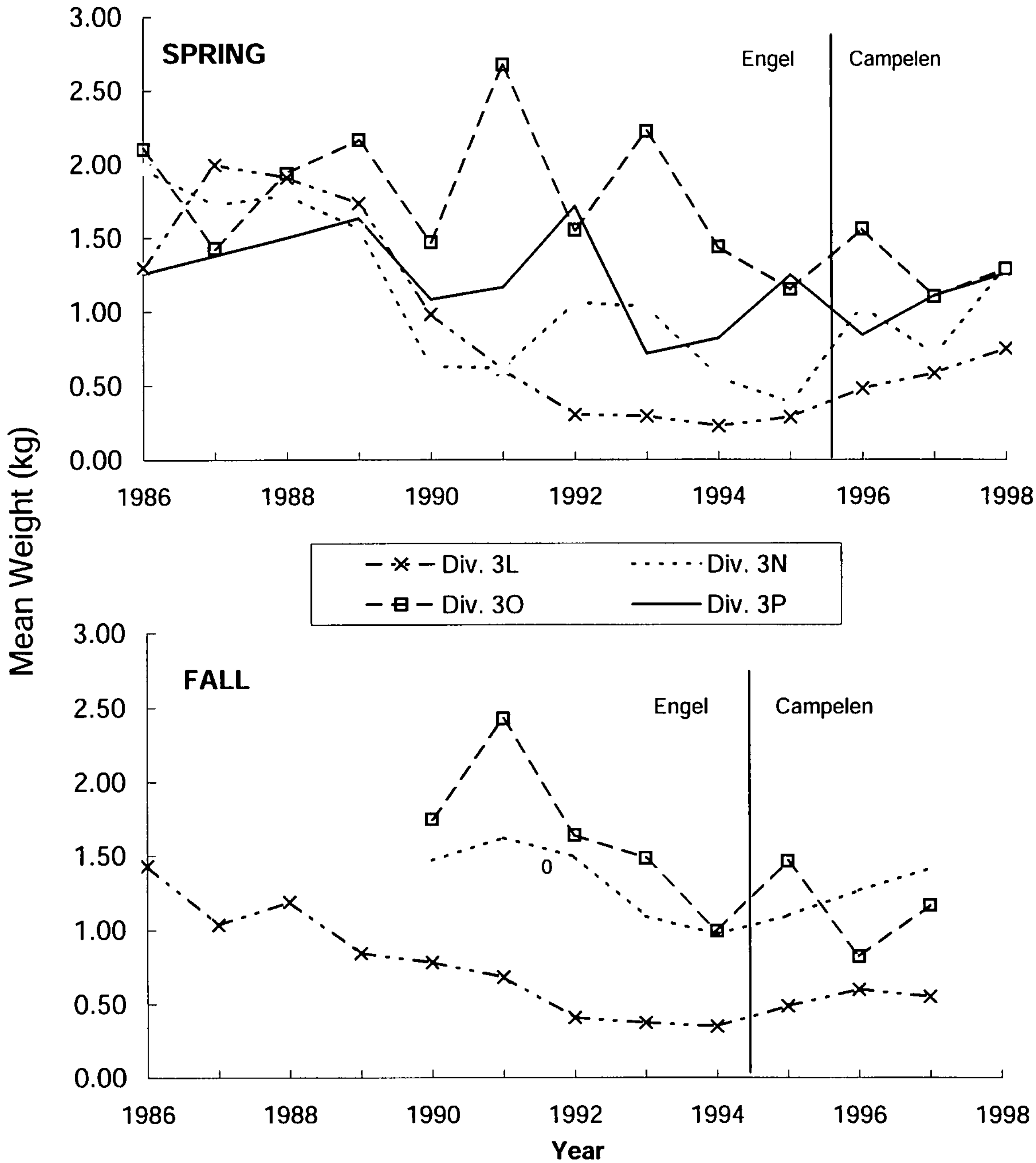


Figure 6. Mean weight of thorny skate in spring and fall research surveys in NAFO divisions 3L, 3N, 3O and subdivision 3Ps, 1986-1998. Data for 1998 are incomplete.

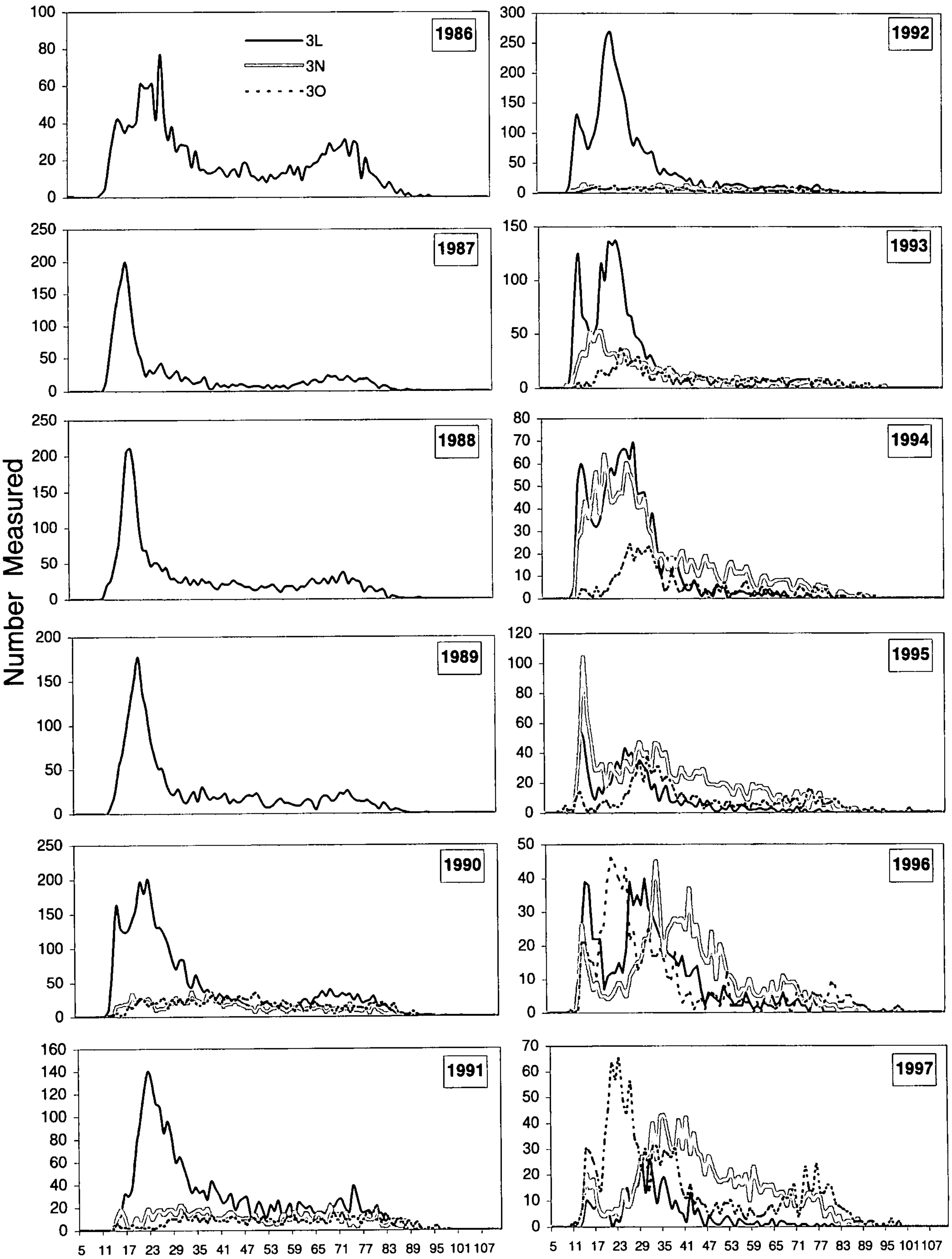


Figure 7a - Length frequency (cm) of thorny skate caught by fall research vessel surveys in NAFO divisions 3LNOPs, 1986-1997.

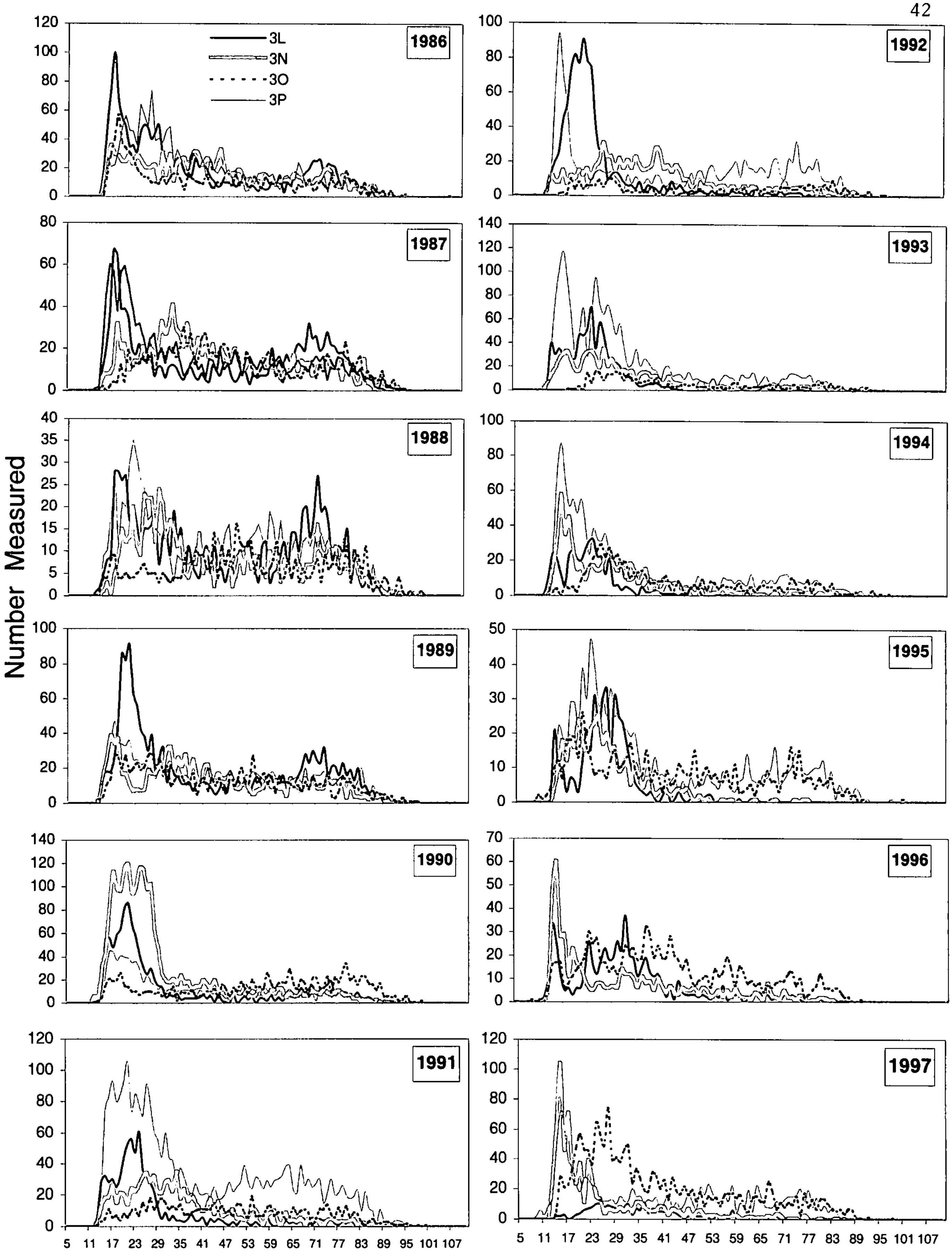


Figure 7b - Length frequency (cm) of Thorny Skate caught by spring research vessel surveys in NAFO divisions 3LNOPs, 1986-1997.

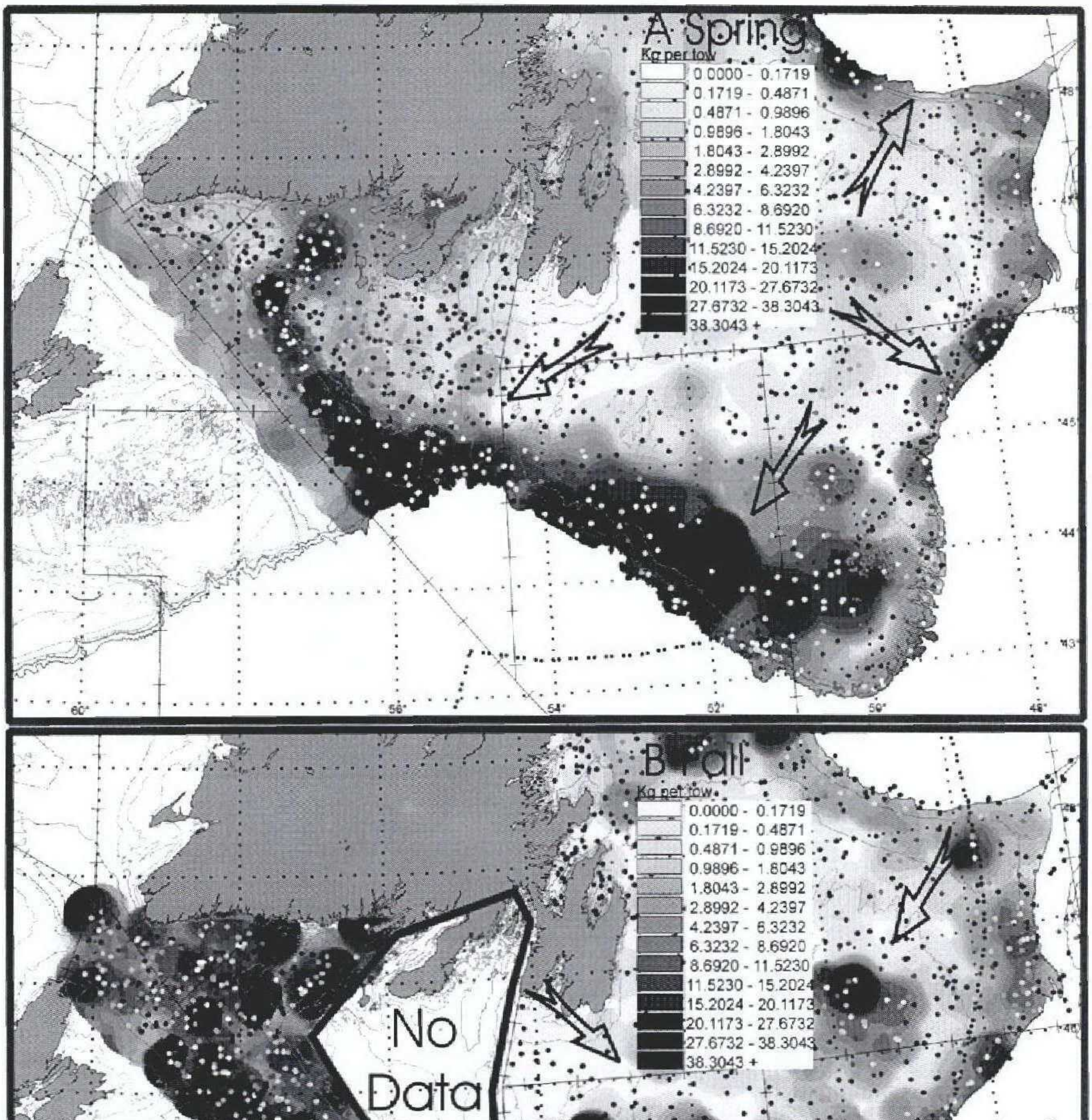


Figure 8 - Biomass of thorny skate from 1995 to 1998 combined research vessel survey Campelen trawls combined shown as kg per tow. Arrows show the general direction of movement of skate. The inner part of 3Ps was not sampled in the fall. The outer edges and Laurentian Channel data are from Aug.

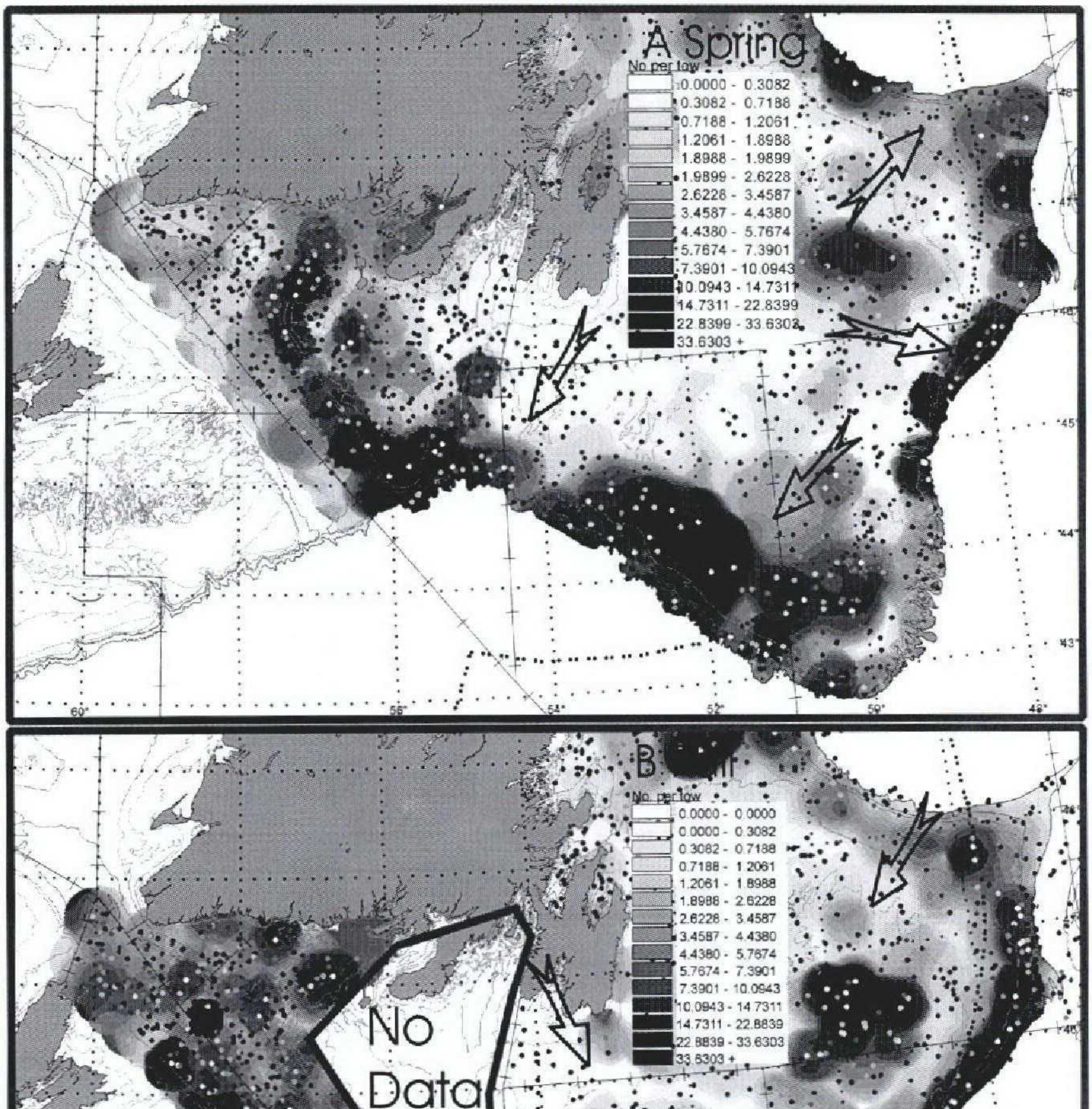


Figure 9 - Abundance of thorny skate from 1995 to 1998 combined research vessel survey Campelan trawls combined shown as numbers of fish per tow.

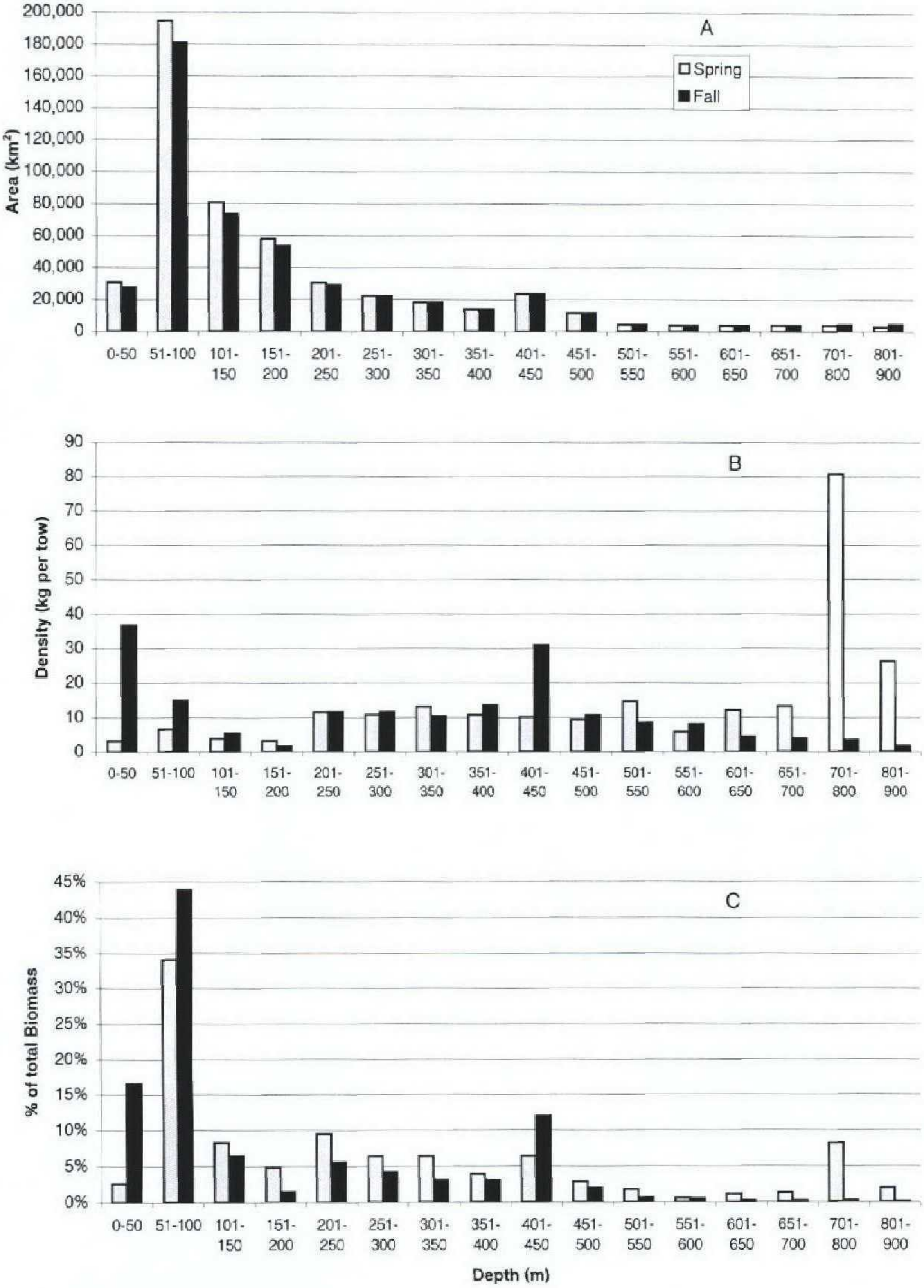


Figure 10 - Available habitat at depth in the surveyed area (A) in relation to thorny skate density at depth (B) and percent of biomas at depth (C) comparing spring and fall surveys, 1995-97.

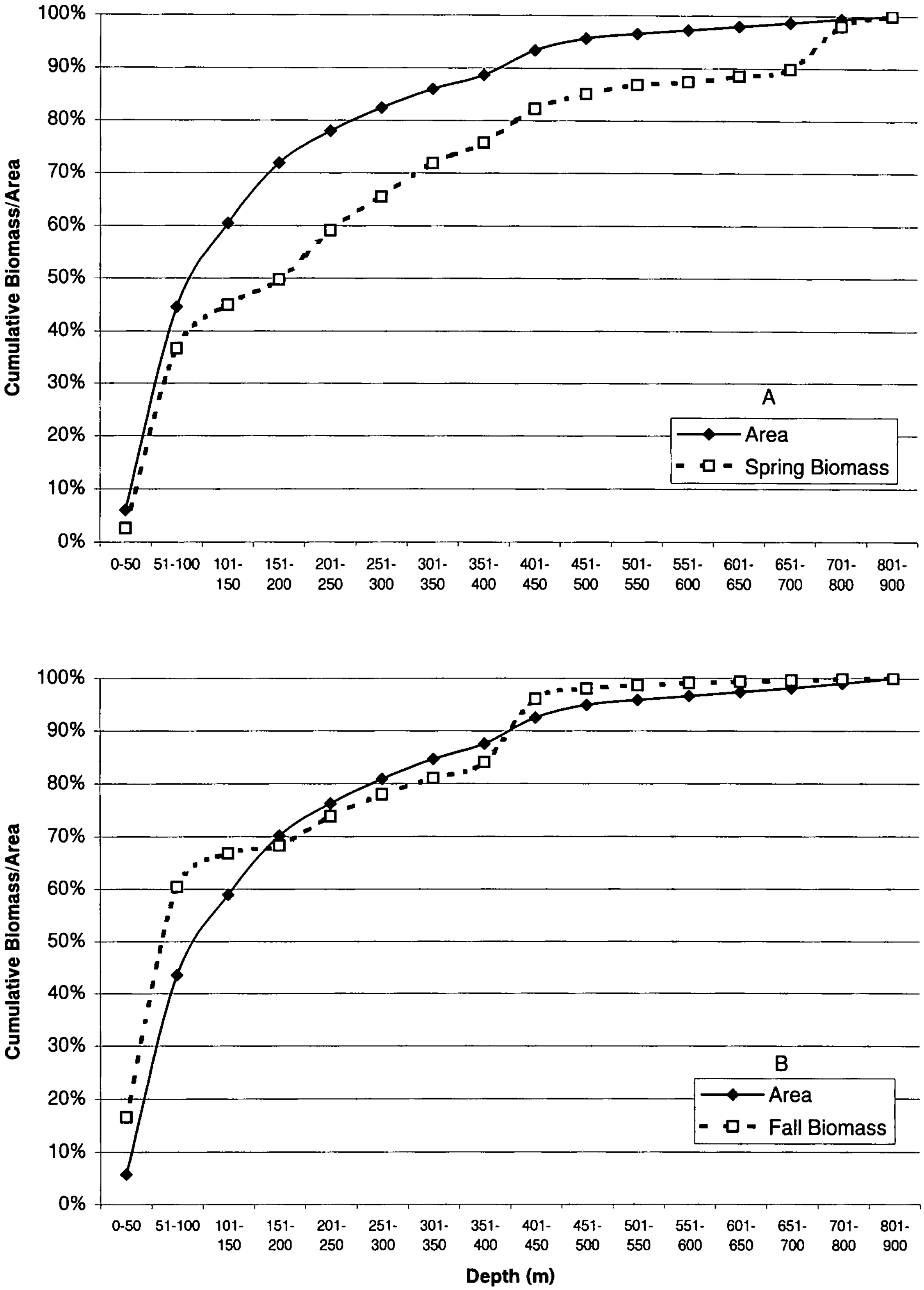


Figure 11 - Cumulative biomass of thorny skate versus cumulative available habitat at depth comparing the spring (A) and fall (B) survey periods, 1995-97.

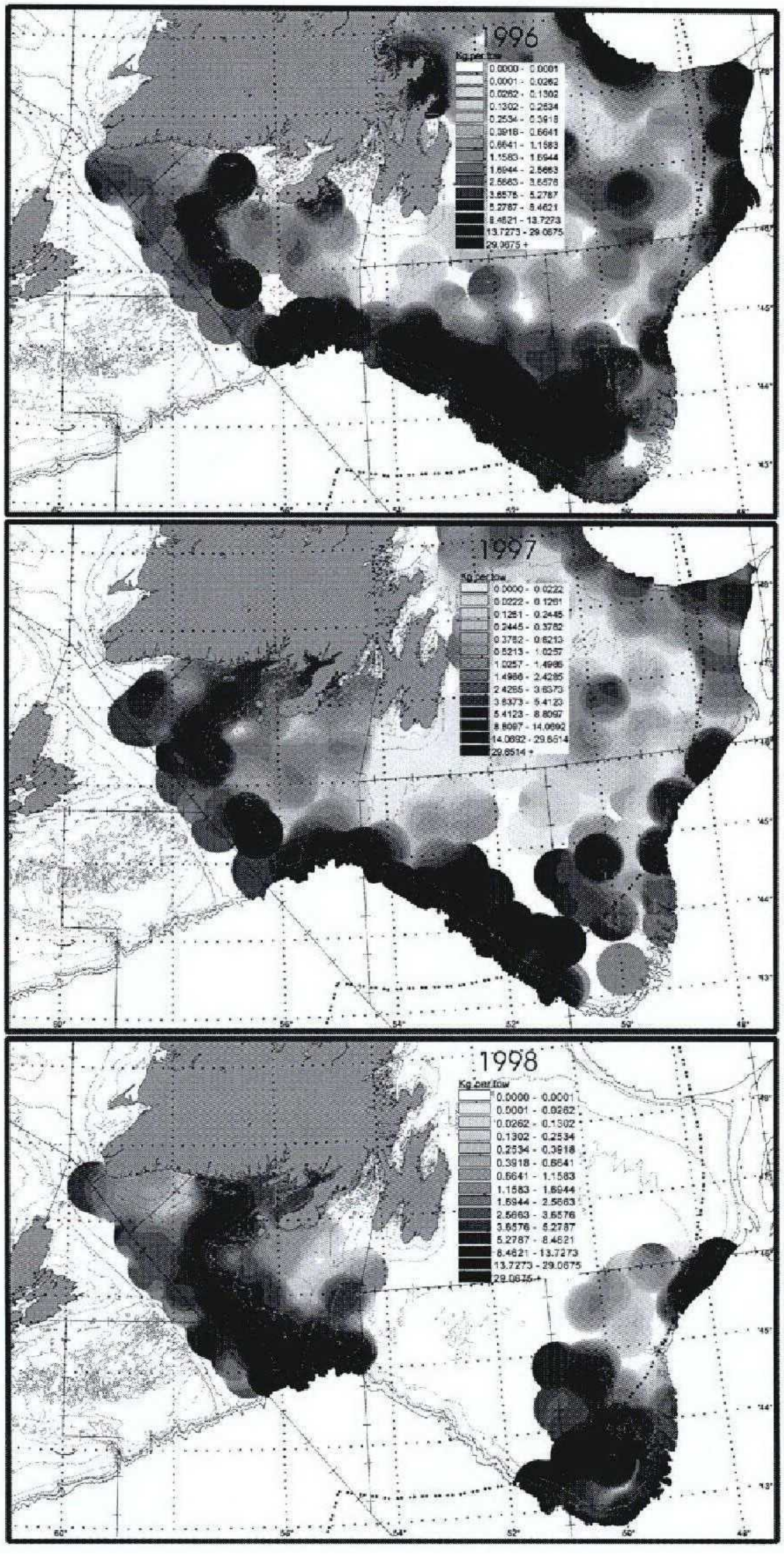


Figure 12 - Biomass of thorny skate from spring research surveys, 1996 to 1998 (3P and 3N only in 1998) shown on the same scale to illustrate changes among years.

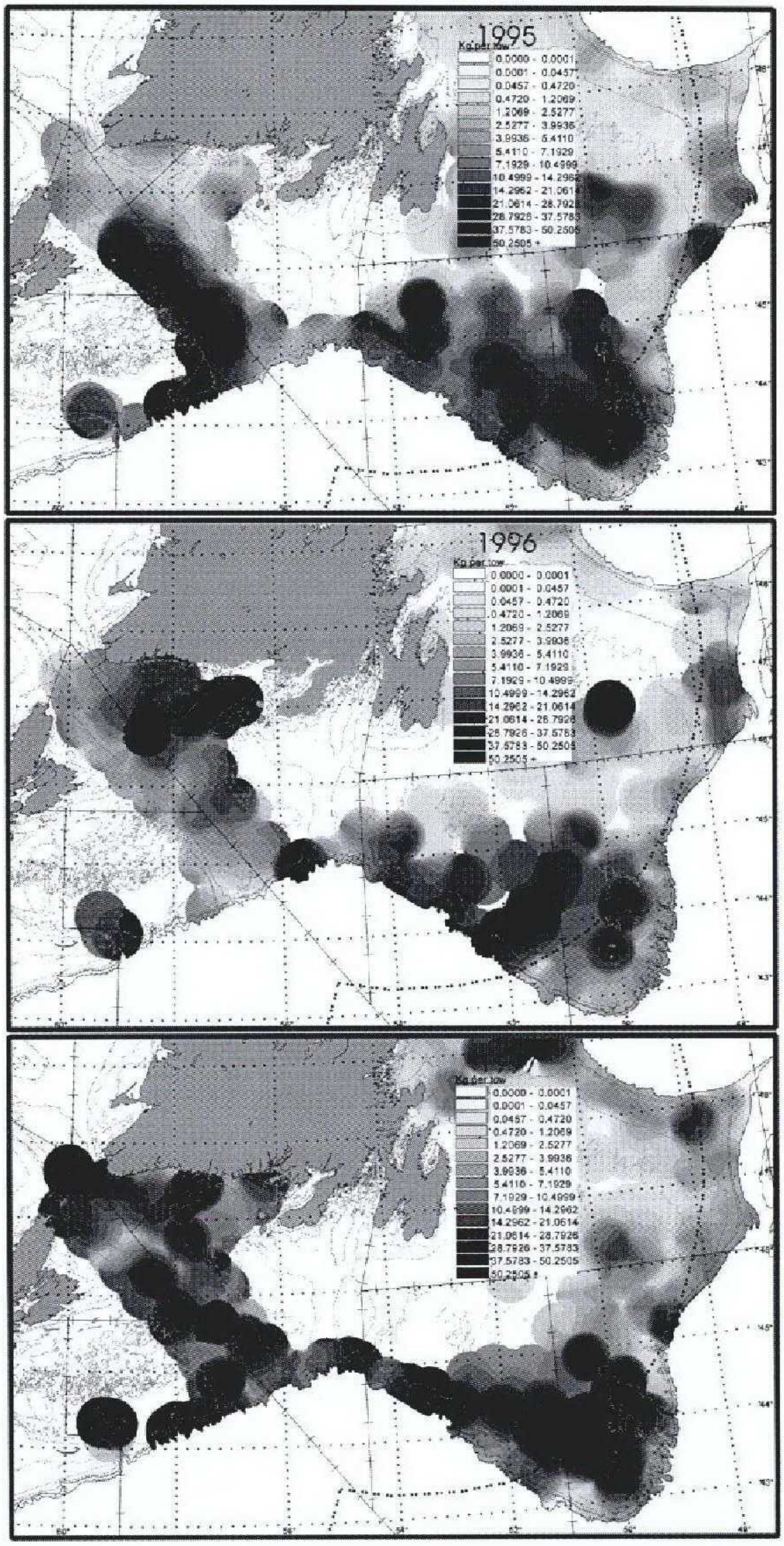


Figure 13 - Biomass of thorny skate from fall research surveys, 1995 to 1997 shown on the same scale to illustrate changes among years.

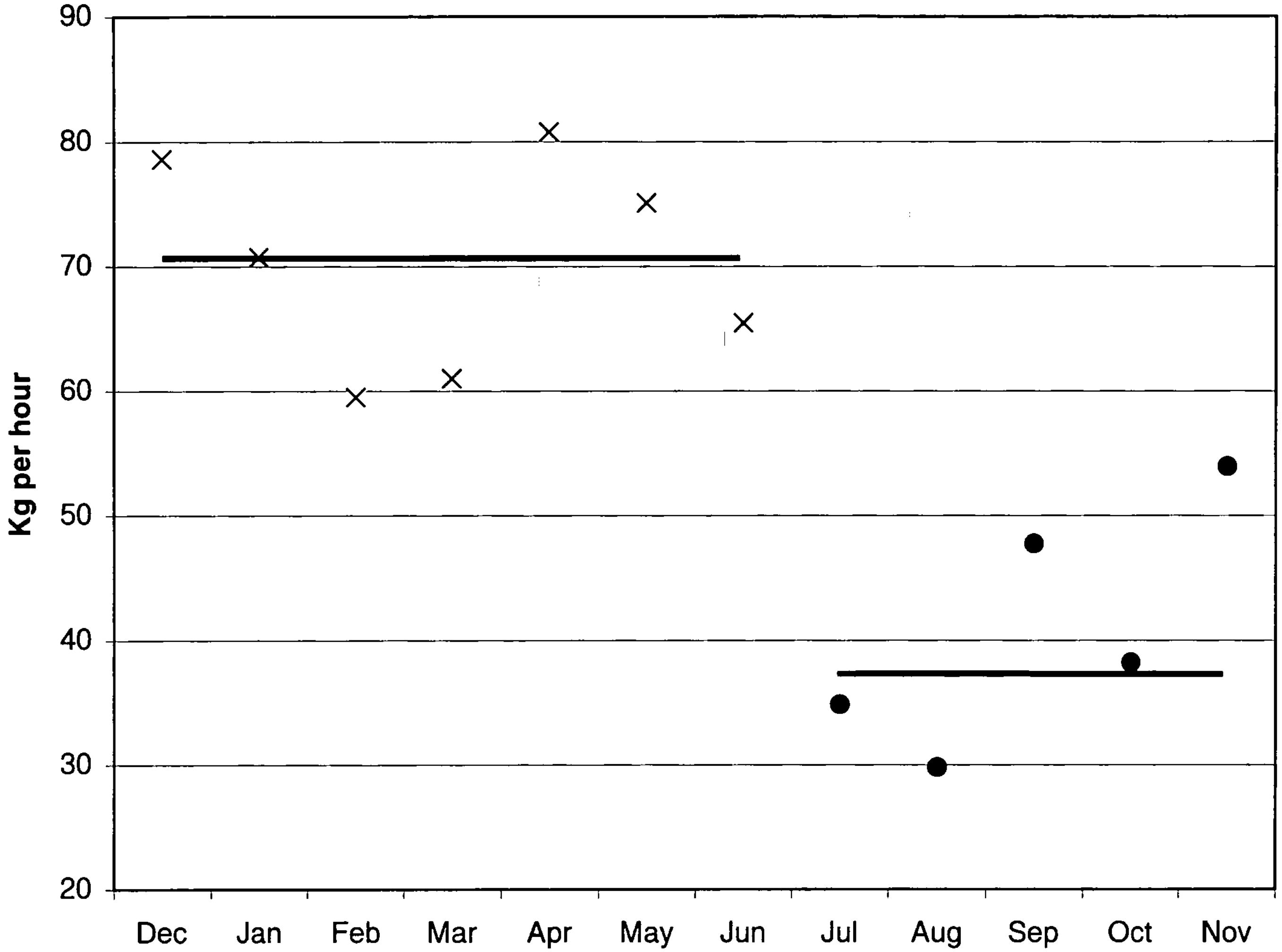


Figure 14 - Catch rate of skate from deep water Spanish otter trawl fisheries along the shelf edge outside 200 miles, 1995-97.

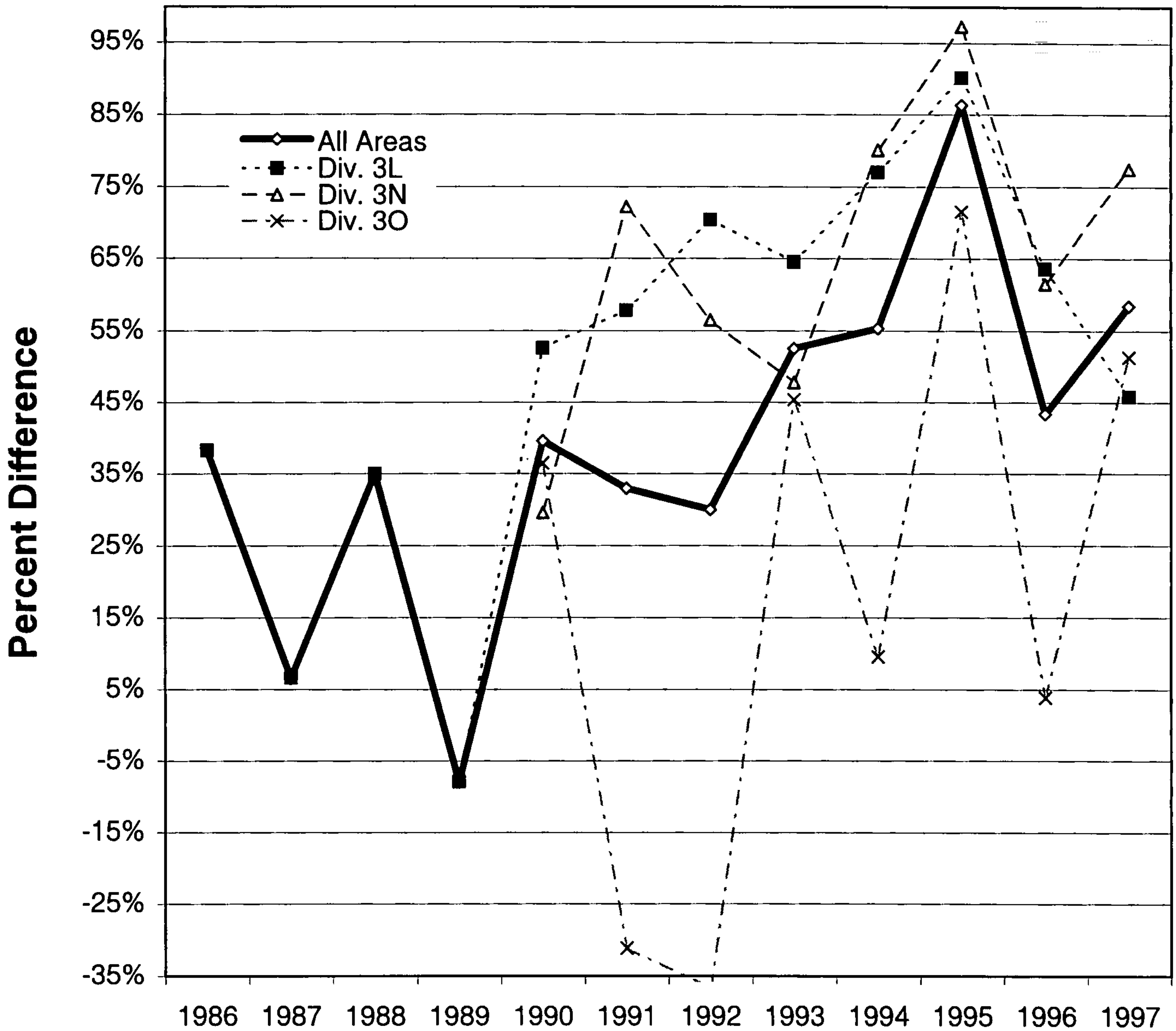


Figure 15 - Percent difference between spring and fall survey biomass estimates.

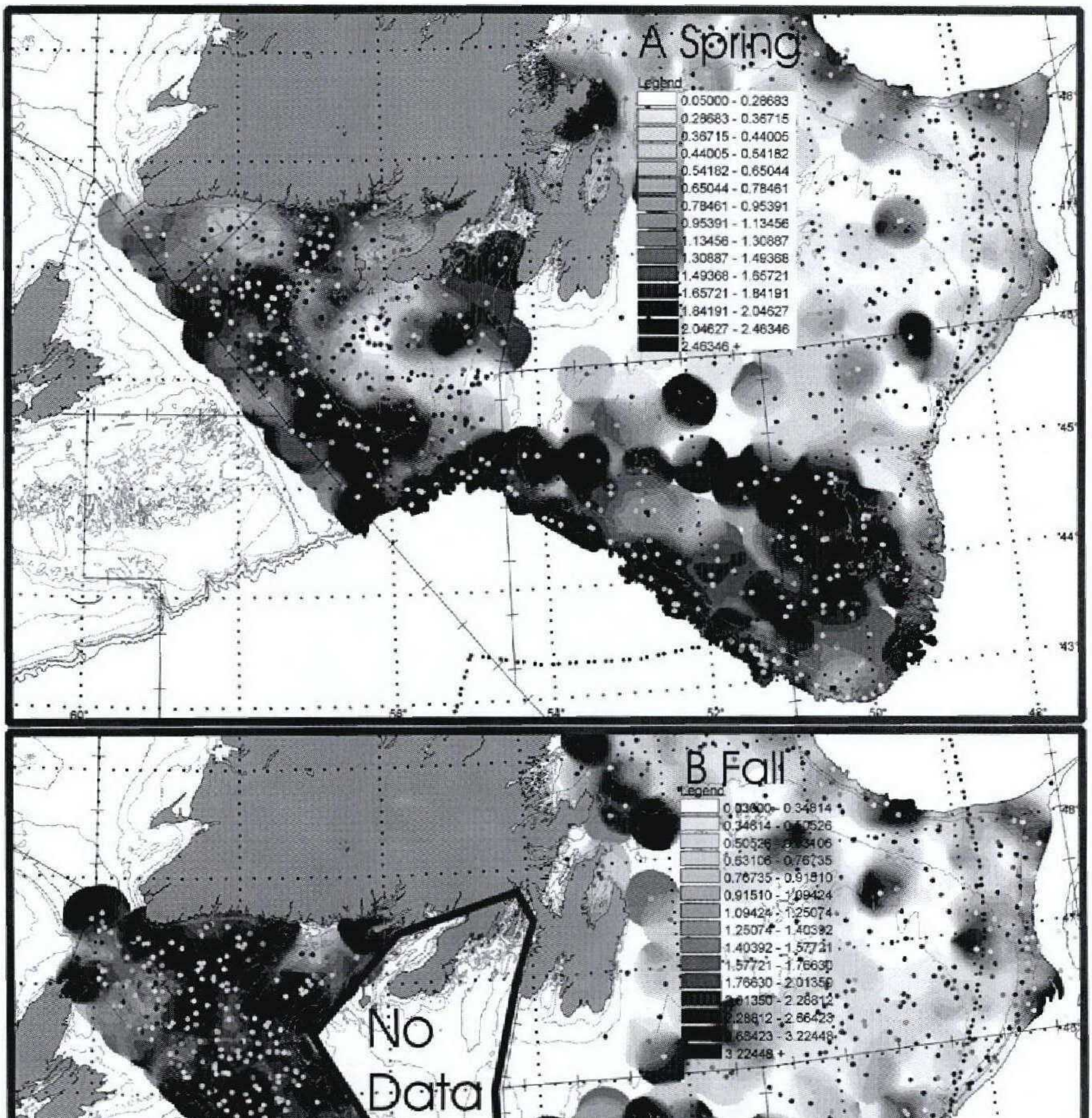


Figure 16 - Size distribution of thorny skate from 1995 to 1998 combined research vessel survey Campelen trawls combined shown as average weight per fish.

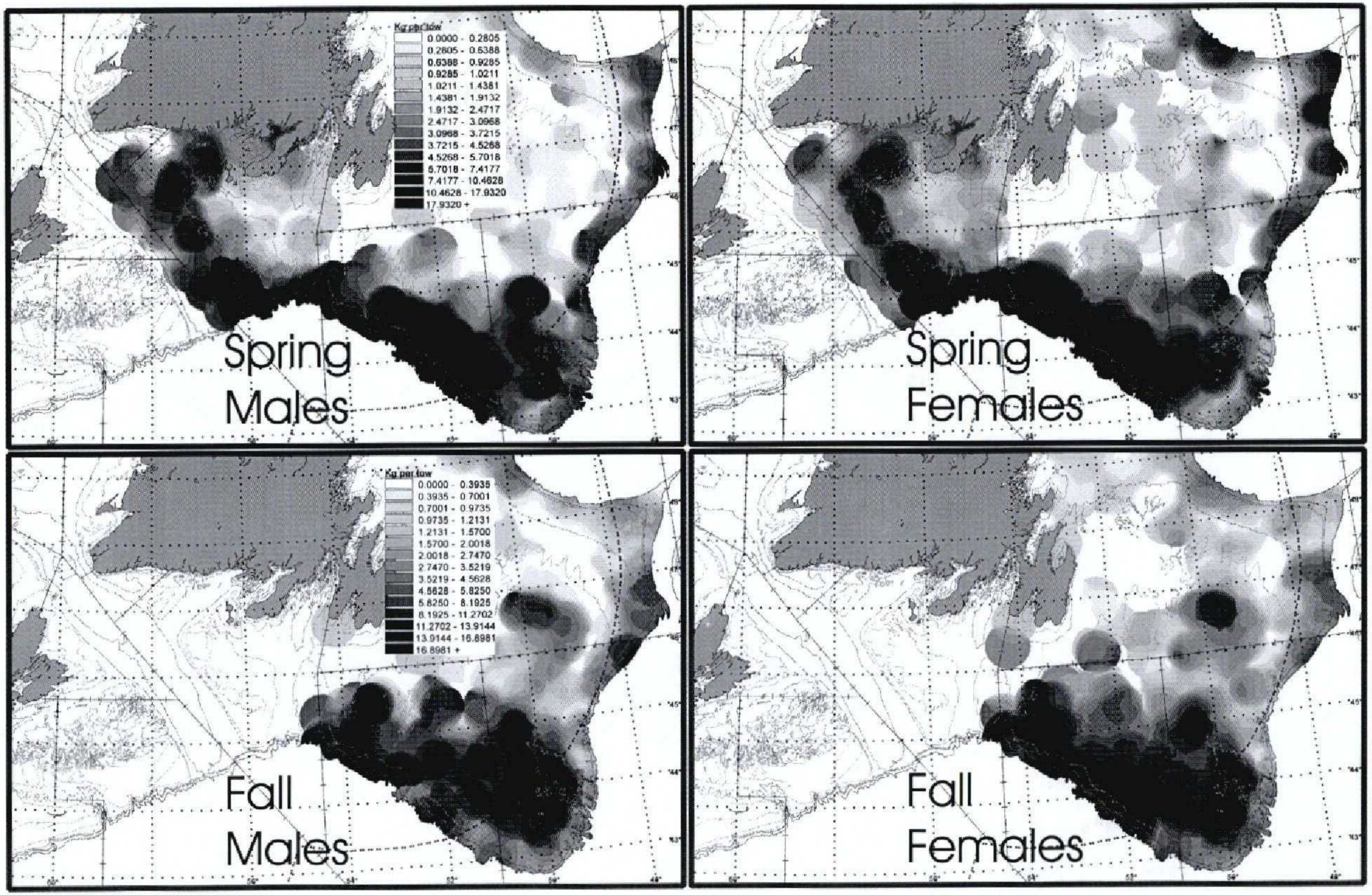


Figure 17 - Distribution of males and females by season surveyed. The same scale is used for males and females. Fall data does not include the summer sets in 3Ps.

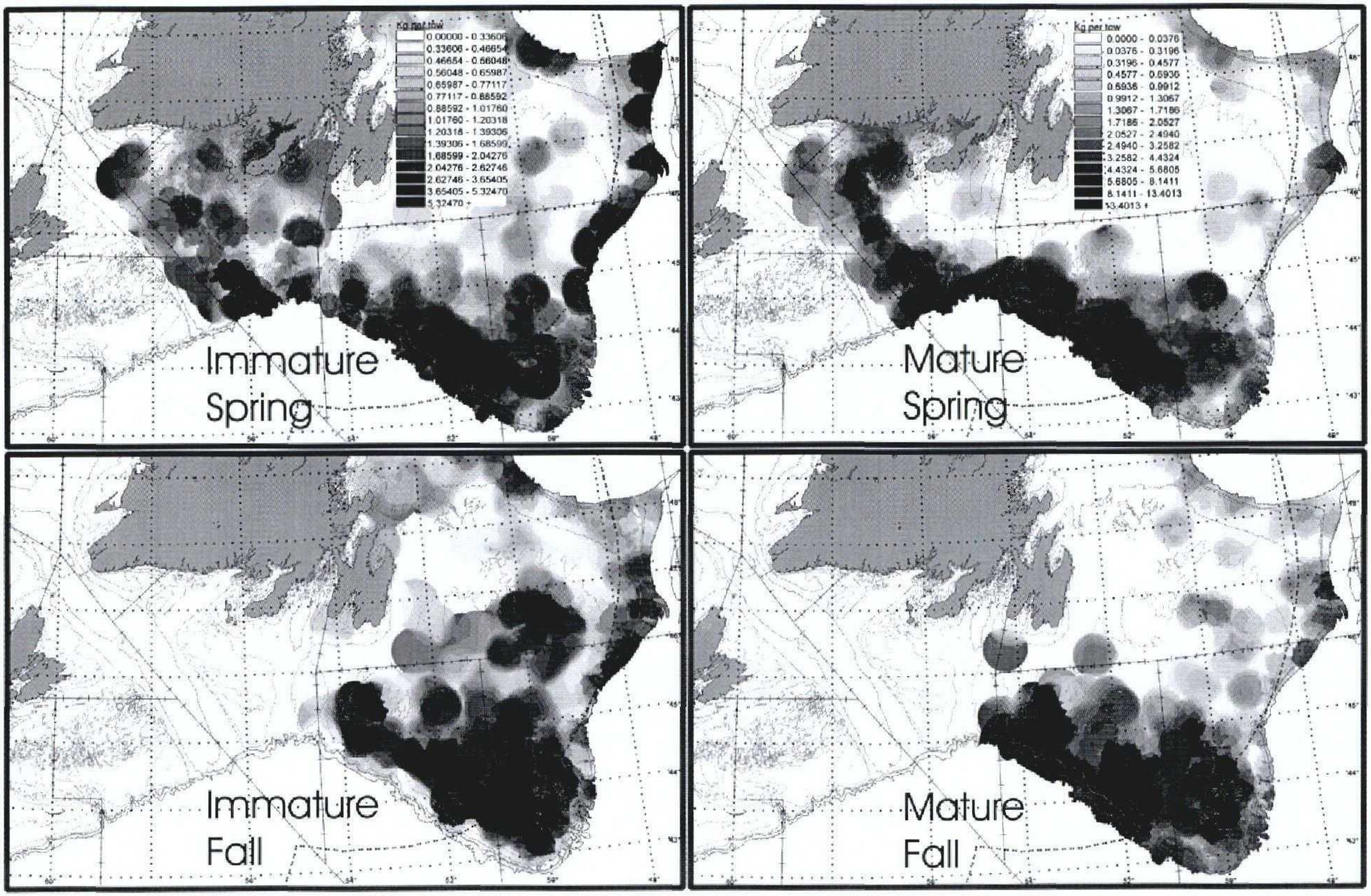


Figure 18 - Distribution of mature and immature fish by season surveyed. The same scale is used between seasons. Fall data does not include the summer sets in 3Ps.

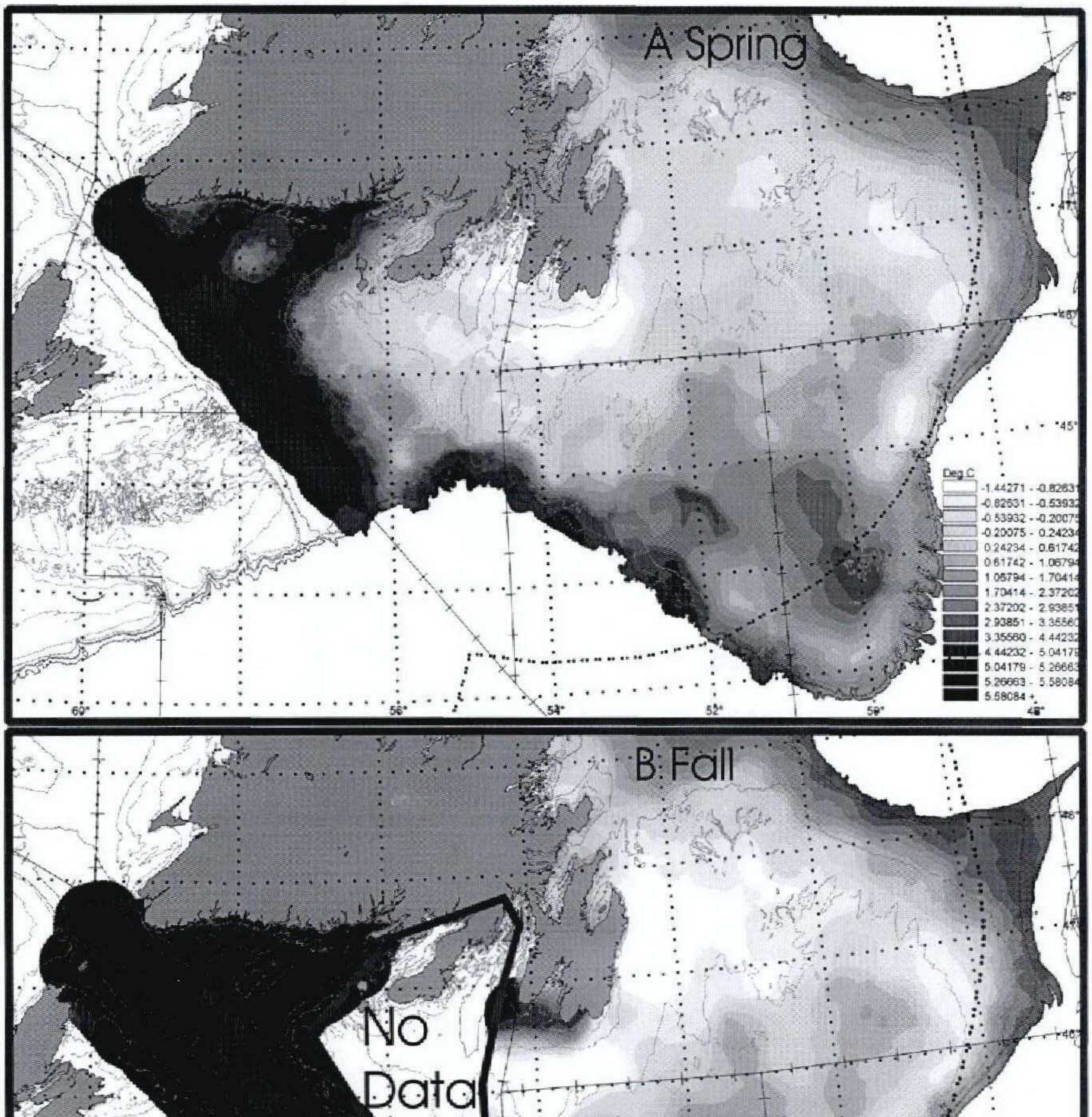


Figure 19 - Spring and fall bottom temperatures collected during research vessel surveys averaged over the period 1995 - 1997. No data are available for NAFO Div. 3Ps except along the Laurentian Channel and the southern slope in the fall.

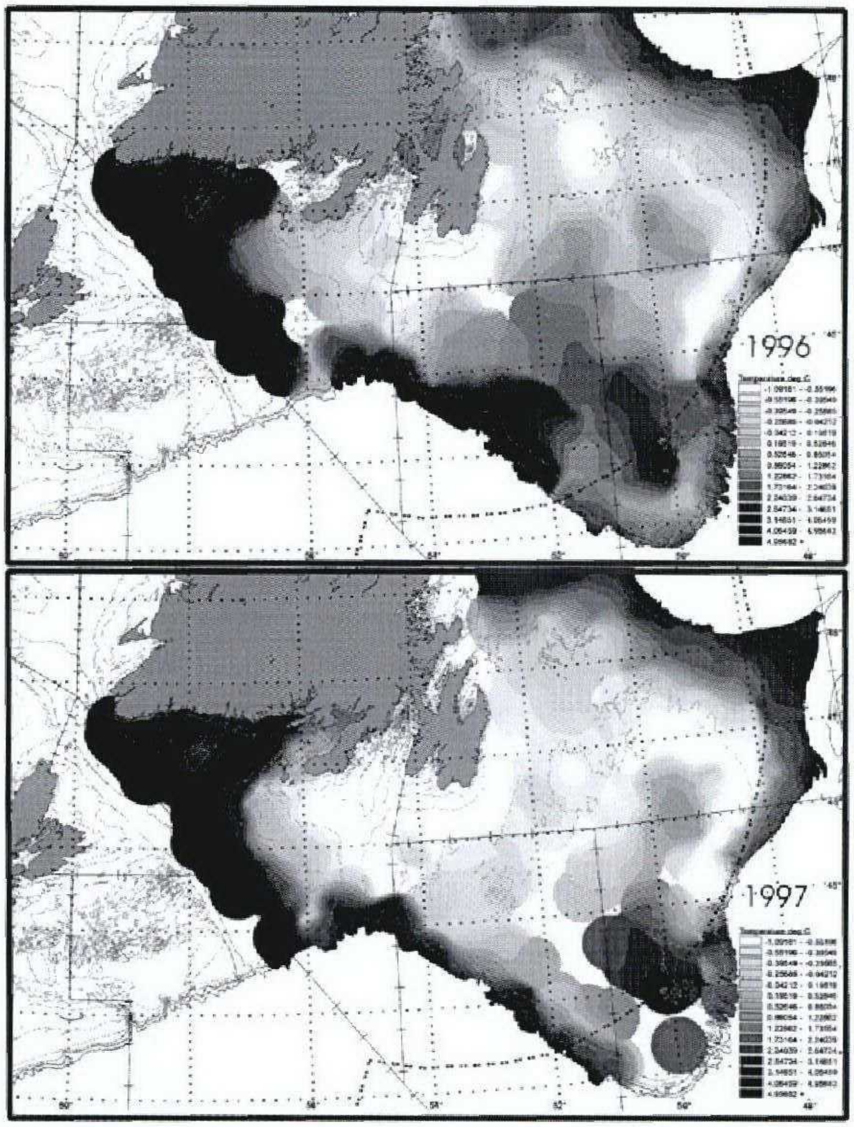


Figure 20 - Spring bottom temperature collected during research vessel surveys shown annually, 1995-1997. No data are available for NAFO division 3Ps except along the Laurentian Channel and southern slope.

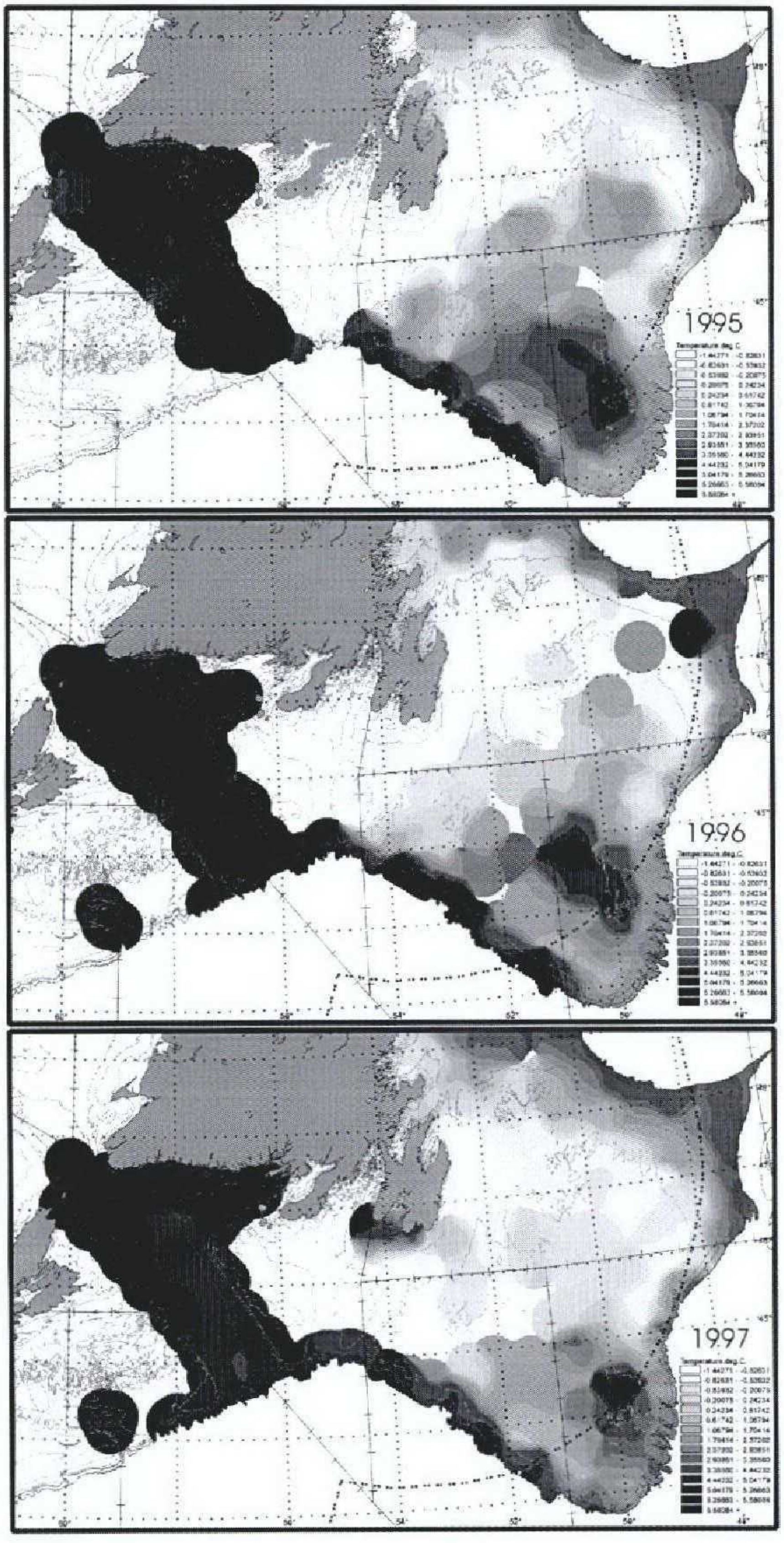


Figure 21 - Fall bottom temperature collected during research vessel surveys shown annually, 1995-1997. No data are available for NAFO division 3Ps except along the Laurentian Channel and southern slope.

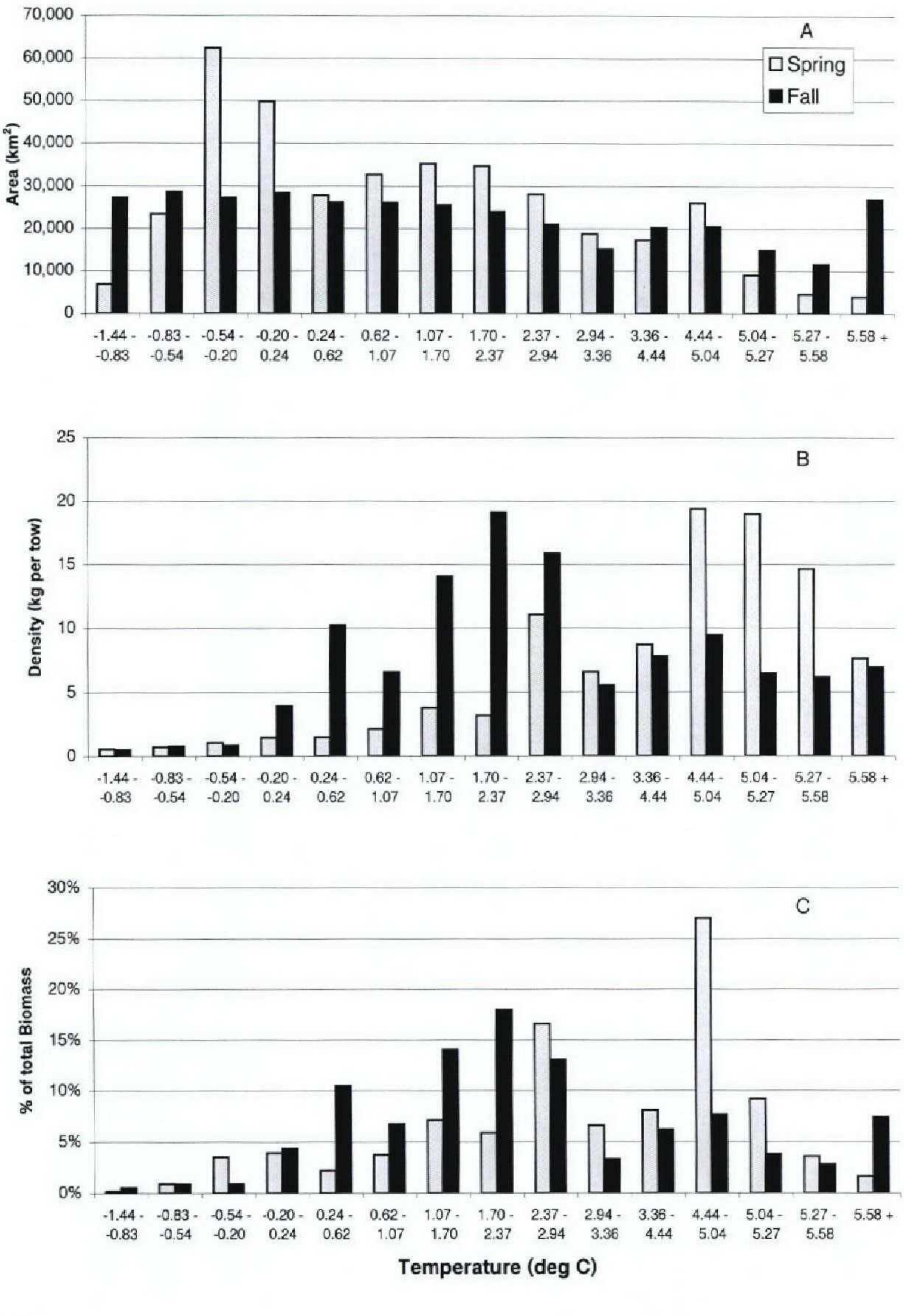


Figure 22 - Available habitat within temperature strata during spring and fall survyes (A) compared to density (B) and biomass (C) of thorny skate within the temperature strata.

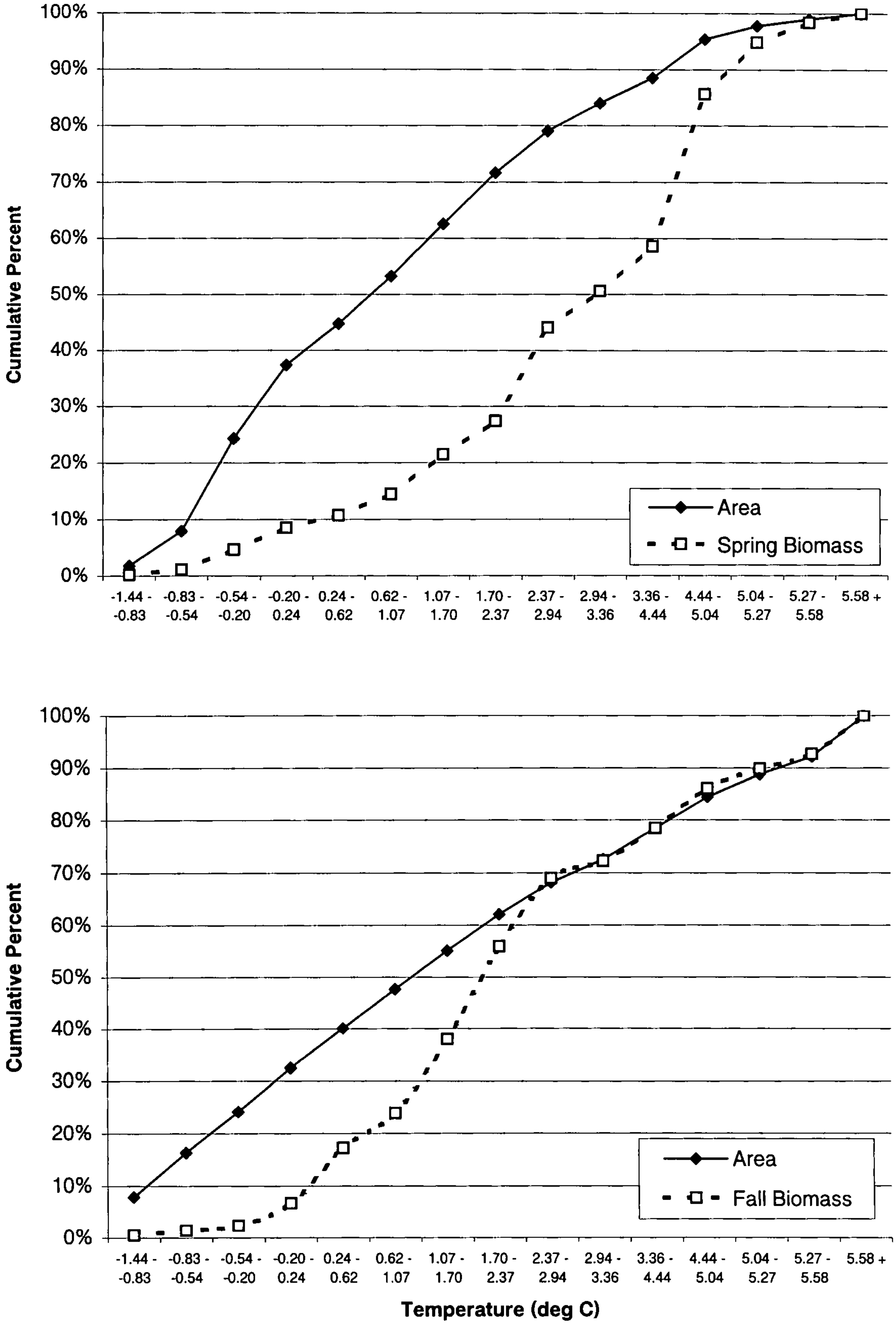


Figure 23 - Cumulative biomass of thorny skate versus cumulative available habitat at depth comparing the spring (A) and fall (B) survey periods.

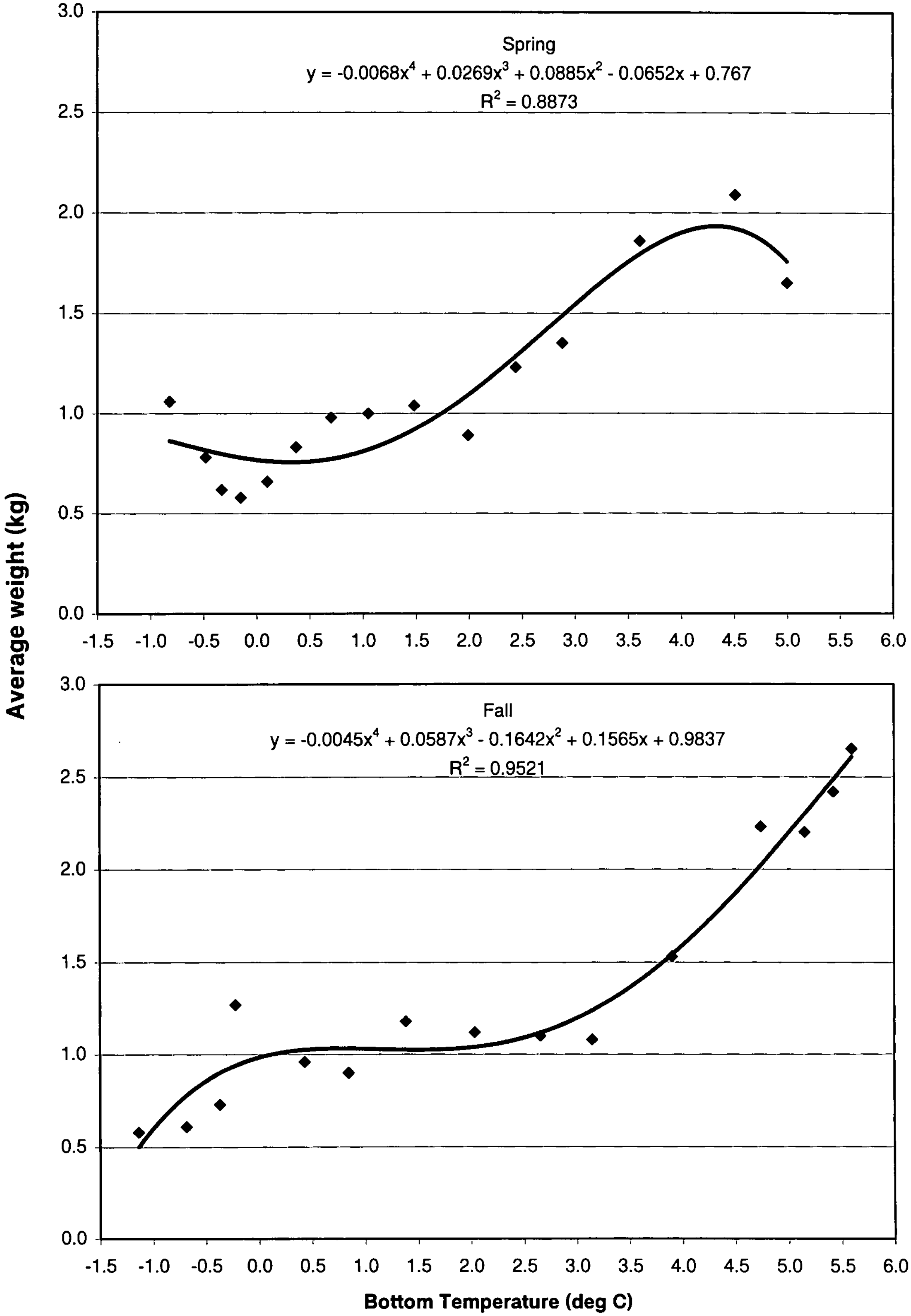
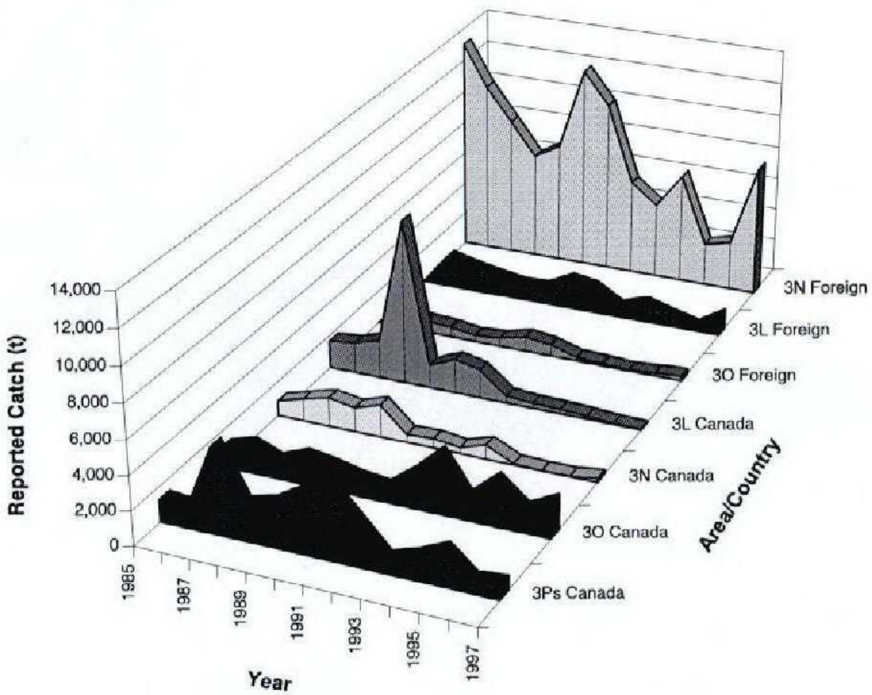
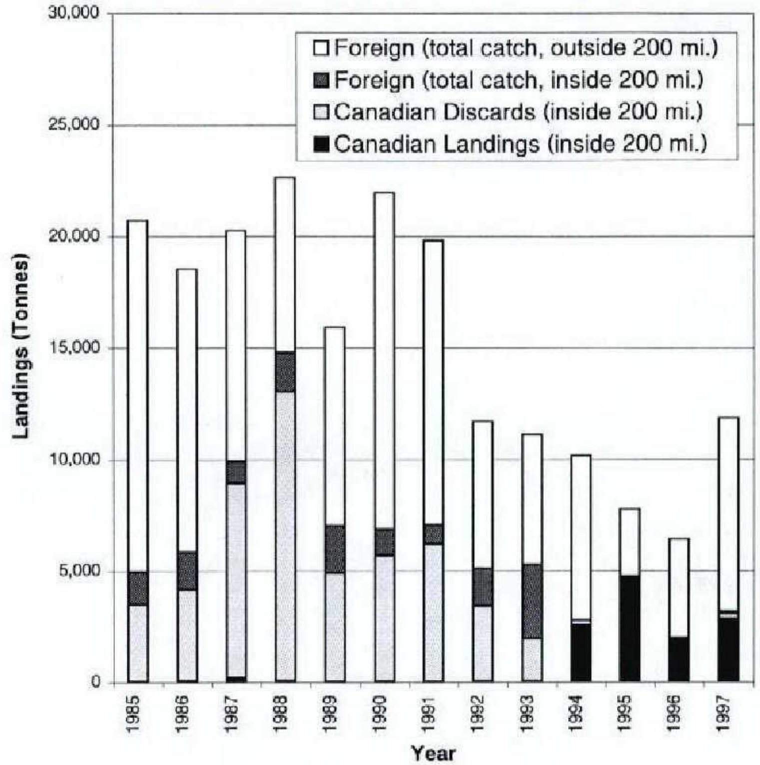


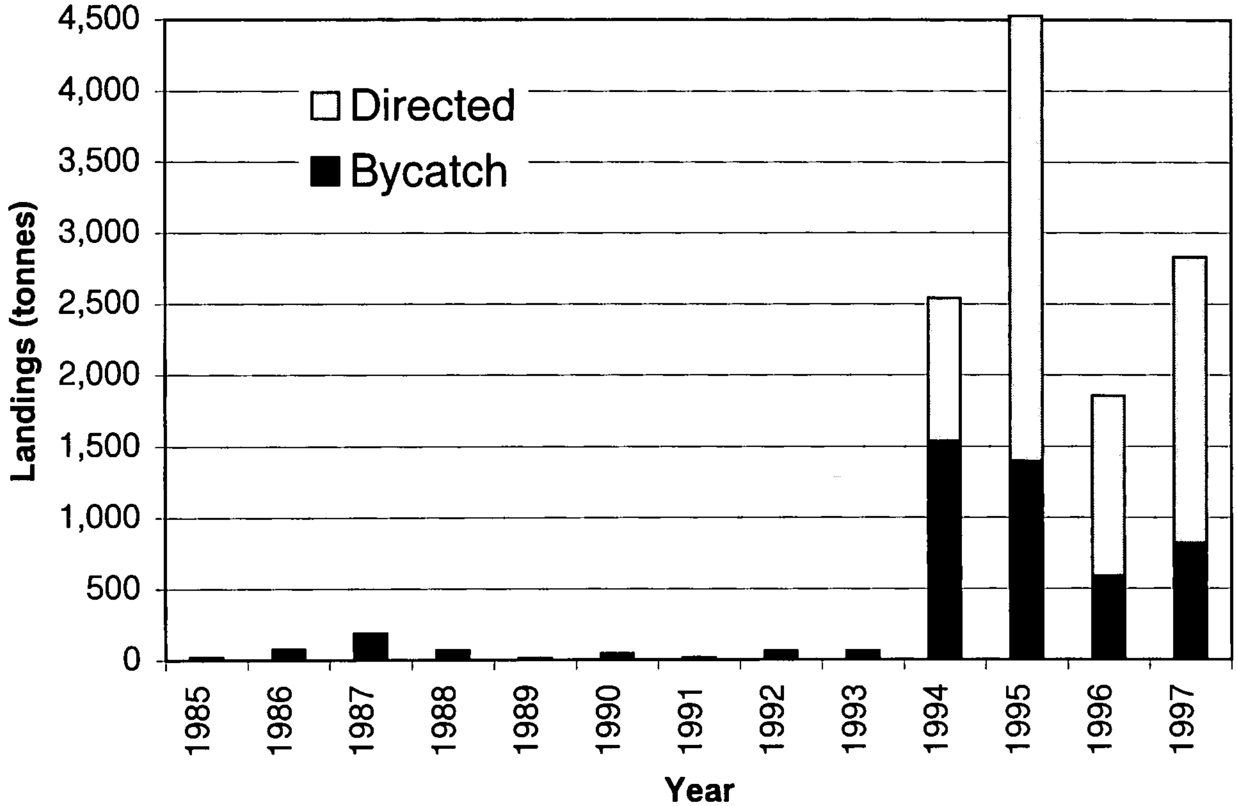
Figure 24 - Average size of thorny skate within temperature strata, 1995-1997





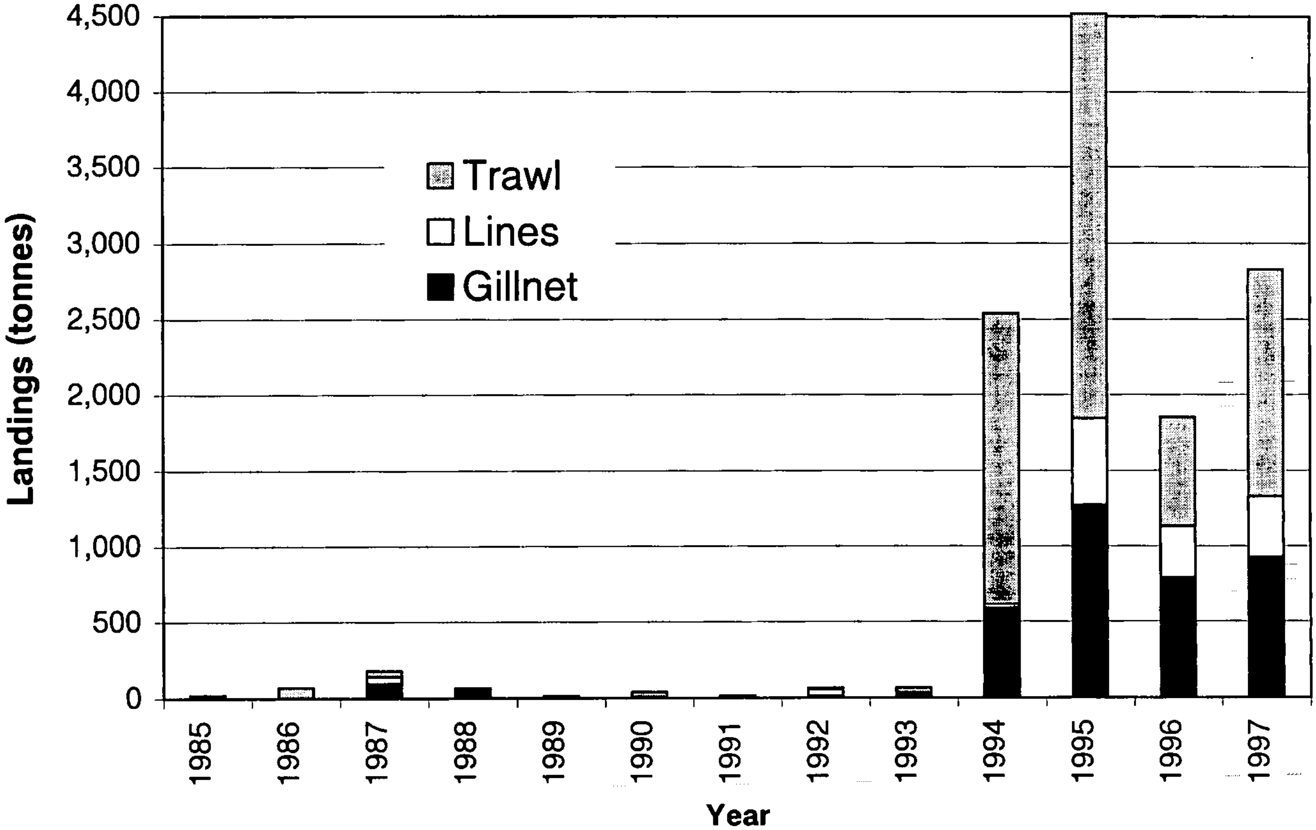
	3L		3N		3O		3Ps	Foreign & Domestic				
Year	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	3L	3N	3O	3PS	Total
1985	1,676	1,850	870	13,000	1,126	900	1,299	3,526	13,870	2,026	1,299	20,722
1986	1,830	1,500	1,314	10,500	1,595	700	1,105	3,330	11,814	2,295	1,105	18,545
1987	2,307	1,200	1,708	8,500	935	600	4,999	3,507	10,208	1,535	4,999	20,249
1988	9,785	950	1,431	6,500	1,567	400	2,006	10,735	7,931	1,967	2,006	22,639
1989	1,367	1,000	1,910	7,400	1,324	500	2,424	2,367	9,310	1,824	2,424	15,925
1990	2,033	1,800	485	12,400	953	900	3,396	3,833	12,885	1,853	3,396	21,966
1991	1,710	1,550	549	10,500	771	700	4,023	3,260	11,049	1,471	4,023	19,803
1992	436	600	343	5,800	1,953	200	2,385	1,036	6,143	2,153	2,385	11,717
1993	303	1,100	853	4,600	3,417	150	711	1,403	5,453	3,567	711	11,135
1994	269	650	63	6,700	1,219	50	1,238	919	6,763	1,269	1,238	10,190
1995	182	250	3	2,600	2,603	200	1,959	432	2,603	2,803	1,959	7,797
1996	69	1,200	6	3,000	1,226	275	666	1,269	3,006	1,501	666	6,442
1997	39	650	226	7,950	2,052	100	845	689	8,176	2,152	845	11,862

Figure 25 - Landings of Skate in Canadian and International waters of NAFO divisions 3LNOPs, 1985-1997. Catches inside 200 miles were calculated from ZIF files (landings) and observer data (Canadian discards and foreign catches). Catches in international waters were estimated from C&P boardings.



	3L		3N		3O		3PS				
Year	catch	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	0	3	2	274	925	256	341	1,855	588	1,268
1997	25	0	3	73	532	1,456	260	479	2,827	819	2,008

Figure 26 - Directed and non-directed Canadian skate landings in 3LNOPs, 1985-1997 (does not include at sea discards).



	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		**31**	12	9	0
1986	1	0	0	0	72	0			**87**	1	0	72
1987	95	0	46	0	40	0	2		**244**	95	46	40
1988	43	0	11	0	14	0	0		**92**	43	11	14
1989	1	0	0	0	8	4	0		**15**	1	0	13
1990	5	0	1	0	33	0	1	4	**50**	5	1	33
1991	0	0	9	0	6	0			**21**	0	9	6
1992	11	0	45	0	7	0	1		**75**	11	45	7
1993	16	0	16	0	10	21			**90**	16	16	31
1994	565	24	24	0	943	982	2		**3,747**	589	24	1,925
1995	820	450	489	86	76	2,598	11		**4,536**	1,270	575	2,674
1996	444	344	120	221	22	703	2		**1,855**	789	341	724
1997	248	673	182	223	389	1,112	1		**2,827**	921	405	1,500

Figure 27 - Canadian skate landings in NAFO divisions 3LNOPs by gear type and mode (directed or bycatch), 1985-1997.

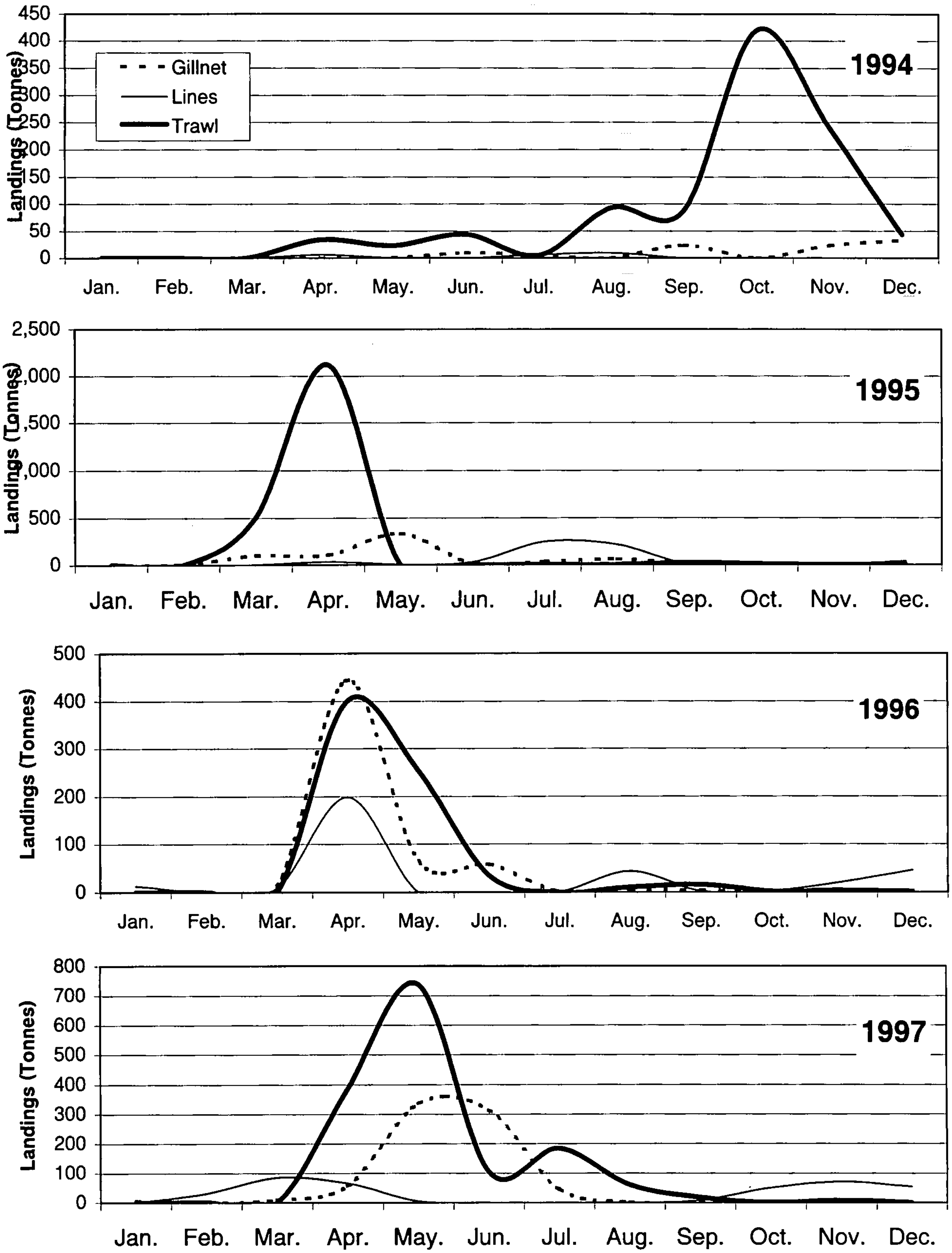


Figure 28 - Monthly domestic landings of skate in NAFO divisions 3LNOP, 1994-1997. Landing records for which no month was recorded are excluded.

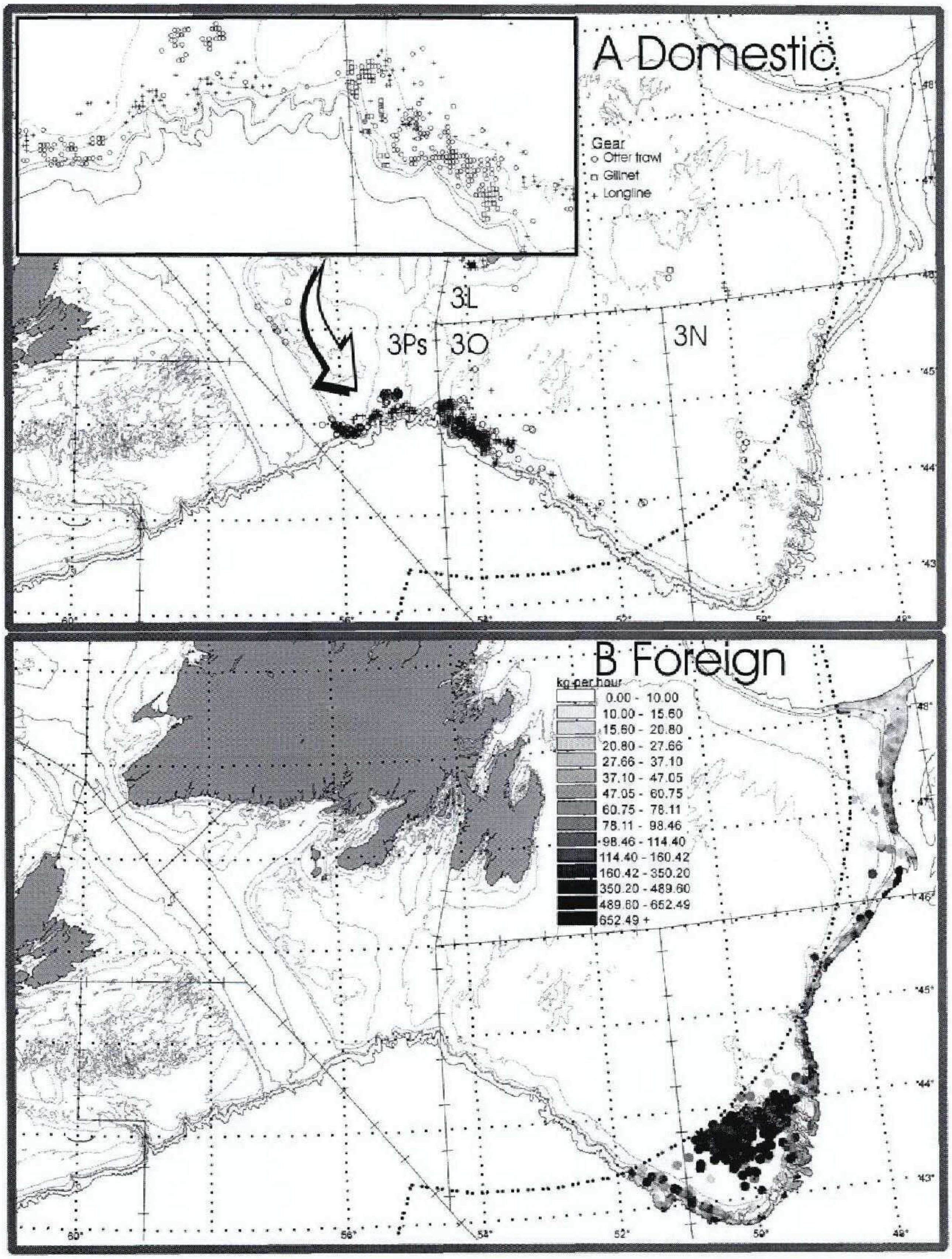
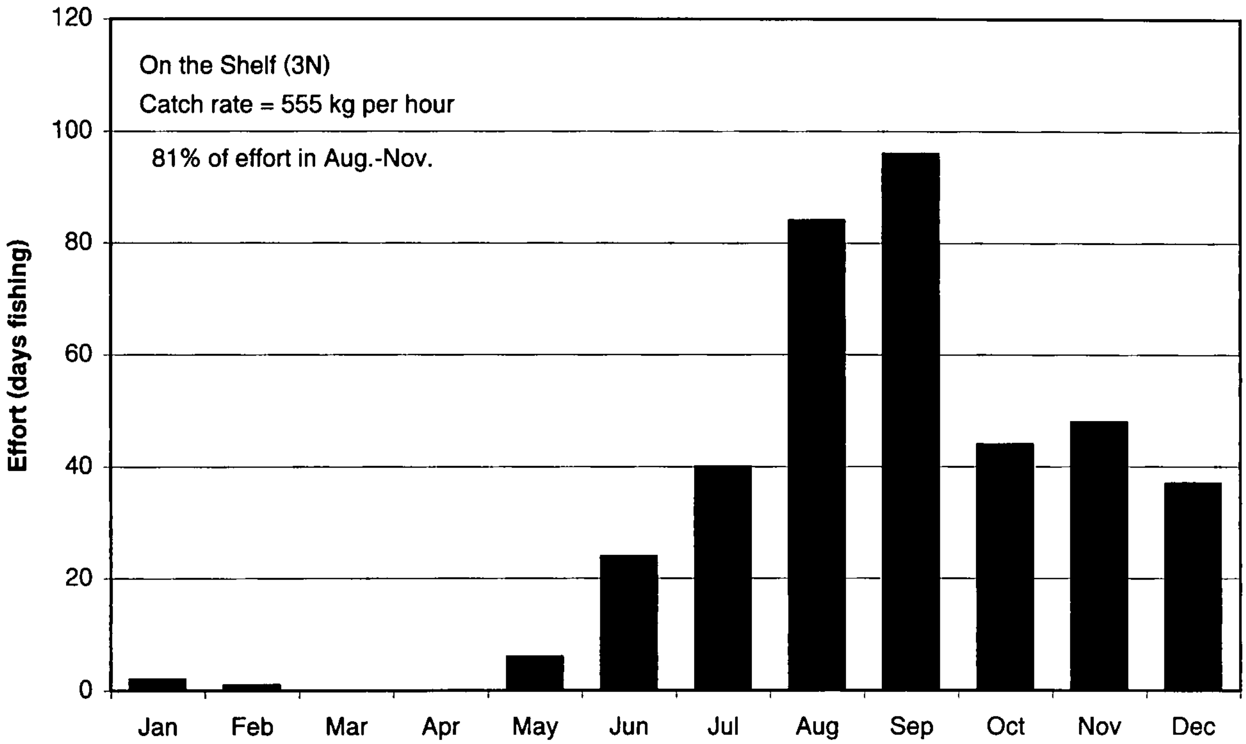


Figure 29 - Location of the observed a) Canadian, 1993-1998(the extent of the fishery) and b) foreign skate fishery, 1995-1997 in NAFO Divisions 3L, 3N, 3O and 3Ps. Different symbols in a) denote different gears used. The box in the upper left corner is a blow up of the main fishing grounds. Catch rate is shown in b) to differentiate where the fishery was directed and where the skate were being taken as bycatch.



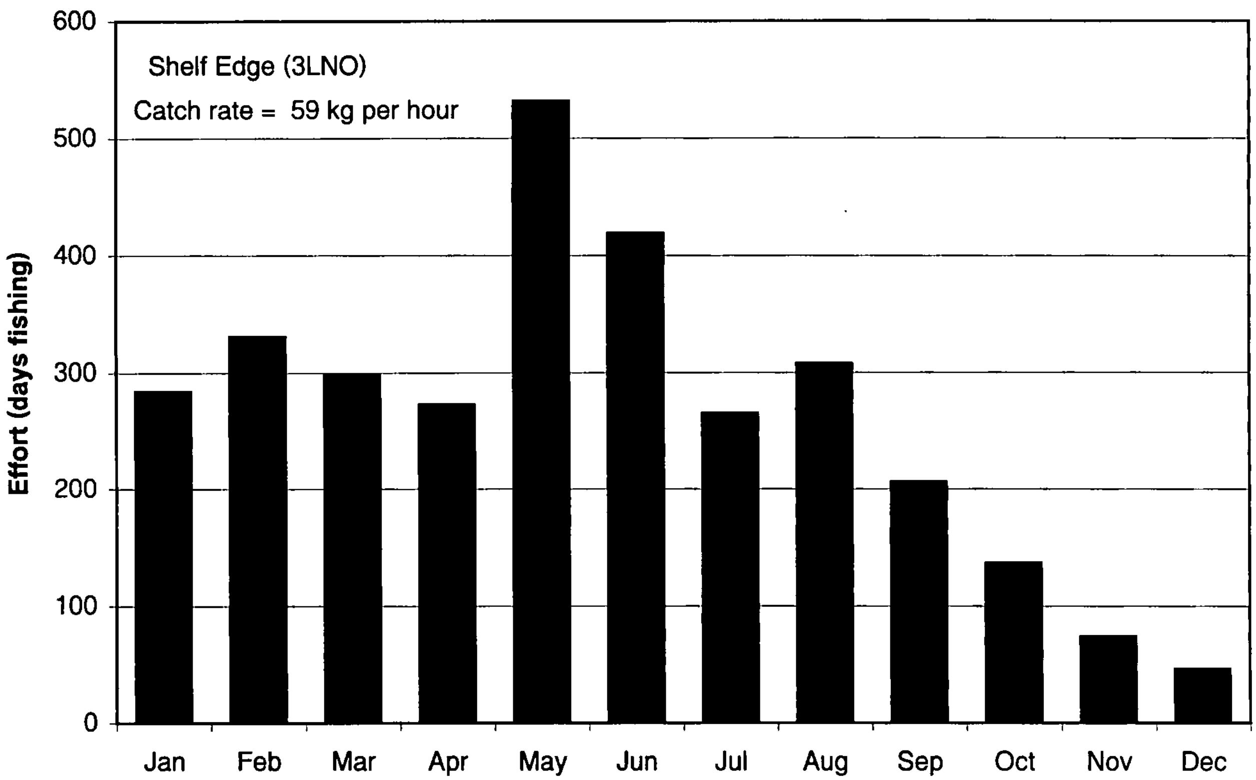


Figure 30 - Distribution of foreign fishing effort (days fished) from boardings outside 200 miles where skate is taken in directed fisheries on the shelf or as bycatch off the shelf. Refer to Fig. 28 for a delineation of fishing areas.

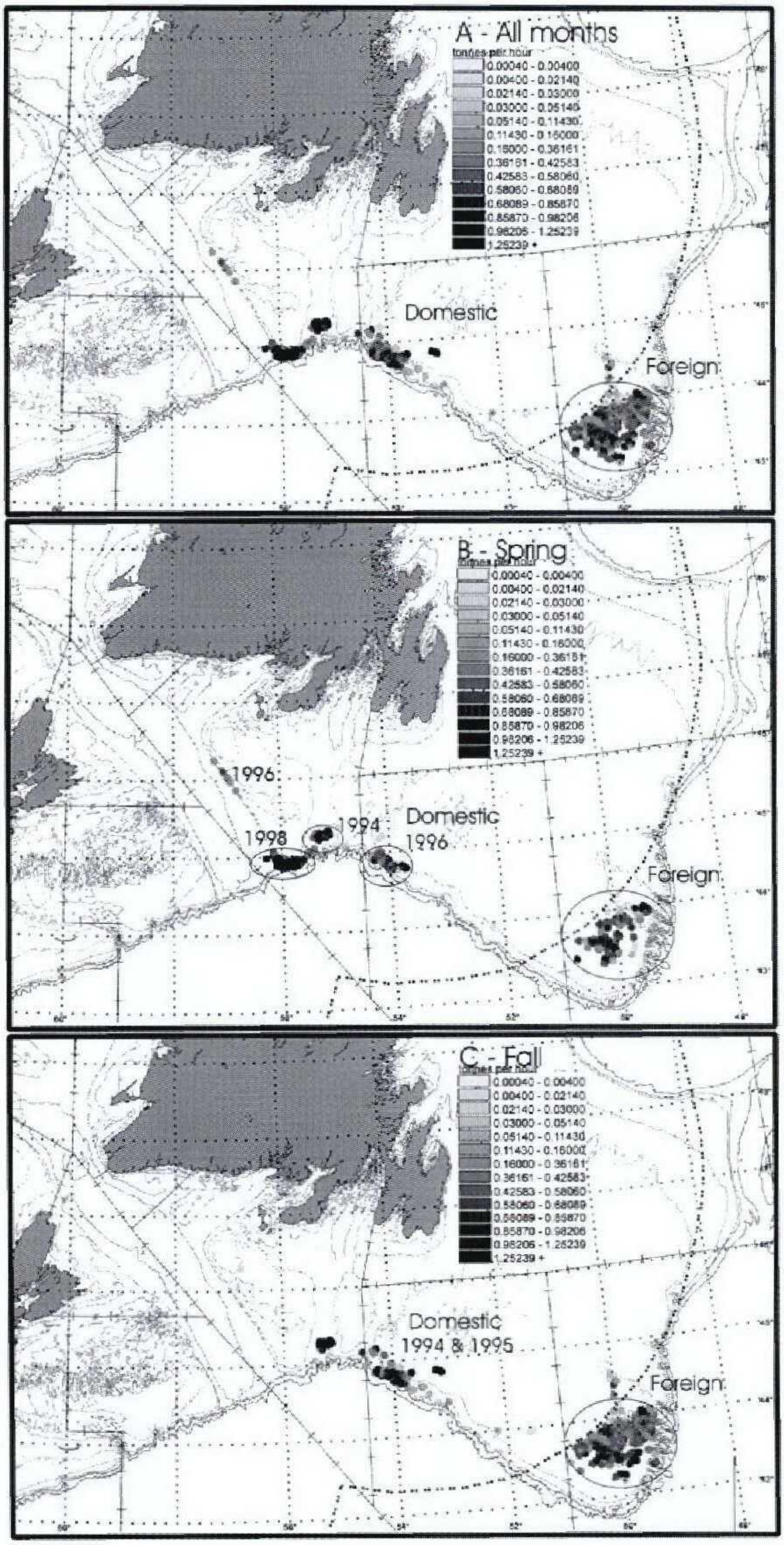


Figure 31 - Catch per unit effort distribution for the observed otter trawl fishery, 1993-1998. Panel A shows the annual fishery, the circled area showing foreign effort for 1995 to 1997 based on boardings. Panel B shows the spring period (Jan-Jul) of the fishery and Panel C shows the fall fishery.

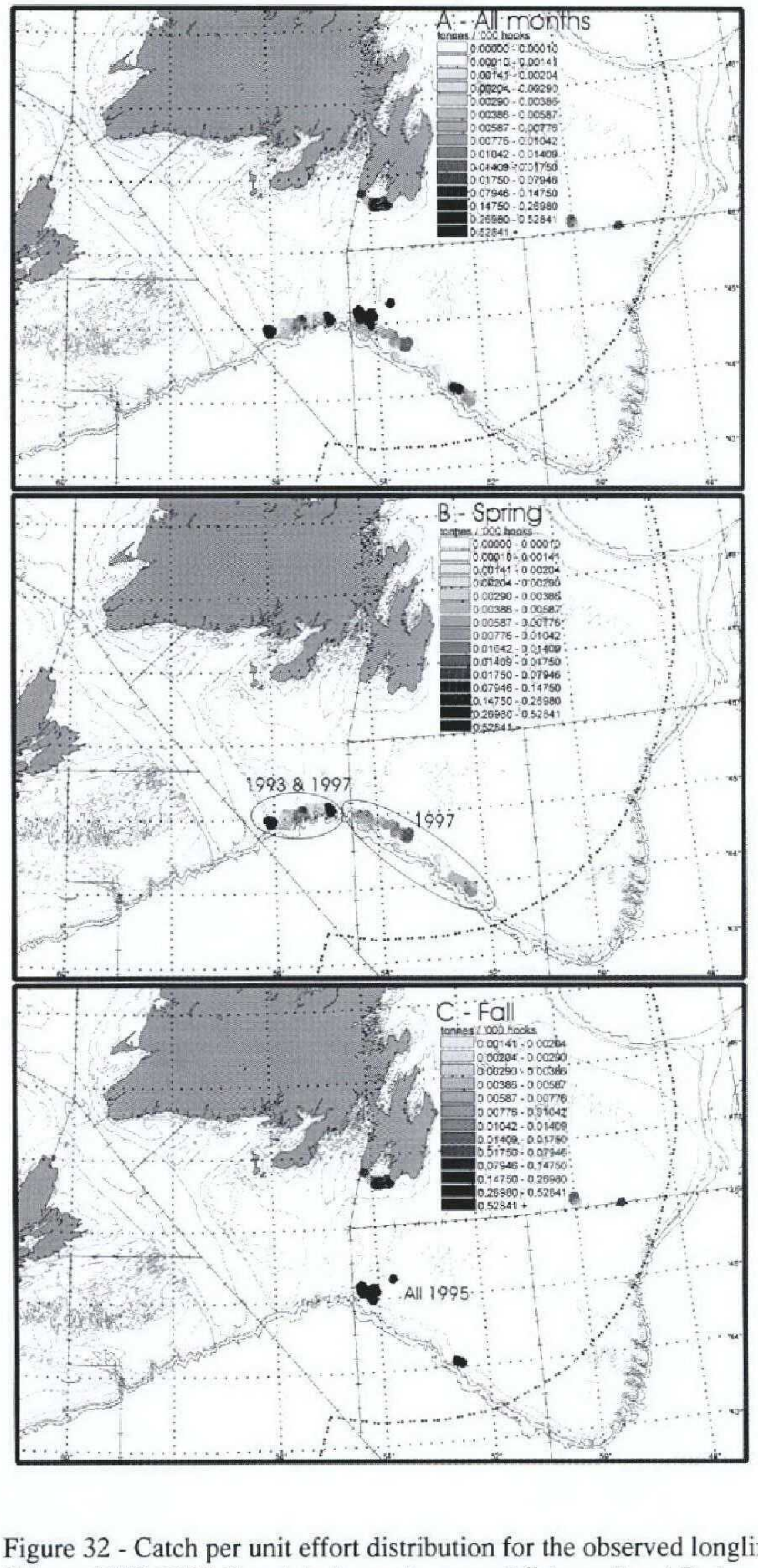


Figure 32 - Catch per unit effort distribution for the observed longline fishery, 1993-1998. Panel A shows the annual fishery, Panel B shows the spring fishery and Panel C shows the fall fishery.

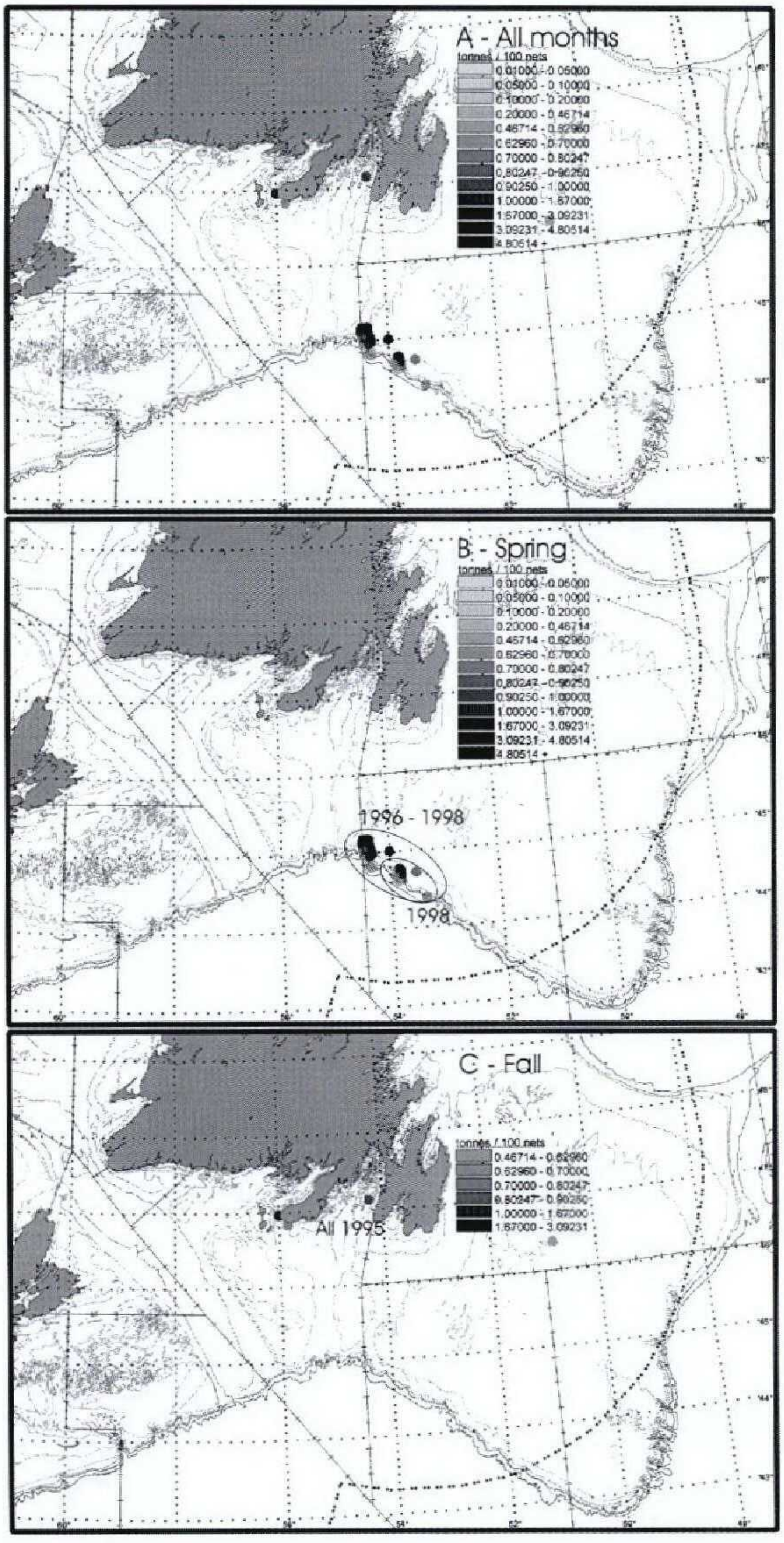


Figure 33 - Catch per unit effort distribution for the observed gillnet fishery, 1993-1998. Panel A shows the annual fishery, Panel B shows the spring fishery and Panel C shows the fall fishery.

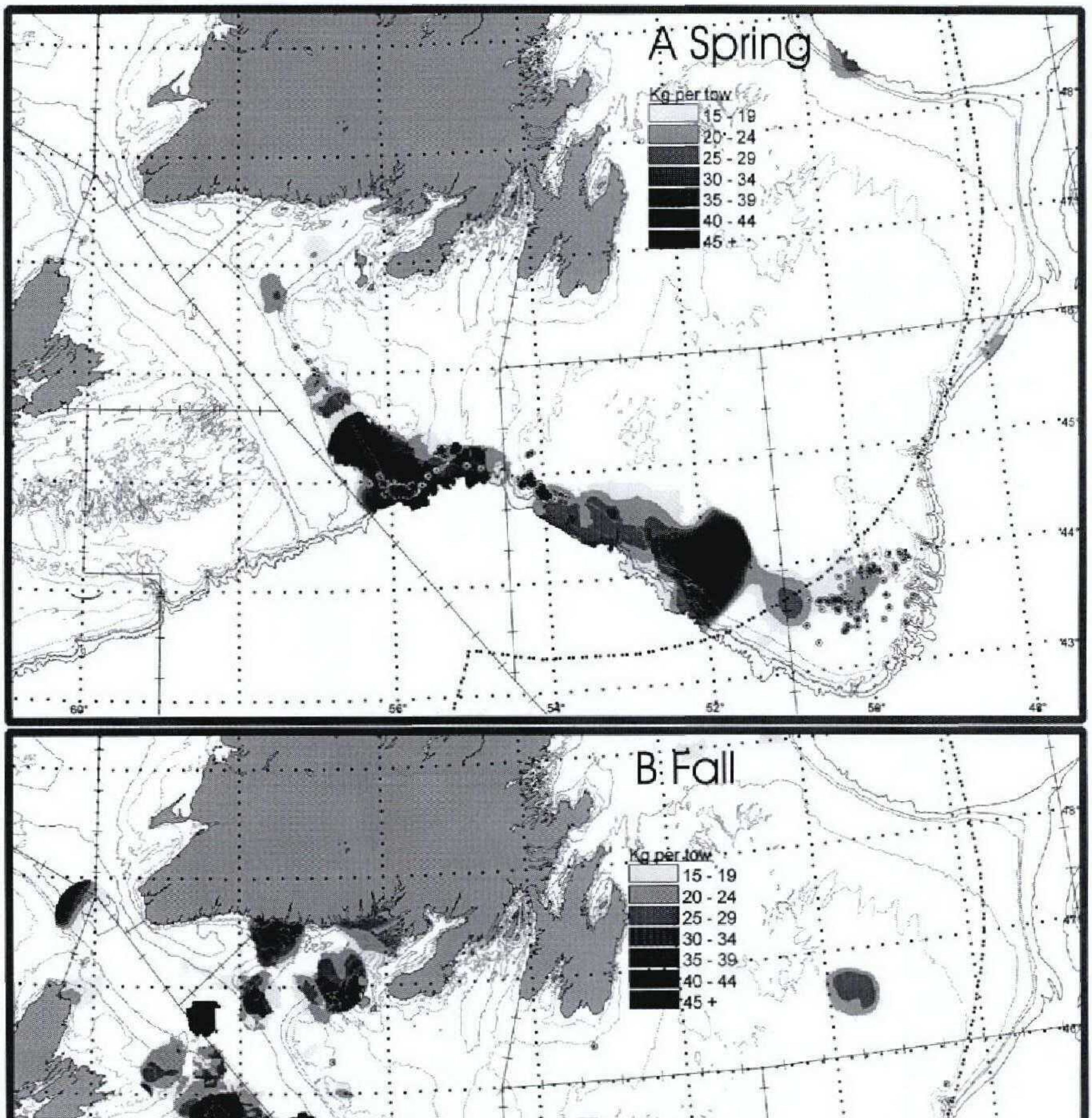


Figure 34 - High density areas of thorny skate from 1995 to 1997 from research vessel survey data for Campelen trawls shown as varying degrees of weight (kg) per tow. Areas shown are of sufficient density to support commercial fishing.

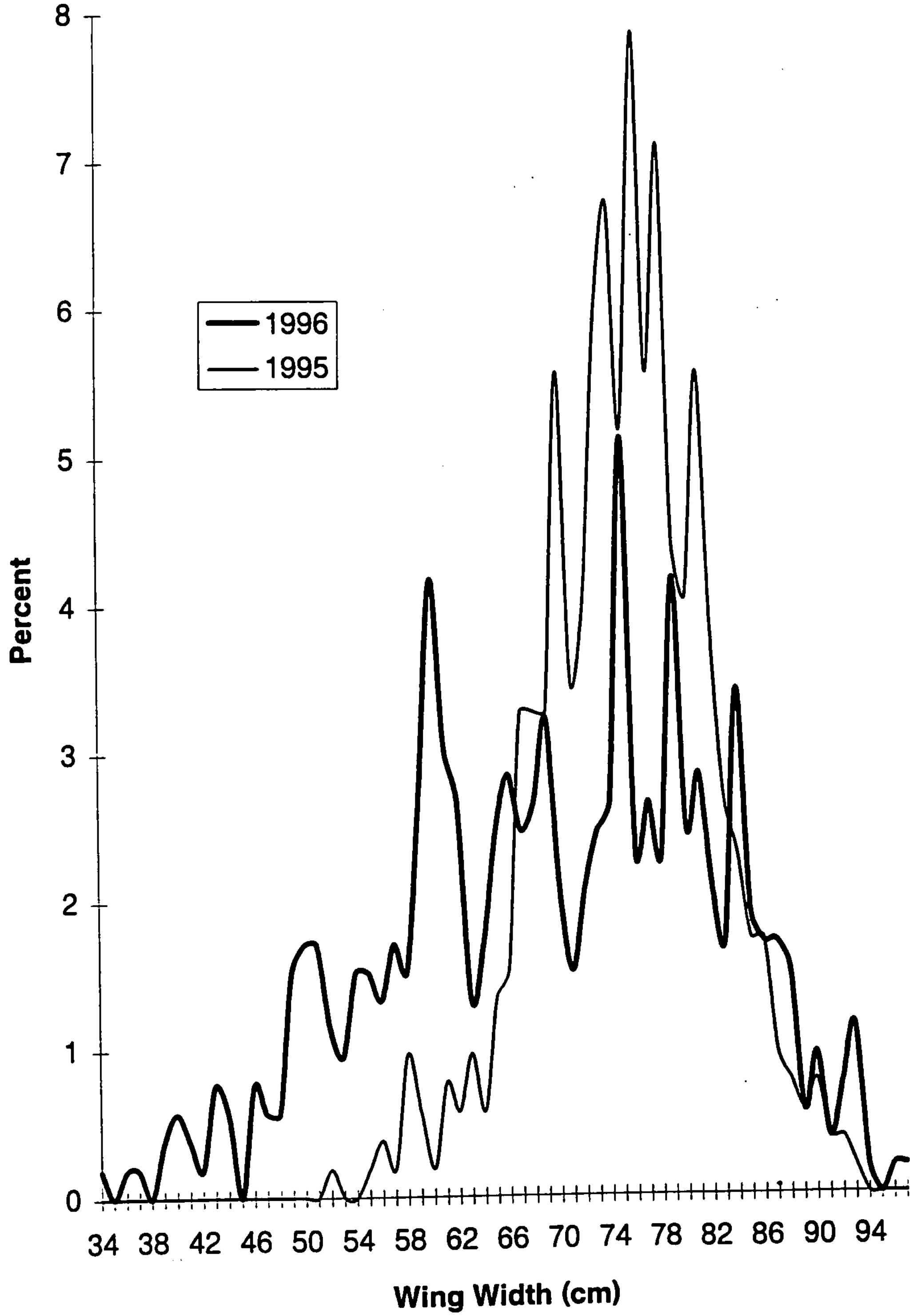


Figure 35 - Wing width frequency for commercial skate catches in NAFO Divs. 3O and 3Ps.