Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

C S A S / **S C C S**

Canadian Science Advisory Secretariat / **Secrétariat canadien de consultation scientifique**

Research Document 2006/003 / **Document de recherche 2006/003**

Not to be cited without permission of the authors *

Ne pas citer sans autorisation des auteurs *

Recovery potential assessment of 4T and 4VW winter skate (Leucoraja ocellata): biology, current status and threats

Évaluation du potentiel de rétablissement de la raie tachetée (Leucoraja ocellata) de 4T et 4VW : biologie, situation actuelle et menaces

D.P. Swain[1], J.E. Simon[2], L.E. Harris[3], and H.P. Benoît[1]

[1]Department of Fisheries and Oceans, Gulf Fisheries Centre,
P.O. Box 5030, Moncton, NB, E1C 9B6

[2]Department of Fisheries and Oceans, Bedford Institute of Oceanography,
P.O. Box 1006 Dartmouth, NS, B2Y 4A2

[3]Department of Fisheries and Oceans, St. Andrews Biological Station,
St. Andrews, NB, E5B 2L9

ISSN 1499-3848 (Printed / Imprimé)

Canada

ABSTRACT

In May 2005, winter skate (*Leucoraja ocellata*) in the southern Gulf of St. Lawrence (sGSL, NAFO Div. 4T) and on the eastern Scotian Shelf (eSS, Div. 4VW) were designated as endangered and threatened, respectively, by the Committee on the Status of Endangered Wildlife in Canada. This report summarizes information on the biology, current status and potential threats to winter skate in these areas to aid in recovery planning.

Winter skate in the sGSL appear to be distinct from those in other areas, possibly reflecting character displacement in areas outside the Gulf where winter skate are sympatric with little skate (*L. erinacea)*. Female winter skate are mature by 42 cm in the sGSL but 50% maturity occurs at 75 cm on the eSS. In summer, winter skate occur in shallow inshore areas in the sGSL and on the offshore banks on the eSS.

Based on catch rates in the summer/fall research vessel (RV) surveys, adult winter skate have declined by 96% since 1971 in the sGSL and by 90% since 1970 on the eSS. There is no indication from the RV survey catch rates that the declines in adult abundance have ceased. A spring industry survey of the eSS, initiated in 1995, shows declines in catch rates similar to the declines in the July RV survey of the eSS. Declines in catch rates in the September RV survey of the sGSL may overestimate population declines if optimal habitat is inshore of the survey area. However, sharp declines in abundance have also occurred in these inshore areas, based on catch rates in an inshore survey conducted since 2000.

Landings of winter skate have been negligible in the sGSL. Median estimates of discarded bycatch in groundfish and shrimp fisheries in the sGSL exceeded 1000 t in most years in the 1970s but declined to low values (<50 t) in recent years. Winter skate are also likely caught in the scallop fishery in the sGSL but the magnitude of this bycatch is unknown. Reported catches by foreign fleets on the eSS averaged 1061 t annually in 1970-1993, 77 t in 1994-1999, and have been negligible since then. Landings in the directed skate fishery on the eSS declined from 2045 t in its first year (1994) to <300 t annually since 2001. Estimated annual discards by domestic groundfish fleets on the eSS averaged 1461 t in 1970-1992 and declined from 350 t to 50 t from 1993 to 2004.

Large demersal fishes, potential predators of small fishes, declined in both the sGSL and eSS in the 1980s. Seal abundance has been increasing in both systems since the 1960s.

Estimates of catchability and availability of winter skate to the RV surveys are given in the appendices. Conclusions of the Recovery Potential Assessment meeting (21-23 November 2005), based on the material in this and a companion document on population modelling, are summarized.

RÉSUMÉ

En mai 2005, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a désigné la population de raie tachetée (*Leucoraja ocellata*) du sud du golfe du Saint-Laurent (SGSL, div. 4T de l'OPANO) et celle de l'est du plateau Néo-Écossais (EPNE, div. 4VW) comme étant en danger de disparition et menacée, respectivement. Le présent rapport résume l'information sur la biologie, la situation actuelle et les menaces possibles de la raie tachetée dans ces zones en vue d'aider à la planification du rétablissement.

La raie tachetée du SGSL semble distincte de celle des autres secteurs, ce qui pourrait correspondre à un glissement de niche vers les zones extérieures au Golfe où la raie tachetée et la raie hérisson (*L. erinacea*) sont des espèces sympatriques. Les raies tachetées femelles viennent à maturité à 42 cm dans le SGSL, mais la longueur à laquelle 50 p. 100 atteignent la maturité dans l'EPNE se situe à 75 cm. En été, la raie tachetée peut être observée dans les zones côtières peu profondes dans le SGSL et sur les bancs hauturiers dans l'EPNE.

D'après les taux de prise des relevés d'été et d'automne du navire de recherche (NR), les raies tachetées adultes ont diminué de 96 % depuis 1971 dans le SGSL et de 90 % depuis 1970 dans l'EPNE. Rien ne semble indiquer, selon les taux de capture au cours des relevés du NR, que cette tendance à la baisse de l'abondance des adultes soit interrompue. Un relevé réalisé par l'industrie au printemps dans l'EPNE depuis 1995 révèle une diminution des taux de prise semblable à celle que dénote le relevé de juillet du NR dans l'EPNE. La baisse des taux de capture illustrée par le relevé de septembre du NR dans le SGSL pourrait entraîner une surestimation du déclin de la population si l'habitat optimal se trouve du côté côtier de la zone de relevé. Toutefois, on a aussi observé des chutes d'abondance dans ces zones côtières, si l'on en juge par les taux de prise au cours d'un relevé côtier réalisé depuis 2000.

Les débarquements de raie tachetée sont négligeables dans le SGSL. L'estimation médiane des prises accidentelles rejetées à l'eau au cours des pêches de poissons de fond et de crevettes dans le SGSL a dépassé 1 000 t au cours de la plupart des années de la décennie 1970, mais elle a glissé jusqu'à des valeurs très faibles (<50 t) ces dernières années. La raie tachetée est aussi vraisemblablement capturée dans le cadre de la pêche du pétoncle dans le SGSL, mais l'ampleur de ces captures accessoires est inconnue. Les prises déclarées par les flottilles étrangères dans l'EPNE se chiffraient en moyenne à 1 061 t par année entre 1970 et 1993, à 77 t entre 1994 et 1999 et sont négligeables depuis. Les débarquements dans le cadre de la pêche dirigée de la raie dans l'EPNE sont passés de 1 045 t la première année (1994) à <300 t par année depuis 2001. Les rejets annuels estimatifs des flottilles nationales de pêche du poisson de fond dans l'EPNE auraient atteint en moyenne 1 461 t entre 1970 et 1992, et se situer entre 350 et 50 t de 1993 à 2004.

Les gros poissons démersaux, prédateurs potentiels de petits poissons, ont connu un déclin aussi bien dans le SGSL que dans l'EPNE au cours des années 1980. L'abondance des phoques s'est accrue dans les deux zones depuis les années 1960.

L'estimation du potentiel de capture et de la disponibilité de la raie tachetée au cours des relevés du NR est indiquée dans les annexes. On trouve aussi un résumé des conclusions de la réunion d'évaluation du potentiel de rétablissement (du 21 au 23 novembre 2005), basées sur le matériel du présent document et d'un document d'accompagnement sur la modélisation de la population.

INTRODUCTION

Winter skate (*Leucoraja ocellata*, Family Rajidae) are endemic to the Northwest Atlantic, occurring from Cape Hatteras to the northern Gulf of St. Lawrence and southern Newfoundland (Fig. 1). In May 2005, the status of winter skate was considered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Four designatable units (DUs) were identified (Fig. 2). The southern Gulf of St. Lawrence DU was designated as Endangered (EN) while that of the eastern Scotian Shelf (4VW) was designated as Threatened (TH). The two other DUs (Georges Bank/Bay of Fundy/Western Scotian Shelf, 4X5Ze and Newfoundland/ northern Gulf of St. Lawrence, 3PnNO4RS) were designated as Special Concern and Data Deficient respectively. These DUs are being considered for listing in Schedule 1 of the Canada's Species at Risk Act (SARA). If listed under SARA as EN or TH, activities that would harm the species would be prohibited and a recovery plan would be required. Before the listing decision is made, decisions on permitting incidental harm and in support of recovery planning need to be made.

This document describes the biology and evaluates the current status of winter skate in the southern Gulf of St. Lawrence (NAFO division 4T) and on the eastern Scotian Shelf (4VW). Potential sources of mortality/harm are also documented. In a second document (Swain et al. 2006), the information presented here is used as input for Bayesian state-space models. These models are used to evaluate causal factors in the changes in abundance of winter skate since the early 1970s and to examine the recovery potential of winter skate in 4T and 4VW, to the extent possible given the limited data available on these populations.

LIFE HISTORY AND BIOLOGY

Winter skate in the southern Gulf appear to be distinct from winter skate elsewhere (McEachran and Martin 1977). Winter skate in the southern Gulf mature at a smaller size and have a smaller maximum size than do winter skate in other areas. They also differ from winter skate in other areas in other morphological characters related to feeding (e.g., the number of tooth rows in the upper jaw, the shape of the upper jaw). Outside of the Gulf, winter skate are sympatric with a closely related species, the little skate *L. erinacea*. McEachran and Martin (1977) suggest that these differences between winter skate inside and outside of the Gulf reflect character displacement between little and winter skate in areas of sympatry.

The biology of winter skate is less well studied for the southern Gulf population than for winter skate on the Scotian Shelf and in areas further south. Following from the hypothesis of character displacement in areas outside the Gulf, when information is lacking for the southern Gulf population, we will assume that it is intermediate between sympatric populations of little and winter skate, or possibly similar to little skate (which it resembles in size at maturity – see below).

Winter skate in Passamoquoddy Bay have been described as "winter periodic", moving inshore in winter and offshore into deeper water in summer, suggesting a preference for cool temperatures (Scott and Scott 1988). However, in the southern Gulf of St. Lawrence, winter skate occur in shallow inshore areas in summer and move offshore in winter (Darbyson and Benoît 2003). Based on catches in the annual September bottom-trawl survey, the median temperature occupied by winter skate in the southern Gulf in September is 8.7°C (D.P. Swain, unpublished data). Smaller skate tend to occupy warmer waters than large skate in September (e.g., average temperatures occupied in September 1982-2002 are 10.0°C for skates under 33 cm in length and 7.3°C for skates over 50 cm in length, D.P. Swain, unpublished data). Median depths occupied in the September survey area (strata 415-439) are 25.4, 30.1 and 31.6 m for winter skate <33, 33-50 and >50 cm in length, respectively (D.P. Swain, unpublished data). In January, the highest densities appear to be at depths between 100 and 200 m along the slope of the Laurentian Channel, though winter skate appear to be distributed at lower densities over much of the Magdalen Shallows at depths over 40 m in this month (Clay 1991).

On the Eastern Scotian Shelf (NAFO Division 4VW) winter skate are found predominantly on the banks. Based on July research vessel (RV) survey data, they are concentrated on Sable Island Bank and northward to Middle Bank, and on Banquereau Bank. They have been caught as shallow as 24 metres; most (76%) were caught in waters less than 100 m in depth. Although skate have been caught in waters up to 657 m in depth during the March RV (also known as 4VW Cod) survey and the summer RV survey of the Eastern Scotian Shelf, only 17 (of 8000+ fish) have been caught deeper than 400 m in both series combined. During the industry ITQ survey of NAFO division 4X it was noted that winter skate occurred in the inshore strata that are not covered by the summer RV survey. Given this observation and the inshore distribution of winter skate in NAFO Division 4T, it is likely that winter skate are found inshore in 4VW as well.

Little is known of seasonal movement of winter skate on the Eastern Scotian Shelf. One tagging study was conducted in 4VW but produced no tag returns. Although the winter skate were alive when brought on deck, many died while in holding tanks suggesting that survival of trawl-caught specimens is low. A comparison of skate abundance and distribution between the summer and March RV surveys suggests that skate are not moving inshore in winter, contrary to what is seen in other areas, such as the Bay of Fundy (Scott and Scott 1988). Instead they are caught in higher numbers in winter, concentrated along the southern side of Sable Island Bank and along the Stone Fence. Members of the fishing industry have reported that it is more difficult to catch skates in summer as they move onto the banks and spread out in spring as water temperature increases. In winter months, winter skate tend to be in deeper waters with a more concentrated distribution. It is not possible to draw any firm conclusions about seasonal migrations since neither survey samples the inshore area.

Winter skate feed mainly on crustaceans, polychaetes and fishes (McEachran et al. 1976). On the eastern Scotian Shelf winter skate diet is almost exclusively fishes, by weight and frequency in stomachs, although crustaceans, polychaetes and molluscs are also found. Of the fish species consumed, over 90% by weight is sandlance based on samples collected during RV and industry surveys (L.E. Harris unpublished data).

Like other elasmobranches, winter skate have low fecundity and (at least outside of the Gulf) late maturity, a life history characteristic which increases their susceptibility to over-exploitation. Skates are oviparous, depositing a single egg in a horny capsule or purse. The purse has adhesive mucus which helps to maintain bottom contact by attaching to substrate materials. Based on the relationship among skate species between annual purse production and length at hatching (Holden 1973), annual fecundity for winter skate would be expected to be fewer than 50 purses per year. Frisk et al. (2002) used an average annual fecundity of 35 for winter skate (and 30 for little skate). Gestation time within the purses is estimated to be 18-22 months for winter skate (J.E. Simon, unpublished data; Sulikoswki et al. 2003). A considerably shorter gestation period has been reported for little skate, 6-9 months depending on water temperature (Scott and Scott 1988). Length at hatching has been reported to be 11.2-12.7 cm (Scott and Scott 1988), approximately 12 cm (J.E. Simon, unpublished data) and 15 cm (Frisk 2004). For little skate, length at hatching has been reported to be 9.5-10.0 cm (Scott and Scott 1988).

In 4VsW, female winter skate begin to mature at 65 cm and 50% maturity occurs at a length of 75 cm (Simon and Frank 1998). Frisk (2004) estimated that 50% functional maturity occurred at a total length of 76 cm in winter skate off the northeastern US coast, corresponding to an age of 12.5 yr. McEachran and Martin (1977) reported that mature winter skate in the Gulf ranged from 50 to 70 cm. Recent observations indicate that female winter skate in the southern Gulf are mature by 42 cm (J.M. Hanson, DFO Moncton, pers. comm.). For little skate off the NE US coast, length at 50% maturity is estimated to be 43-46 cm, corresponding to an age of 6.5-7 yr (Frisk 2004).

Age and growth data are not available for winter skate in the Gulf of St. Lawrence or on the eastern Scotian Shelf. Predicted growth curves based on ageing studies conducted on winter skate elsewhere (Gulf of Maine, Georges Bank and areas further south) and on little skate (Gulf of Maine) are given in Table 1.

Predation by gastropods (which are able to bore holes through the leathery egg capsule) is thought to be the main source of mortality during the egg-capsule stage. Estimates of predation rates on skate egg cases range from 14 to 42% and average 24% for all studies to date (Lucifora and García 2004). After hatching, winter and little skate are eaten by many predators, such as sharks, other rays and grey seals (Scott and Scott 1988). Frisk (2004) estimated an instantaneous rate of natural mortality (*M*) of 0.22 for winter skate and 0.35 for little skate using Hoenig's method. Frisk et al. (2002) used values of 0.21 and 0.45 for *M* of winter and little skate, respectively.

Under the Species At Risk Act, Threatened and Endangered species residences are protected. The act defines residence as:

" *a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating*" .

There is very little published information based on observations of winter skate *in situ*. In a field study of little and winter skates off outer Cape Cod, Michalopoulos (1990) found that these skate remain buried in depressions during the day. During the study, he tagged and released 70 skates, none of which were re-sighted suggesting that these skate do not demonstrate site fidelity. Winter skate do not have any known dwelling-place similar to a den or nest during any part of their life cycle. Hence, the concept of "residence" does not apply.

CURRENT STATUS

Southern Gulf (4T) Population

Trends in the relative abundance of winter skate in the southern Gulf were evaluated using data from the September bottom-trawl survey, conducted each year since 1971. Analyses were restricted to the 24 strata sampled since 1971 (strata 415-439, Fig. 3). The target fishing procedure in all years was a 30-min tow at 3.5 knots. All catches were adjusted to a standard tow of 1.75 nautical miles. Surveys were conducted by the research vessel *E. E. Prince* using a Yankee 36 trawl from 1971 to 1985, by the *Lady Hammond* using a Western IIA trawl in 1985 to 1991, and by the *Alfred Needler* using a Western IIA trawl from 1992 to 2002. Relative fishing efficiency between these vessels and gears was estimated from comparative fishing experiments conducted during or before the September survey. No differences in fishing efficiency for winter skate were detected (Benoît and Swain, 2003).

Fishing was conducted only during daylight hours (07:00-19:00) in the period 1971-1984, but done throughout the 24 hr day since 1985. Catches were adjusted for diel differences in fishing efficiency, as described in Benoît and Swain (2003). Winter skate have higher catchability at night than in day, and night catches were adjusted to be equivalent to day catches. These adjustments were length-dependent, with greater adjustment at smaller lengths.

In 2003, the *Alfred Needler* was disabled shortly before the start of the September survey. The survey was conducted by the *Wilfred Templeman* in 2003, and by the

Teleost in 2004, using a Western IIA trawl in both cases. The fishing efficiencies of these vessels relative to the *Alfred Needler* have not been evaluated.

Winter skate tend to be caught in shallow inshore areas in September (Fig. 4). Highest catch rates in the survey tend to be along the NE New Brunswick coast from western PEI to Miscou, at the eastern end of the Northumberland Strait southeast of PEI, and east of the Magdalen Islands.

Catch rates of winter skate in the survey are shown in Figure 5 by 3-cm size class. Winter skate less than 20 cm in length are rarely caught in the survey. Other skate species are frequently caught in the survey at these small sizes (Swain et al. 2005). These other species (thorny and smooth skate) are distributed further offshore than winter skate in September. The failure to catch very small winter skate in the survey may indicate that these small sizes are distributed in shallow water inshore of the survey area. Catch rates of skates below about 40 cm in length were very low at the start of the time series (1971-1973). In these same years, catch rates of large skates were relatively high. However, catch rates of large skates declined dramatically in the 1980s, reaching very low levels by the mid 1990s (Fig. 5).

We grouped skates into two size classes: (1) 42 cm and longer, roughly corresponding to the adult portion of the population, and (2) 21-41 cm, roughly corresponding to juveniles one year of age and older. (In other areas, both little and winter skate average approximately 20 cm at one year of age, see Table 1). Juvenile catch rates fluctuated quite widely early in the time series, but tended to increase from the early 1970s to the mid 1980s (Fig. 6). Juvenile catch rates declined beginning in the late 1980s, returning to low levels in recent years. Adult catch rates were relatively high early in the time series but declined steadily throughout the 1980s and early 1990s, and have been at a very low level since the mid 1990s (Fig. 6). Trends are very similar for both juveniles and adults including the three inshore strata fished since 1984, and including only daytime tows (see Appendix A).

A linear time trend is fit to the $\log_e$ catch rates of adults in Figure 7. Restricting the analysis to the calibrated portion of the time series (1971-2002) yields a slope of -0.1042 (SE=0.0094, P<0.0001). This corresponds to a 96% decline over the 32-yr time series (estimated as $100 \cdot (1-e^{-bt})$ where b is the slope of the trend in abundance and t is time in years). Results are similar including the 2003 and 2004 points (b=-0.1071, SE=0.0084, P<0.0001). The data in Figure 7 suggest that the decline in adult abundance may be on-going.

Based on ecological considerations, animals are expected to expand their distribution into marginal habitat as their abundance increases and contract their distribution into optimal habitat as their abundance decreases (e.g., MacCall 1990). Winter skate in the southern Gulf appear to conform to this expectation, with their distribution within the survey area expanding and contracting as abundance increases and decreases (Fig. 8). Because winter skate tend to be distributed near margins of the survey area, this suggests that availability to the survey may be density-dependent. If the optimal habitat for winter skate occurs within the survey area, then availability may increase as abundance declines, and the survey will underestimate changes in population size. If the optimal habitat occurs inshore of the survey area, then availability may decrease as abundance declines, and the survey will overestimate changes in population size. Catch rates of winter skate in the survey tend to be highest in the shallowest water available (Fig. 9). This suggests that optimal habitat for winter skate may be inshore of the survey area in September. If so, the survey may overestimate changes in population size.

Information on winter skate abundance and distribution in the Northumberland Strait (including areas not covered by the September survey) is available from a bottom-trawl survey conducted between mid July and early August since 2000. Winter skate appear to be largely confined to the western half of the strait in July – August (Fig. 10 & 11). Winter skate abundance and biomass in the strait appeared to decline sharply between 2001 and 2002 (Fig. 12). Catch rates (fish/tow) declined further in 2003 and 2004, again suggesting that the decline in abundance is on-going.

We attempted to make a rough estimate of the absolute abundance of winter skate in the southern Gulf based on catch rates in the September survey. This estimate required assumptions about catchability to the survey gear and the proportion of the population available within the survey area. Details on these assumptions and calculations are given in Appendices B and C. Based on survey catch rates adjusted to daytime catchability, we estimated average adult abundance at 4.94 million in the 1971-1975 period, declining to 360,000 in the 2000-2004 period. Using survey catch rates adjusted to night catchability, our estimates were 22.06 million adults in the 1971-1975 period, declining to 1.70 million in 2000-2004 period.

Eastern Scotian Shelf (4VW) Population

The main source of information used to evaluate trends in the relative abundance of winter skate on the eastern Scotian Shelf was the July RV survey, which has been conducted since 1970. Additional information was obtained from an industry survey conducted each spring since 1995.

Summer RV survey (4VWX)

The July RV survey is the longest running of the 5 main DFO research vessel bottom-trawl survey series in the Maritimes region. It is an annual survey that samples the Scotian Shelf and Bay of Fundy. It follows a random stratified design, stratification being based primarily on depth. Most sets are in waters shallower than 200m although basins and some slope strata are included. Four additional deeper water 'redfish' strata along the slope were added to the survey in 1995.

These were excluded from the analyses for consistency. The research survey data are generally considered to be of high quality and resolution. They include hydrographic information, detailed fish sampling and spatial and temporal data. The catchability of winter skate to the survey gear is unknown but considered low.

The vessel and gear changed in 1982 from the *A.T. Cameron* using a Yankee 36 trawl to the *Lady Hammond* using a Western IIA trawl. In 1983, the vessel again changed, from the *Lady Hammond* to the CCGS *Alfred Needler*. In 2004 the CCGS *Teleost* was used to conduct the survey. The effect of these changes on winter skate catch rates is unknown. Sampling is conducted 24 hours per day, and consists of 30-minute sets at 3.5 knots. Catch rates presented here have been standardised to 1.75 nautical miles. We restricted our analyses of the July survey to the 4VW strata (strata 440-466, Fig. 13a).

We omitted skates less than 36 cm in length from further analysis. At these small sizes, it is difficult to distinguish winter skate from little skate, with which they are sympatric on the Scotian Shelf. We grouped skates into three size classes: (1) 75 cm and longer, roughly corresponding to the adult portion of the population, (2) 60-74 cm, juvenile skate that are caught at a relatively high rate in the directed skate fishery, and (3) 36-59 cm, juveniles caught at a low rate in the directed skate fishery.

Figures 13b, 13c and 13d describe the distribution of these three length groups in the survey in 6-year blocks. Generally, the distribution of winter skate in the July RV survey is concentrated on the banks including Middle Bank, Sable Island Bank and Banquereau Bank. Immature fish of 35-59 cm were primarily caught on Sable Island Bank in the earliest time block (Fig. 13b). As the abundance in this length group increased in the 1980s to early 1990s, they were found also on Banquereau and Middle Banks. In the most recent time period, this length group was primarily found in the deeper strata near Sable Island Bank, particularly along the outer edge, but not up on the bank. Few were caught on Banquereau in the 2000-2005 period. The maturing length group (60-74 cm) was found in both 4Vs and 4W in all time blocks (Fig. 13c). As with the immature-sized skate, the distribution of the maturing length group spread to Middle Bank, the eastern tip of Sable Island Bank and covered more of Banquereau Bank during the 1980s to early 1990s. The mature length group (75 + cm) was initially distributed across Western, Sable Island, and Banquereau Banks, but as overall abundance decreased, very few fish have been caught in 4W (Figure 13d). In the 2000-2005 period, catches in the survey were restricted to the eastern edge of Banquereau and central Sable Island Bank. These changes in distribution may reflect reductions in abundance and consequent vacating of marginal habitat.

March (4VWCOD) RV Survey

A spring RV survey has been conducted since 1986 by the *Alfred Needler* using the Western IIA trawl in 4VsW. The survey has not been conducted every year and in some years was not completed due to ice and weather. This survey used a different stratification scheme than the summer RV survey, but otherwise the procedures used were similar. Additional deeper water sets (>200 fm) are included in some years but very few winter skate were caught in those strata. Catch rates for the regular strata sampled were generally higher than in the summer RV and were concentrated on the edges of the banks. In 4W, the distribution extends onto Sable Island Bank where water temperatures were warmer (Fig. 13e).

Industry Survey in 4VsW

As part of the domestic harvesting plan established in 1994, industry agreed to conduct two skate surveys per year. Sampling of the catch was to be undertaken by observers from the International Observer Program (IOP) with costs borne by industry. The survey objectives were to map the extent of the resource in NAFO Divisions 4VsW, estimate by-catch levels of traditional groundfish species, and collect detailed biological information on individual skates. The area surveyed was chosen to coincide with the winter skate distribution of the summer RV survey (strata 446-458 in Fig. 13a). In 1995, a stratified random survey design was implemented with surveys conducted in April and October. Mesh sizes used ranged from 255 to 315 mm. In 1996, the survey gear reverted back to 155-mm mesh in the codend in order to provide more complete sampling of the size range of the population. In 1999, both surveys ended after the initial 5-year evaluation period. The 2000 stock assessment determined that continued monitoring was required and the 2001 Harvesting Plan required that only the spring survey be continued. Only the data from the longer Spring series was used in these analyses. Since 1995, three directed fishing sets ('captain's sets') were permitted in addition to the 12 to 16 regular survey sets allocated to each vessel; these directed sets were excluded from our analyses.

Distribution in the spring survey is presented in Figure 14. High catch rates tended to occur along the edge of the shelf in the areas south of Sable Island Bank and Banquereau Bank. This pattern is similar to that observed in the recent summer RV surveys. The fall survey, summarized in the 2000 skate assessment, revealed a pattern similar to the summer survey with a concentration noted to the west of Sable Island. This concentration was in the area where fishers have observed spawning winter skate in late summer.

Abundance Trends

As in the September survey of the southern Gulf, catch rates in the 4VW area of the July survey were mainly of large skates early in the time series (1970-1972,

Fig. 15). In this case, early catches were mainly of skates greater than 80 cm in length. (In the southern Gulf, early catches were mainly above 40 cm in length, Fig. 5.) Catches of smaller skates subsequently increased, reaching a peak in the early to mid 1990s, and then declined. Catches of large skates declined throughout the time series, reaching very low levels by the mid 1990s (Fig. 15).

Catch rates of both juvenile size classes increased sharply throughout the 1970s (Fig. 16). Catch rates of the smallest size class (36-59 cm) remained at a roughly constant high level throughout the 1980s and early 1990s, and then declined to a low level. Catch rates of the larger juvenile size class (60-74 cm) peaked in the early 1980s and then tended to decline slightly. The decline appeared to accelerate in the late 1990s, with consistently low catch rates observed since 2001. Adult (75+ cm) catch rates declined steadily throughout the time series.

A linear time trend is fit to the $\log_e$ catch rates of adults in Figure 17, yielding a slope of -0.0655 (SE=0.0120, $P<0.0001$). This corresponds to a 90% decline over the 35-yr time series. There is no indication from the data in Figure 17 that the decline in adult abundance has ceased.

Catch rates in the industry survey are compared to those in the July RV survey in Figure 18. The two surveys suggest comparable trends in winter skate biomass. In both cases, the biomass index declines from the mid 1990s to the early 2000s. The average index in the 2003-2005 period is 36% of the average for the 1995-1997 period in the case of the RV survey, and 24% of the average for the 1995-1997 period in the case of the industry survey.

Adjusting for catchability (see Appendix B) and expanding to the survey area, we estimate average adult abundance in the 4VW area at 4.6 million skates in the 1970-1974 period, declining to 0.7 million in the 2000-2004 period.

THREATS

Fishery removals

Southern Gulf

1. Groundfish and shrimp fisheries

Reported landings of skates in the southern Gulf of St. Lawrence are low (Fig.. 19), exceeding 50 t in only four years between 1971 and 2002 and under 10 t in most years. Most of these landings are likely of thorny skate. We considered landings of winter skate to be negligible in the southern Gulf.

Benoît (2006) estimated discarded bycatch of winter skate in groundfish and shrimp fisheries in the southern Gulf based on bycatch data collected by at-sea observers. Comparable data for crustacean trap and scallop fisheries are not collected, precluding any estimation of bycatch in those fisheries. Median estimates of discards exceeded 1000 t in most years in the 1970s but declined to low values in recent years (<50 t in each year since 2001). In order to evaluate the possible impact of these discards on the skate population, we converted these estimates of biomass discarded to estimates of numbers discarded at length as follows:

- Length frequencies of 26 commercial otter trawl catches of thorny skate were available from the southern Gulf in 1994 (5494 skates measured). These were examined by mesh size (88 mm – 253 fish; 161 mm – 2471 fish; 180 mm – 2770 fish) and compared to the RV survey length frequency for 1993 – 1995 (see example in Fig. 20). Based on these comparisons, skate retention curves were estimated for each mesh size (Fig. 21). The mesh sizes used in the mobile gear fisheries over most of the 1971 – 2004 period were intermediate between the 88-mm and 161-mm meshes available here. Thus, we constructed a hypothetical retention curve, intermediate between those estimated for 88-mm and 161-mm meshes (Fig. 21).
- Length composition of the discarded catch was estimated for each year from 1971 to 2004 by fishing the RV survey population using the hypothetical retention curve above. A 3-year running average was used for the survey length distribution. The retained length frequency in each year was converted to biomass using the survey length-weight relationship (estimated in 5-yr blocks). This biomass was divided into the median estimate of discarded biomass to obtain the factor used to scale the retained length frequency to total numbers discarded at length. Estimated numbers discarded were grouped into two lengths classes: juveniles (21-41 cm in length) and adults (42+ cm).

These calculations depend on a large number of assumptions and the resulting estimates of the size composition of the catch are highly uncertain.

Figure 22 shows the median estimate of discards by size class. Estimated discards exceeded one million fish in the early to mid 1970s and declined to 500,000 – 700,000 fish per year in the late 1970s and the 1980s. A sharp drop in estimated discards occurred in 1991. Estimated discards have been below 100,000 fish in most years since then, and at or below 10,000 fish since 2002.

2. Scallop fishery

The scallop fishery in the southern Gulf represents another potential source of winter skate bycatch mortality, but the magnitude of bycatch in this fishery is unknown. However, scallop dredging accounted for roughly 50% of the skate discards off New England in the 1989-1998 period (Sosebee and Terceiro 2000). Scallop landings in the southern Gulf rose sharply in the mid 1960s (Lanteigne and Davidson 1991), peaking in the late 1960s and early 1970s. Landings declined rapidly in the early 1970s, fluctuating between about 200 and 300 t from the mid

1970s to the early 1990s (Fig. 23; Lanteigne and Davidson 1991; L.-A. Davidson, DFO Moncton, pers. comm.). Landings increased in the mid 1990s and then declined to relatively low values in recent years.

Winter skate are occasionally observed in scallop dredge catches, but no quantitative estimates of bycatch rates are possible. A DFO survey of the western Northumberland Strait was conducted in June 1997 using a 8-10 bucket scallop dredge towed for roughly 1 km (J.M. Hanson, DFO Moncton, pers. comm.). A total of 52 winter skate were caught in 121 tows. Catch rates averaged 0.43 skates/tow overall, 0.34 skates/tow in the tows catching scallop, and 0.25 skates/tow in the tows catching 3 or more scallop. However, these bycatch rates are not likely representative of those in a scallop fishery. Each tow in the survey was conducted at a different location. In the scallop fishery, a site is fished repeatedly until catch rates decline. Thus, the survey bycatch rate may apply to the first fishery tow at a site but likely exceeds the bycatch rate in subsequent tows at the site (unless skate are attracted into the area by bottom disturbance).

Scallop fishing effort in the southern Gulf in recent years varied from 99,964 tows in 2001 to 67,320 tows in 2004 (L.-A. Davidson, DFO Moncton, pers. comm.). Towing is at about 3-5 knots for 30 min (M. Lanteigne, DFO Moncton, pers. comm..), for tow distance of about 4 km. A bycatch rate of 0.25 skates/km would result in a bycatch of 70,000 – 100,000 skates in recent years. Our rough estimates of skate abundance in 2001 – 2004 are 0.7 – 1.3 million (day catchability) or 6 – 9 million (night catchability). These values correspond to bycatch rates of 10% or 1%. However, it could be argued that bycatch rates in the scallop fishery are actually much lower because the rate of 0.25 skates/km only applies to a small fraction of tows (the first tows at a site).

Eastern Scotian Shelf

Estimated landings and discards of winter skate in groundfisheries on the eastern Scotian Shelf are presented in Appendix D. Landings (t) in the directed skate fishery were converted to numbers at length based on the length frequency of samples taken from the catch in that fishery. In other fisheries, biomass landed or discarded was converted to numbers at length using the procedure (and retention curve) described above for the southern Gulf.

Figure 24 shows estimated landings and discards by size class. Large mature fish (75+ cm) comprised a relatively high proportion of the estimated landings in the early to mid 1970s. This reflects their predominance in the survey population during this period. Large fish (60+ cm) also dominate the estimated landings since the mid 1990s. This reflects the targeting of these large fish by the directed skate fishery that began in 1994. Estimated landings varied between 200,000 and 400,000 fish in most years prior to the late 1990s. Estimated landings were highest in the mid 1970s, early 1990s and mid 1990s, exceeding 500,000 fish per year in these periods. The high landings reported in the early to mid 1970s are from the foreign fishery (and their true magnitude is very uncertain, see Appendix D). The high landings in the early 1990s are associated with high effort in the cod-haddock-pollock (CHP) fishery. Those in the mid 1990s are from the directed skate fishery. Estimated landings declined to low values in recent years (<100,000 fish), associated with reduced catches in the directed fishery and low effort in other groundfisheries in 4VW.

Large mature fish dominated the estimated discards in the early to mid 1970s. Again, this reflected their predominance in the survey population at this time. Estimated discards of adults remained fairly constant throughout the 1970s and 1980s. Estimated discards of juveniles increased substantially in the late 1970s, associated with their increased abundance in the survey population. Increased catch in the CHP fishery in the 1980s was also associated with the increase in discard estimates in the 1980s. Estimated discards have been at a low level since the mid 1990s, associated with reduced groundfisheries during this period.

Habitat alteration

Dredging and trawling might physically alter bottom habitat and might also result in a re-suspension of bottom sediments that might smother spawning areas and damage gills (COSEWIC 2005). However, there may be a low probability that alteration of the bottom by trawling would affect adults, given their preference for sand and gravel bottoms (COSEWIC 2005). Although survival during the egg case stage may be affected, no studies have been undertaken to evaluate the effects of trawling on the survival of skates.

Predators

Both the southern Gulf and eastern Scotian Shelf ecosystems have undergone dramatic changes over the past 30 years. Demersal fish biomass collapsed in both systems in the early 1990s. This likely resulted in a dramatic decline in fish predation on small fishes (Fig. 25). Prior to their collapse in the early 1990s, cod was the dominant demersal fish (in terms of biomass) in the southern Gulf and was also among the most important demersal fishes on the eastern Scotian Shelf. Piscivory by cod increases with size, with fish representing an important component of the diet of large (60+cm) cod. The abundance of large cod declined in both systems in the 1980s (Fig. 26), prior to the stock collapses.

Skates are a component of seal diets (Benoit and Bowen 1990; Hammill and Stenson 2000). Their contribution to seal diets appears to be minor, though this may be underestimated because they lack otoliths and other bony parts (which are persistent in seal digestive tracts). Grey seal abundance has been increasing in both systems since the 1960s (Fig. 27).

Environmental conditions

In both the southern Gulf and on the eastern Scotian Shelf, temperatures in the cold intermediate layer (CIL) were at an intermediate level in the mid 1970s, and increased to a high level in the late 1970s and early 1980s (Fig. 28 and 29). Temperatures cooled throughout the 1980s, reaching very low levels in the early to mid 1990s. CIL temperature increased in the late 1990s, reaching an intermediate level in the southern Gulf and a high level on the eastern Scotian Shelf in the early 2000s.

The CIL temperature index is relevant for winter skate in the 4VW area where they occupy CIL waters in summer. Winter skate in the southern Gulf enter the CIL in fall when they move offshore. However, during the summer growing season, they occur in shallow inshore areas above the CIL. Temperature in these inshore waters shows a different pattern, increasing over the 1971-2004 period (Fig. 28).

DISCUSSION AND CONCLUSIONS

In this section, we address the evaluation framework established by DFO to support recovery planning and to allow determination of whether SARA incidental harm permits can be issued. This section is based on the material presented above and the results of population modeling presented in Swain et al. (2006).

Southern Gulf of St. Lawrence (4T) designatable unit

Winter skate in NAFO Division 4T occur primarily in the southern Gulf of St. Lawrence where they occupy shallow inshore waters in summer and early fall. Winter skate also occur in the Estuary in 4T, but appear to be very rare in this area. This analysis and the data presented in the COSEWIC status report focused on winter skate in the southern Gulf (COSEWIC 2005).

Species Status

1. Evaluate present species trajectory

Our analyses indicate that adult winter skate have declined steadily in 4T since the early 1980s. The decline appears to be on-going. The decline has continued despite a sharp reduction in fishery removals (i.e., discarded bycatch) in the early 1990s, when effort in groundfisheries decreased sharply in the sGSL. The decline appears to be associated with an increase in the natural mortality of adults (Swain et al. 2006).

In contrast to adults, juveniles were at a low level of abundance in the early 1970s. Their mortality appeared to decrease in the early to mid 1970s. Their abundance increased in the 1970s to a peak in the mid-1980s. Since then, their abundance has been declining. Unlike adults, the decline in juvenile abundance since the mid-1980s does not appear to be associated with any increase in their mortality. Instead, the decline in juveniles appears to result from the decline in the spawning stock.

2. Evaluate present species status

Survey catch rates indicate a 96% decline in the abundance of adults between 1971 and 2002. Because optimal habitat for winter skate appears to be inshore of the survey, survey catch rates may over-estimate the extent of the population decline. This would occur if geographic range contracted as abundance declined. In the summer survey of the Northumberland Strait conducted since 2000, winter skate abundance declined by over 50% from 2000 to 2004. Thus, large declines in abundance have also occurred in the part of the range not covered by the September survey. It is certain that there has been a large decline in adult abundance since the 1970s, and this decline has continued up to 2004.

Juvenile abundance has also been declining and research surveys show no signs of improvement.

Rough estimates of abundance can be derived from the survey catch rates given various assumptions about catchability to the survey gear and availability within the survey area. Using “day-adjusted” indices, our rough estimates of adult abundance are about 5 million in the 1971-1975 period, declining to 360,000 in the 2000-2004 period. Using “night-adjusted” indices, our rough estimates are about 22 million in the 1971-1975 period, declining to less than 2 million in the 2000-2004 period.

3. Evaluate expected order of magnitude / target for recovery

Recovery targets have not been established for winter skate. In this stock, it is not possible to estimate either unfished biomass or MSY. Potential recovery targets could be the survey catch rates observed in the 1970s or the long term mean. As the average survey catch rate for adults in 2000-2004 is 7% of the average for 1971-1975, these proposed targets would be 5 or 10 times the current rates.

4. Evaluate expected general time frame for recovery to the target

A stage-structured population model was used to project population abundance 10 years into the future (Swain et al. 2006). Variants of the model considered projections with and without catch in the groundfish and shrimp fisheries. Bycatch in the scallop fishery was unknown and could not be incorporated in the models. All model variants indicated that the population is expected to continue to decline even in the absence of any bycatch in fisheries. The uncertainty about the median projection is high but does not include recovery. No recovery is expected without a decrease in adult natural mortality (or unknown human-induced mortality that is interpreted as natural mortality in our models).

5. Evaluate Residence Requirements

Winter skate do not have any known dwelling-place similar to a den or nest during any part of their life cycle, hence the concept of “residence” does not apply.

Scope for Human – Induced Mortality

6. Evaluate maximum human-induced mortality which the species can sustain and not jeopardize survival or recovery of the species

At the current high rate of adult natural mortality, no recovery is expected even if bycatch in fisheries for groundfish and shrimp is held to zero (Swain et al. 2006). Bycatch at the most recent (2002-2004, about 10 t) level has a negligible effect on the expected rate of decline. However, slightly higher bycatch, at the 1993-2001 level (about 50 t), sharply accelerates the expected rate of decline.

Based on the model projections (Swain et al. 2006), there is little or no scope for human-induced mortality if this population is to recover, and even then recovery seems unlikely.

7. Document major potential sources of mortality/harm, **and**
8. For those factors NOT dismissed, quantify to the extent possible the amount of mortality or harm caused by each activity

There is no directed fishery for winter skate in the sGSL. Major potential sources of mortality/harm include:

- Bycatch in fisheries for groundfish and shrimp: Although more substantial in the 1970s and 1980s, estimated bycatch in these fisheries has been between 6.5 and 64.5 t since 2000.
- Bycatch in the scallop fishery: The scallop fishery occurs in the area occupied by winter skate in summer in the southern Gulf. Winter skate are caught by scallop dredges. However, there is no observer coverage of this fishery and bycatch in this fishery is not recorded.
- Although not human-induced, natural mortality of adults has increased over the same period that seal abundance has increased (Swain et al. 2006). This increase in adult natural mortality seems to be the dominant factor in the lack of recovery potential for this population.
- Skate egg purses occur on the bottom for a year or more and are susceptible to trawling, dredging and other bottom disturbances.

9. Aggregate total mortality / harm attributable to all human causes and contrast with that determined in task 6

Because the cause of the decline appears to be primarily an increase in the natural mortality of adults, removal of the aggregate human-induced mortality would not be sufficient to allow recovery. However, unaccounted sources of human-induced mortality (e.g., scallop dredging) may be a component of the mortality interpreted as natural mortality in our analyses.

Sources of uncertainty

- No ageing information. There is no growth model or information on age at maturity. There is no information on whether growth rate changed during the survey period. If growth rate slowed, the increase in juvenile abundance may reflect reduced growth rather than increased survival. However, simulated growth changes had little impact on mortality trends in exploratory model runs (Swain et al. 2006).
- The population dynamics for this stock are poorly understood. For example, juvenile abundance in the 1960s and 1970s was very low relative to adult abundance. Subsequent increases in juvenile abundance and decreases in adult abundance appeared to indicate a five-fold increase in adult mortality.
- The magnitude of bycatch in the scallop fishery is unknown.
- The survival rate of discarded catch is uncertain.
- Potential anthropogenetic impacts on habitat have not been evaluated.
- Possible impacts of increased predation by seals were apparent for adults but not for juveniles, even though predation by seals is thought to be focused on small fish.
- The distribution of this stock is near the margins of the survey area. Trends in the survey catch rates may be influenced by changes in the proportion of the stock within the survey area.

Eastern Scotian Shelf (4VW) designatable unit

Species status

1. Evaluate present species trajectory

At the beginning of the July RV survey time series (1970s) juvenile winter skate abundance was low. Juvenile winter skate abundance increased in the 1970s. Juvenile abundance was fairly stable in the 1980s but has been declining since the early 1990s.

Adult winter skate (75+ cm) abundance has declined since 1970 in the July RV survey data. The decline appears to be ongoing. Both the July RV survey and Spring Industry survey show similar declines in total biomass over the 1995 to

2005 period. Based on population models (Swain et al. 2006), increases in adult *M* contributed to the decline.

2. Evaluate present species status

Catch rates of mature winter skate in the July RV survey indicate a decline rate of 90% over a 35 year time series.

A comparison of catch rates in the Spring Industry survey and the July RV survey revealed comparable trends in winter skate biomass. In both surveys, the biomass index declines from the mid 1990s to the early 2000s. The average index in the 2003-2005 period is 36% of the average for the 1995-1997 period in the RV survey, and 24% of the average for the 1995-1997 period in the industry survey.

Based on catchability-corrected survey data, average adult abundance in the 4VW area was estimated at ~5 million skates in the 1970-1974 period, and declined to 700 000 in the 2000-2004 period. There is considerable uncertainty around these estimates. Based on population models, the absolute adult abundance in the 1970-1974 period is estimated at 4.1 million (2.5 to 8.6) and 500 000 (206 000 to 1.1 million) in the 2000-2004 period.

Juvenile abundance has declined over the last 10 years and research surveys show no signs of improvement in abundance.

3. Evaluate expected order of magnitude /target for recovery

Recovery targets have not been established for winter skate on the eastern Scotian Shelf. It is not possible to estimate either unfished biomass or MSY for this stock. Potential recovery targets could be the survey catch rates observed in the 1970s or the long term mean. As the average survey catch rate for adults in 2000-2004 is 16% of the average for 1970-1974, these proposed targets would be 3- 6 times the current rates.

4. Evaluate general time frame for recovery to the target

A stage-structured population model was used to project population abundance 10 years into the future (Swain et al. 2006). Variants of the model considered projections with and without directed skate landings and groundfish bycatch . Bycatch in the scallop fishery was unknown and could not be incorporated in the models. The model predicted a continued decline in abundance at current levels of removal and a reduced decline or stability if removals are set at zero. However, the uncertainty about the median projection was very great and encompassed both extirpation and recovery. Based on the most probable trend, no recovery is expected without a decrease in adult natural mortality (or unknown human-induced mortality that is interpreted as natural mortality in our models).

5. *Evaluate residence requirements*

Winter skate do not have any known dwelling place or residence as defined in the Species at Risk Act.

Scope for Human Induced Mortality.

6. *Evaluate maximum human-induced mortality that the species can sustain and not jeopardise survival or recovery of the species*
    - Total mortality is estimated in the model and is apportioned between natural and fishing mortality. For the purpose of the model, the fishing mortality is only attributed to catches that have been quantified.
    - At the current high rate of adult natural mortality, no recovery is expected even if reported directed and incidental catch is held to zero.
    - Model-based estimates of adult natural mortality may be misspecified by including unknown sources of human-induced mortality. For example, bycatch in the scallop and offshore clam fisheries is unquantified.
    - There is little or no scope for human-induced mortality if this population is to recover and even then recovery is not certain.

7. *Document major potential sources of mortality/harm* ***and***
8. *For those factors not dismissed , quantify to the extent possible the amount of mortality or harm caused by each activity.*

    - There has been a directed skate fishery, of which most are winter skate, since 1994. A progressive reduction in total allowable catch has resulted in landings falling from over 2000t in the first years to less than 300t annually since 2001. The 2005 quota is set at 200 t.
    - Winter skate are caught as bycatch in many fisheries. With moratoria or reduced effort for most groundfish fisheries on the eastern Scotian Shelf, this bycatch is estimated at less than 300t annually in the last 10 years. Bycatch since 2000 has averaged 74 t.
    - The offshore scallop and clam fisheries may have substantial amounts of bycatch, as seen in other areas. However, because this bycatch is not recorded, estimates are not possible at this time.
    - Foreign fleets removed significant amounts of skate in earlier time periods but these removals have been less than 200 t in the last 10 years and have been negligible since 2000.
    - Skate egg cases occur on the bottom for 18-22 months and hence are susceptible to bottom trawling, dredging, and other bottom disturbances.
    - Although not human-induced, natural mortality of adults has increased over the same period that seal abundance has increased. This increase in adult natural mortality seems to be a contributing factor in the lack of recovery potential for this population.

9. *Aggregate total mortality /harm attributable to all human causes and contrast that determined in task 6*

- Total catch from 2000-2004 averaged 300 t. annually. This corresponds to an estimated fishing mortality of 0.1.
- Because an increase in *M* of adults appears to contribute to the decline in abundance, removal of the aggregate human-induced mortality may not be sufficient to allow recovery.
- However, a portion of the apparent increase in adult *M* may be due to unaccounted sources of human-induced mortality.

Sources of uncertainty

- Limited ageing information. There is no information on whether growth rates changed over the survey time period.
- The population dynamics of this population are poorly understood. For example, juvenile abundance in the 1960s and 1970s was very low relative to adult abundance. Both juvenile and adult mortality have changed over the period of investigation.
- The magnitude of bycatch in the offshore scallop and clam fisheries is unknown.
- The survival rate of discards is unknown
- Potential impacts of human activities on habitat have not been evaluated.
- Possible impacts of increased predation by seals
- No correction for day-night differences in survey catch were made in analyses of the RV survey data in 4VW in contrast to 4T survey data where such corrections were required. These corrections can change perception of absolute abundance.
- The potential impacts of oil and gas exploration and production were mentioned during the review meeting but there was inadequate information to draw any conclusions.

ACKNOWLEDGEMENTS

We thank Mark Hanson for providing data on winter skates from the summer surveys of the Northumberland Strait and from the 1997 scallop dredge survey, Leslie-Ann Davidson for information on the scallop fishery, Joël Chassé for calculating the inshore temperature time series, and Tom Hurlbut and Jamie Gibson for discussion.

REFERENCES

Benoit, D., and Bowen, W.D. 1990. Summer diet of grey seals (*Halichoerus grypus*) at Anticosti Island, Gulf of St. Lawrence, Canada. *In*: Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. W.D. Bowen (ed.). Can. Bull. Fish. Aquat. Sci. 222: 227-242.

Benoît, H.P. 2006. Estimating the discards of winter skate (*Leucoraja ocellata*) in the southern Gulf of St. Lawrence, 1971-2004, under multiple sources of uncertainty. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/002: 47 pp.

Benoît, H.P., and Swain, D.P. 2003. Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: adjusting for changes in research vessel, gear and survey protocol. Can. Tech. Rep. Fish. Aquat. Sci. No. 2505: iv + 95 pp.

Clay, D. 1991. Seasonal distribution of demersal fish (Osteichthyes) and skates (Chondrichthyes) in the southeastern Gulf of St. Lawrence. Can. Special Publ. Fish. Aquat. Sci. 113: 241-259.

COSEWIC 2005. COSEWIC assessment and status report on the winter skate *Leucoraja ocellata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 41 pp.

Darbyson, E., and Benoît, H. P. 2003. An atlas of the seasonal distribution of marine fish and invertebrates in the southern Gulf of St. Lawrence. Can. Data Rep. Fish. Aquat. Sci. 1113: 294 p.

Frisk, M.G. 2004. Biology, life history and conservation of elasmobranchs with an emphasis on western Atlantic skates. Ph.D. thesis, University of Maryland, College Park, 239 pp.

Frisk, M.G., Miller, T.J., and Fogarty, M.J. 2002. The population dynamics of little skate *Leucoraja erinacea*, winter skate *Leucoraja ocellata*, and barndoor skate *Dipturus laevis*: predicting exploitation limits using matrix analyses. ICES J. Mar. Sci. 59: 576-586.

Hammill, M. O., and Stenson, G. B. 2000. Estimated prey consumption by harp seals (*Phoca groenlandica*), hooded seals (*Cystophora cristata*), grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) in Atlantic Canada. J. Northw. Atl. Fish. Sci. 26: 1-23.

Holden, M. J. 1973. Are long-term fisheries for elasmobranchs possible? Rapp. P.-V. Réun. Cons. Int. Explor. Mer 164: 360-367.

Lanteigne, M., and Davidson, L.-A. 1991. Catch and effort statistics for the giant scallop (*Placopecten magellanicus*) fishery in the southern Gulf of St.

Lawrence - historical review from 1923 to 1989. Can. Tech. Rept. Fish. Aquat. Sci. 1804: 59 p.

Lucifora, L.O., and García, V.B. 2004. Gastropod predation on egg cases of skates (Chondrichthyes, Rajidae) in the southwestern Atlantic: quantification and life history implications. Mar. Biol. 145: 917-922.

MacCall, A. D. 1990. Dynamic geography of marine fish populations. University of Washington Press, Seattle.

McEachran, J. D., and Martin, C. O. 1977. Possible occurrence of character displacement in the sympatric skates *Raja erinacea* and *R. ocellata* (Pisces: Rajidae). Env. Biol. Fishes 2: 121-130.

McEachran, J.D., Boesch, D.F., and Musick, J.A. 1976. Food division within two sympatric species-pairs of skates (Pisces: Rajidae). Mar. Biol. 35: 301-317

Michalopoulos, C. 1990. A field study on the ecology and behavior of the winter skate (*Raja ocellata*) and little skate (*Raja erinacea*) off outer Cape Cod, Massachusetts. M.Sc. thesis, Southeastern Mass. Univ., North Dartmouth, MA. 71 p.

Scott, W.B., and Scott, M.G. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

Simon, J.E., and Frank, K.T. 1998. Assessment of the winter skate fishery in Division 4VsW. DFO Can. Stock Assess. Sec. Res. Doc. 98/145.

Sosebee, K., and Terceiro, M. 2000. Assessment of the United States Northeast Region skate complex for 2000. NAFO SCR Doc. 00/15: 107 pp.

Sulikowski, J. A., Morin, M. D., Suk, S. H. and Howell, W. H. 2003. Age and growth estimates of the winter skate (*Leucoraja ocellata*) in the western Gulf of Maine. Fish. Bull. 101: 405-413.

Swain, D. P., and Sinclair, A. F. 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Can. J. Fish. Aquat. Sci. 51: 1046-1054.

Swain, D. P., T. Hurlbut and H. P. Benoît 2005. Changes in the Abundance and Size of Skates in the Southern Gulf of St. Lawrence, 1971–2002. J. Northwest Atl. Fish. Sci. 36: art. 2, 15 p.

Swain, D.P., Jonsen, I.D., and Myers, R.A.. 2006. Recovery potential assessment of 4T and 4VW winter skate (*Leucoraja ocellata*): population models. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/004.

Table 1. Predicted length-at-age and von Bertalanfy parameters for winter and little skates (sexes combined).

Source:	Sulikowski et al 2003	Frisk 2004	Frisk 2004
Species:	Winter Skate	Winter Skate	Little Skate
L_∞	131.4	122.1	59.3
k	0.064	0.07	0.18
t_0	-1.531	-2.06	-1.15
Age	Length (cm)	Length (cm)	Length (cm)
0	12.3	16.4	11.1
1	19.7	23.5	19.0
2	26.6	30.2	25.7
3	33.1	36.4	31.2
4	39.2	42.2	35.8
5	44.9	47.6	39.7
6	50.3	52.6	42.9
7	55.3	57.3	45.6
8	60.0	61.7	47.9
9	64.4	65.8	49.8
10	68.6	69.6	51.3
11	72.5	73.2	52.6
12	76.1	76.5	53.7
13	79.6	79.6	
14	82.8	82.4	
15	85.8	85.1	
16	88.6	87.6	
17	91.3	89.9	
18	93.8	92.1	
19	96.1	94.1	

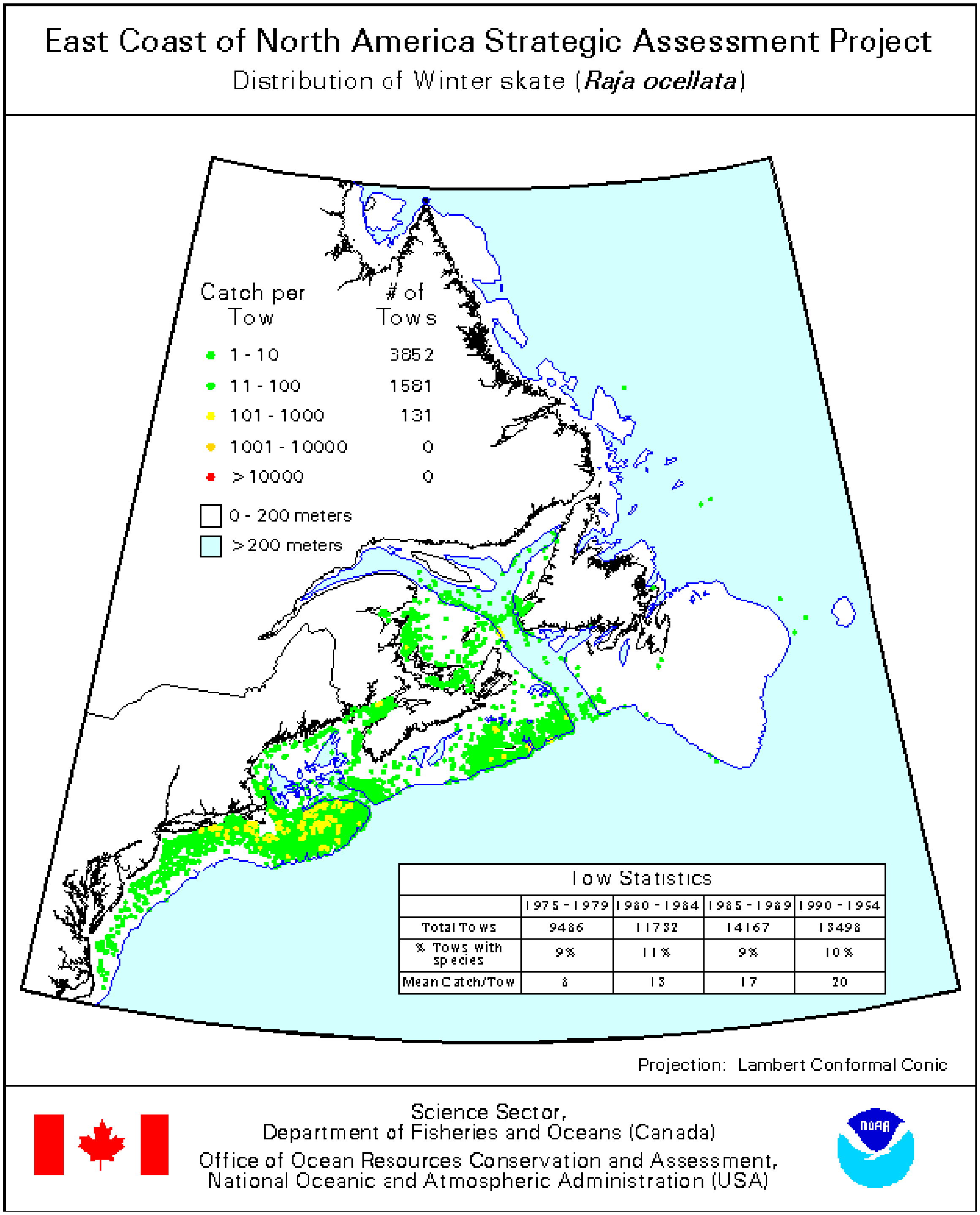


Figure 1. Distribution of winter skate in the northwest Atlantic based on Canadian and U.S. trawl survey data in the ECNASAP database.

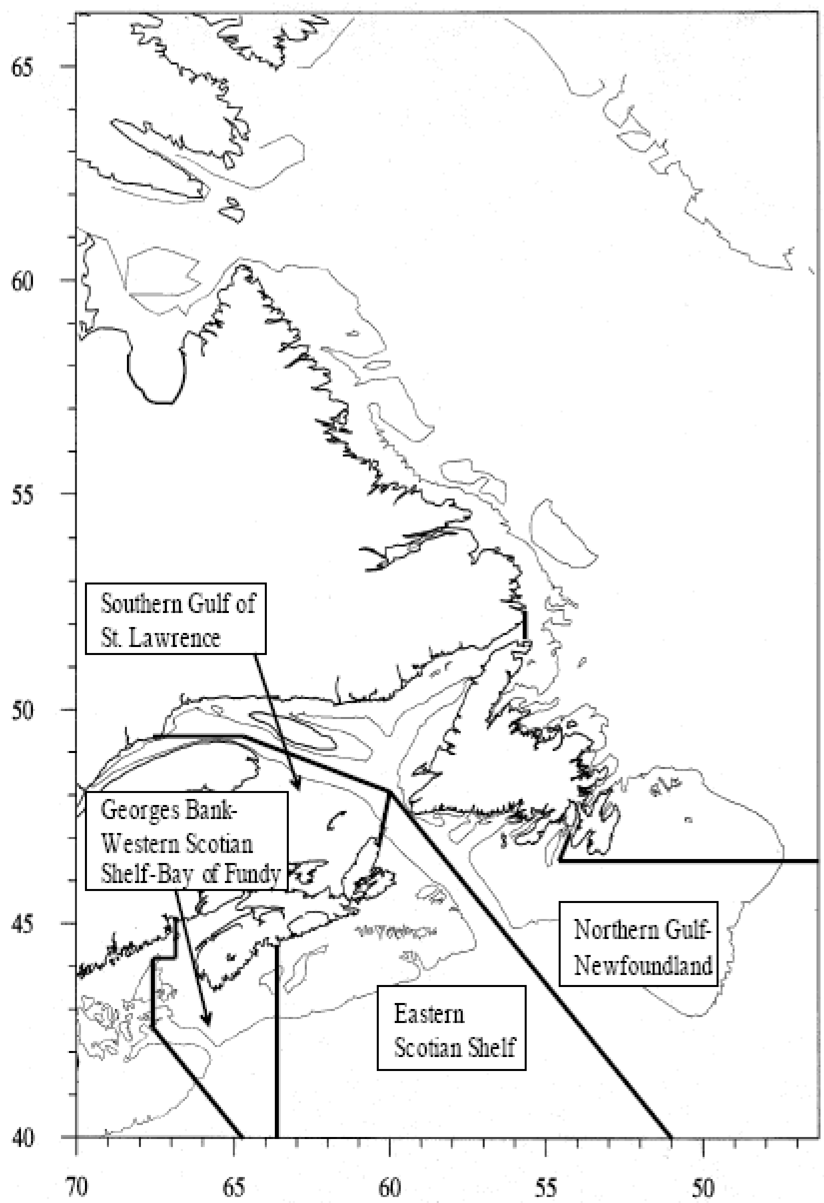


Figure 2. The four designatable units identified for winter skate in the 2005 COSEWIC status report (from COSEWIC 2005).

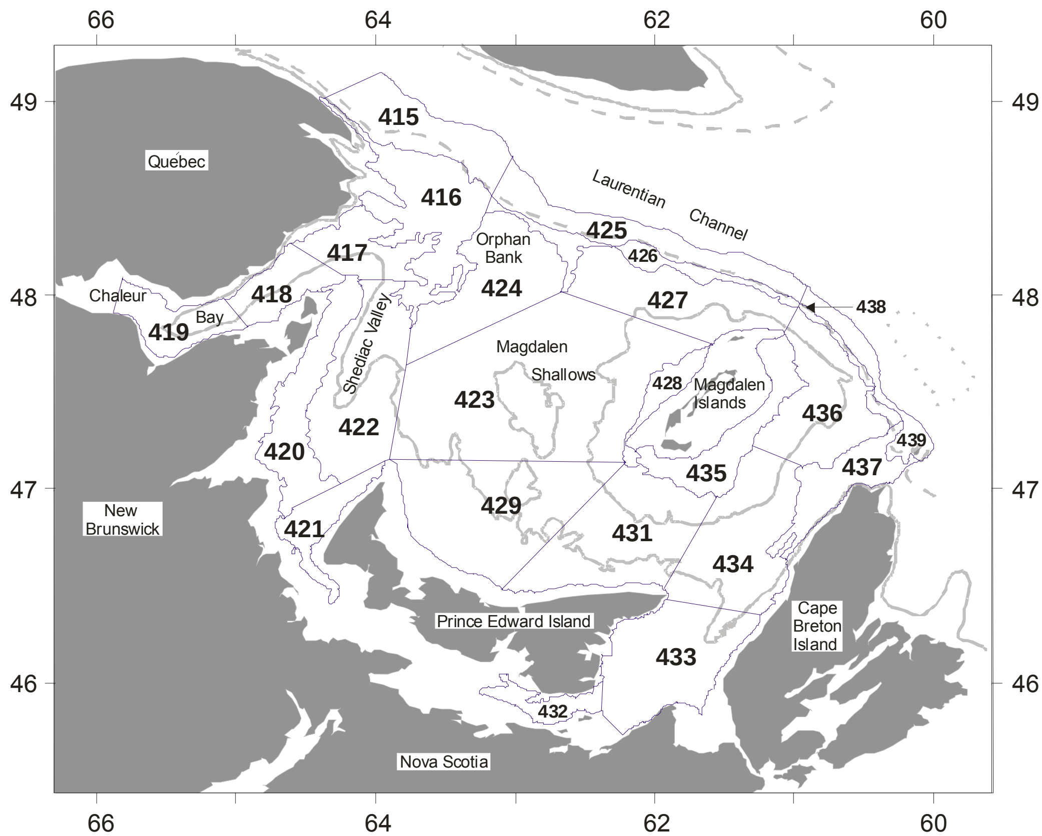


Figure 3. The southern Gulf of St. Lawrence, showing the strata (numbered 415-429, 431-439) used in the annual September bottom-trawl survey. Depth contours: solid grey line = 60 m; dashed grey line = 200 m; dotted grey line = 500 m.

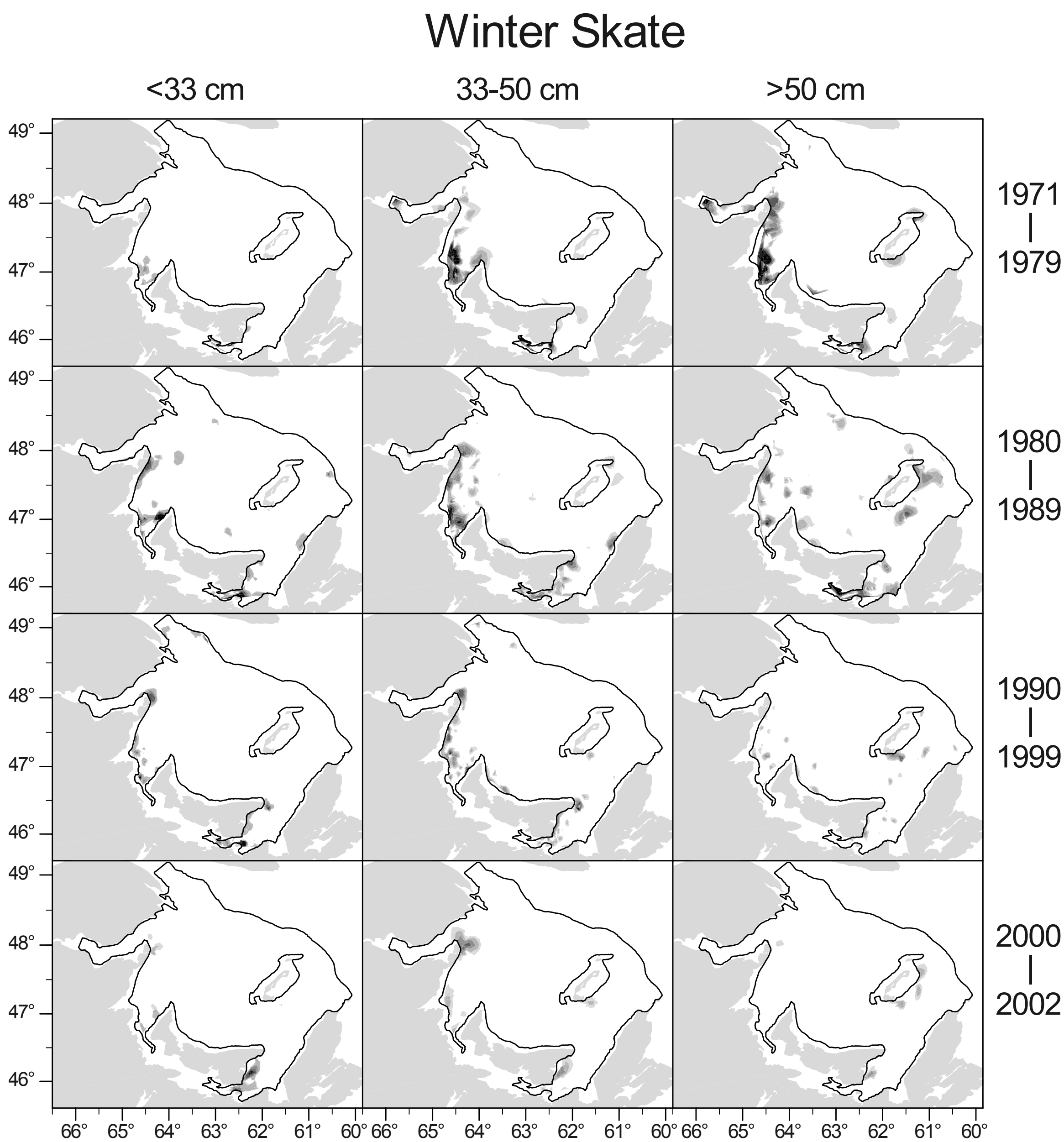


Figure 4. Distribution of three size-classes of winter skate in the southern Gulf of St. Lawrence in September, based on catches in strata 415-439 of the annual bottom-trawl survey. Shading is based on the 10th, 25th, 50th, 75th, and 90th percentiles of catch (fish/tow) within each size class. Darker shading indicates higher skate density.

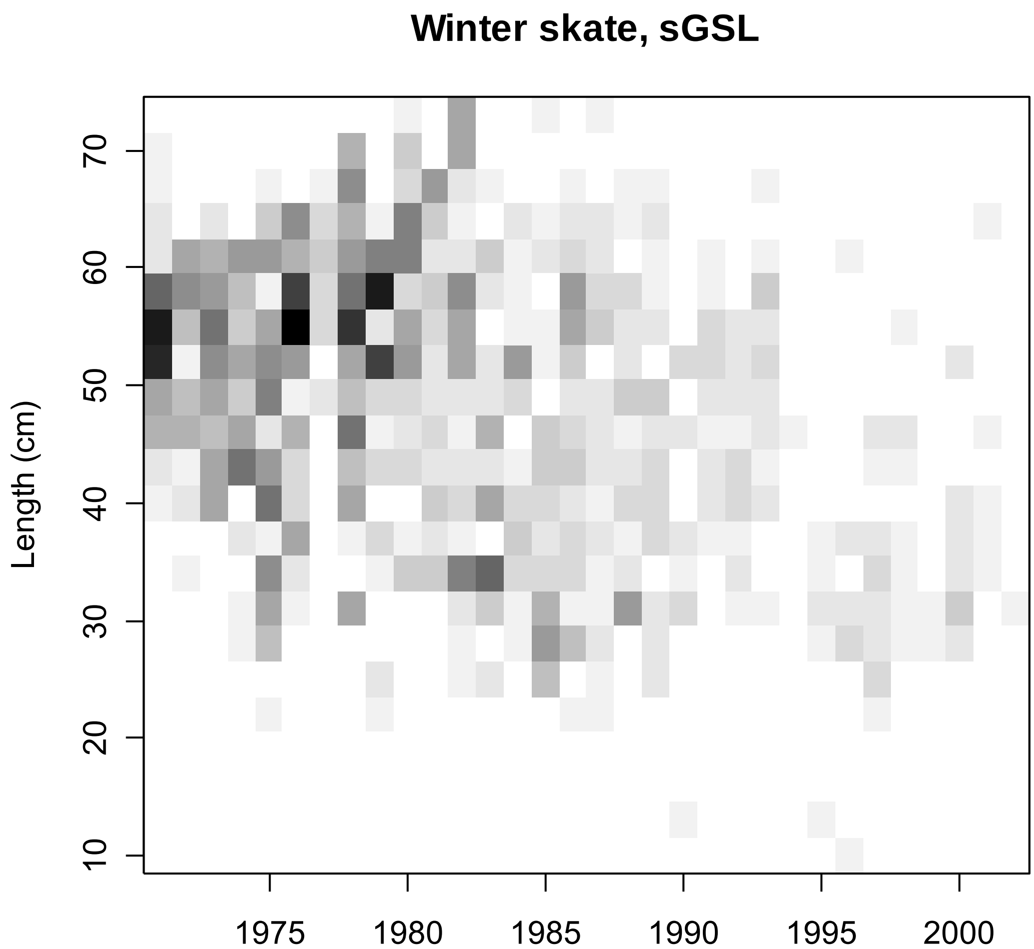


Figure 5. Catch rates (fish/tow) of winter skate by 3-cm length class in the September survey of the southern Gulf, 1971-2002. Darker shading indicates a higher catch rate.

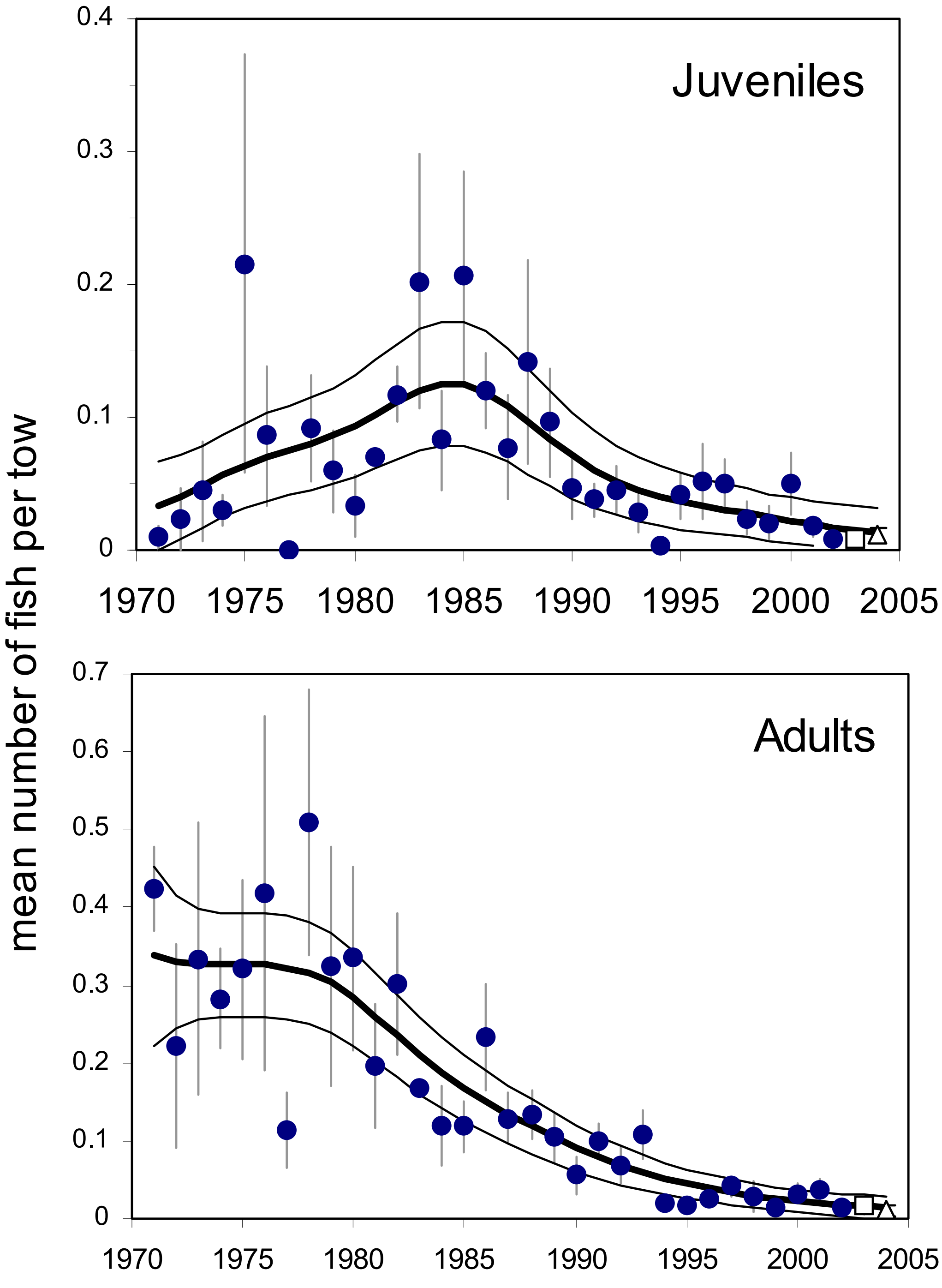


Figure 6. Catch rates of two size classes of winter skate in the September survey of the southern Gulf of St. Lawrence. Juveniles correspond to the 21-41 cm length class, and adults correspond to skates 42 cm or longer. Error bars are ± 1SE. Heavy lines show the fit of a generalized additive model (GAM) to the time trend in catch rates, and light lines show approximate 95% confidence intervals around the fitted line. The GAMs used a log link and a Poisson error distribution allowing for overdispersion. Symbol denotes vessel (see Figure 7 caption).

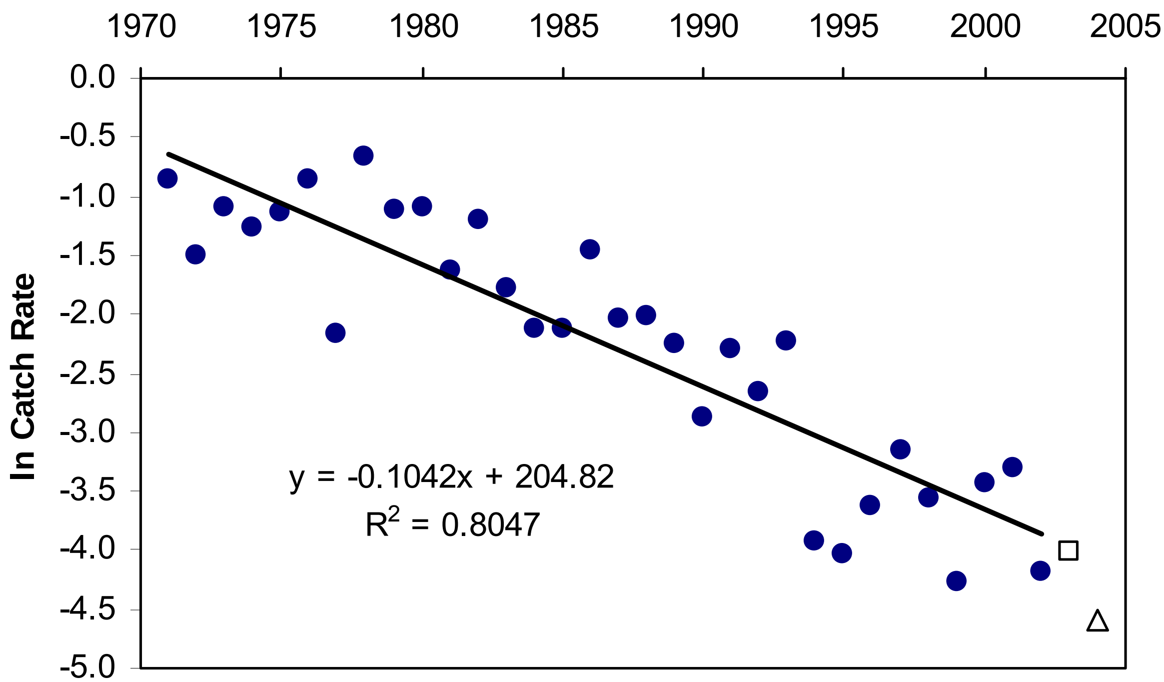


Figure 7. Log$_e$ catch rates of adult winter skate (i.e., skate 42 cm or longer) in the September survey of the southern Gulf. The linear trend in catch rates is shown for the calibrated portion of the time series (circles). The mean catch rate by the *Wilfred Templeman* in 2003 and by the *Teleost* in 2004 are denoted by a square and triangle, respectively.

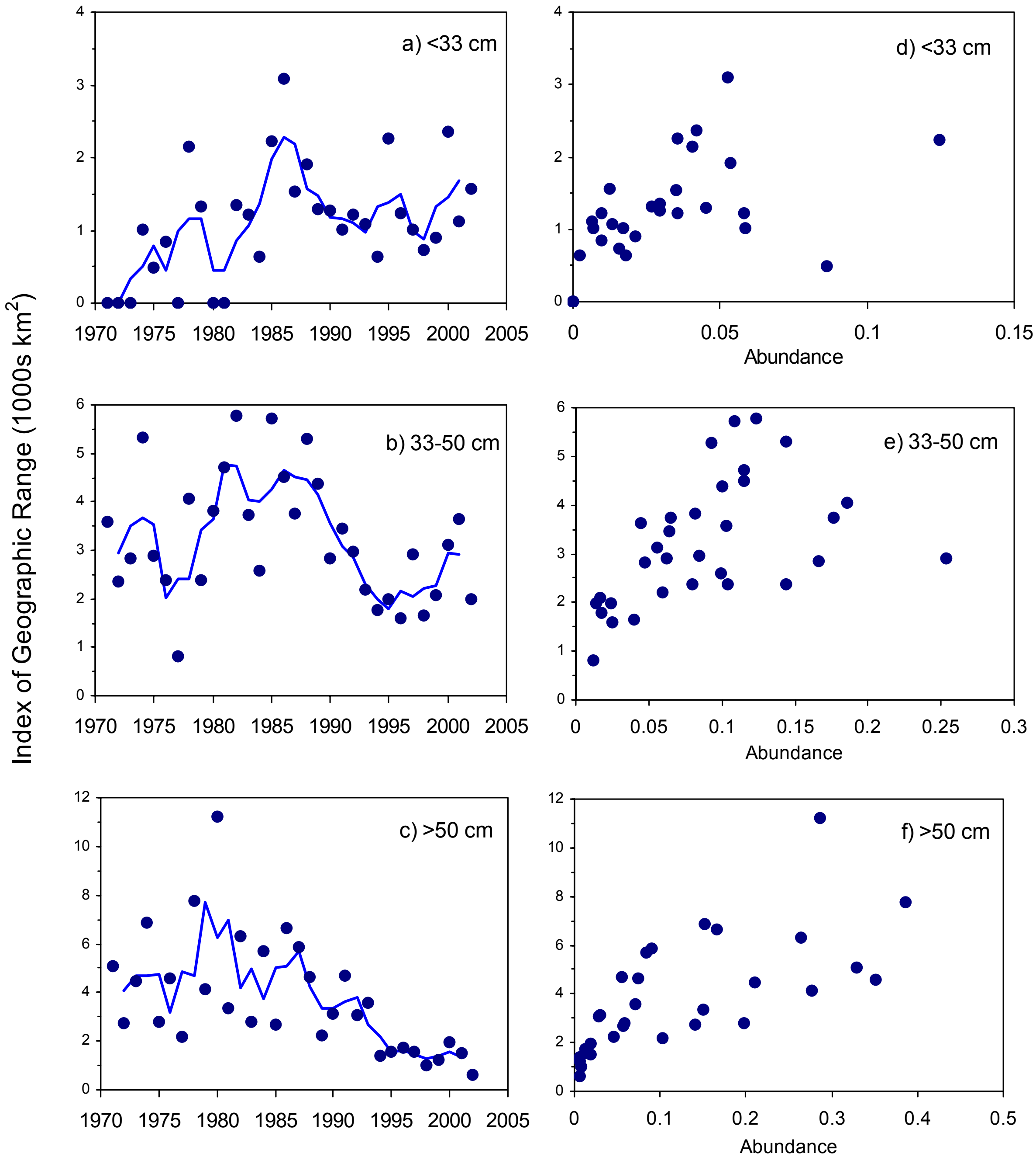


Figure 8. Index of geographic range for three size-classes of winter skate in the southern Gulf of St. Lawrence; *a-c*: interannual variation, with 3-year running average, *d-f*: relationship with an index of abundance (survey catch rate, fish/tow). The index is the minimum area containing 95% of skates (see Swain and Sinclair 1994 for details).

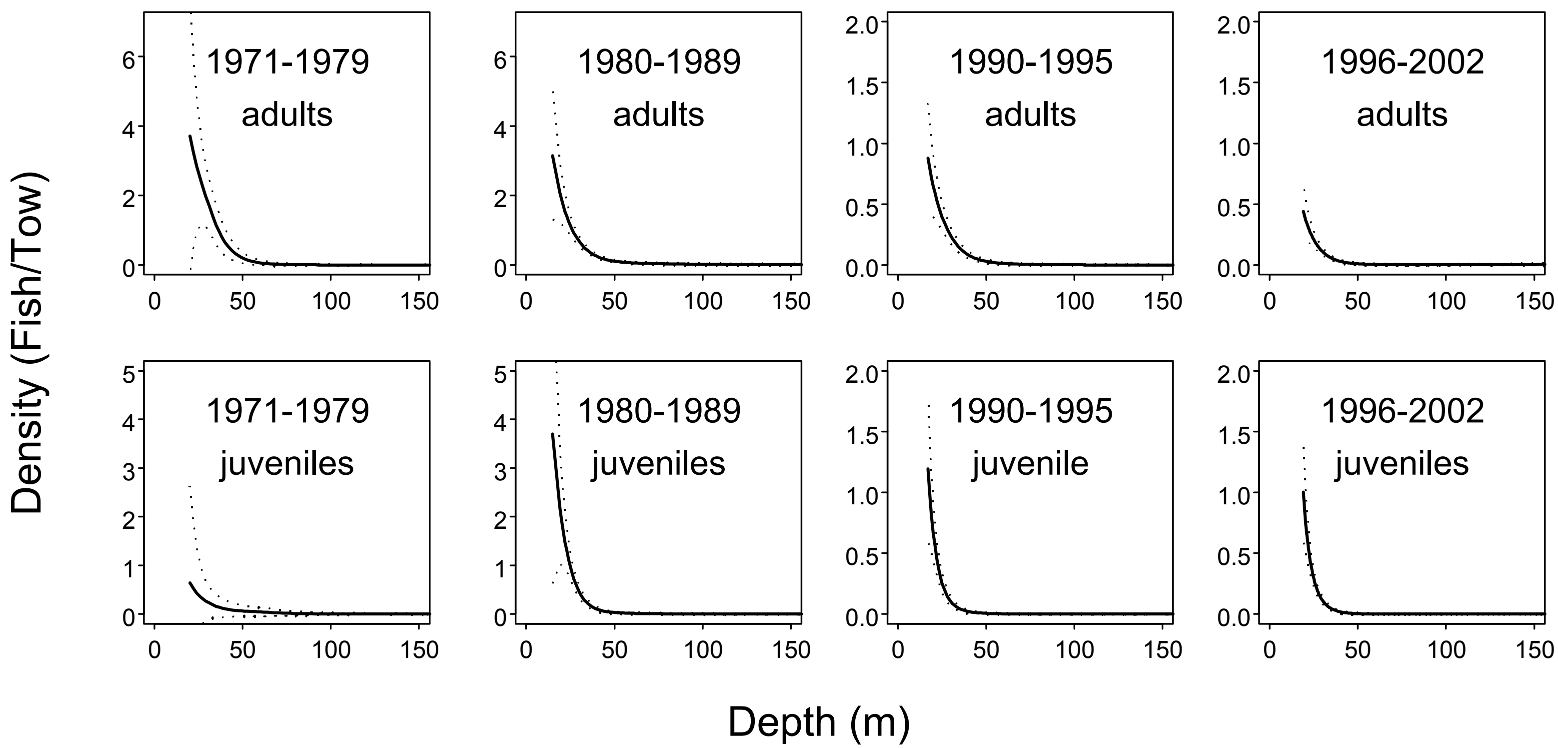


Figure 9. Effect of depth on the local density of winter skate in the southern Gulf of St. Lawrence in September. Solid line shows the predicted relationship from a generalized additive model (smoothing spline with 4 df, log link, Poisson error with overdispersion). Dotted lines are approximate 95% confidence intervals. Analyses were restricted to strata 415-439.

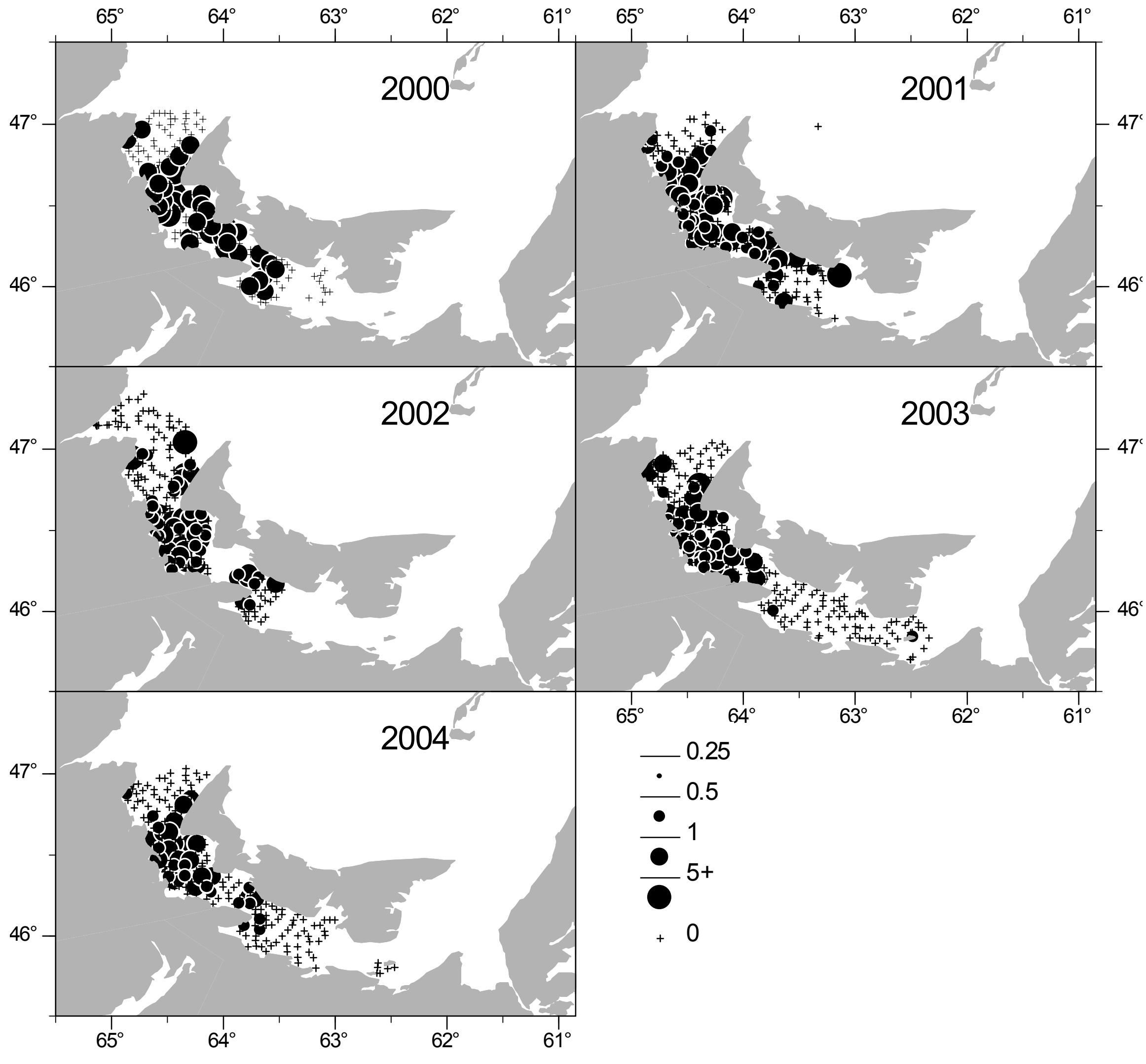


Figure 10. Distribution of tows and winter skate catches in the July-August trawl survey of the Northumberland Strait. Circle size is proportional to winter skate catch (fish/km). Crosses indicate tows catching no winter skate.

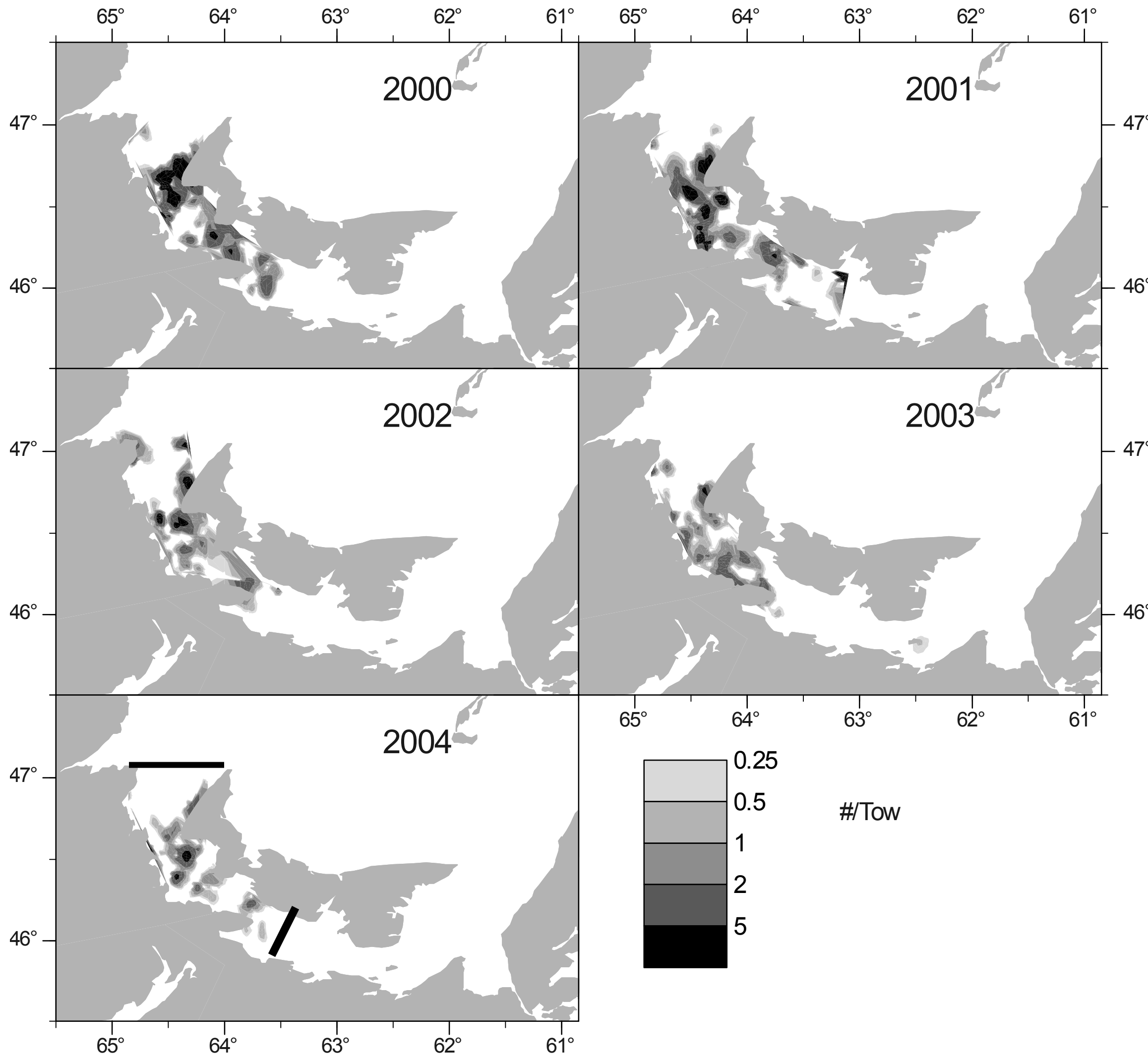


Figure 11. Distribution of winter skate in the Northumberland Strait in late July – early August. Note that the eastern Strait was not sampled in all years (see Figure 10 for the distribution of tows in each year). Heavy lines enclose strata 1- 4 (which were sampled in all years).

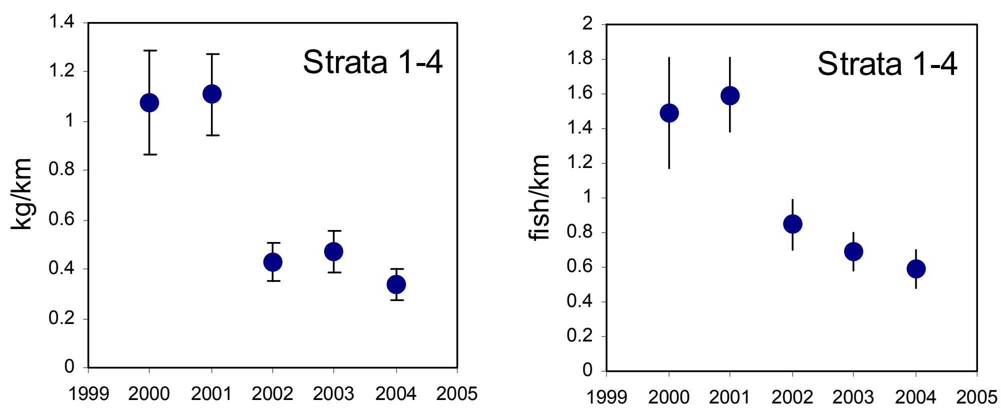


Figure 12. Mean catch rates of winter skate in strata 1-4 of the Northumberland Strait survey. Vertical lines are ±1SE.

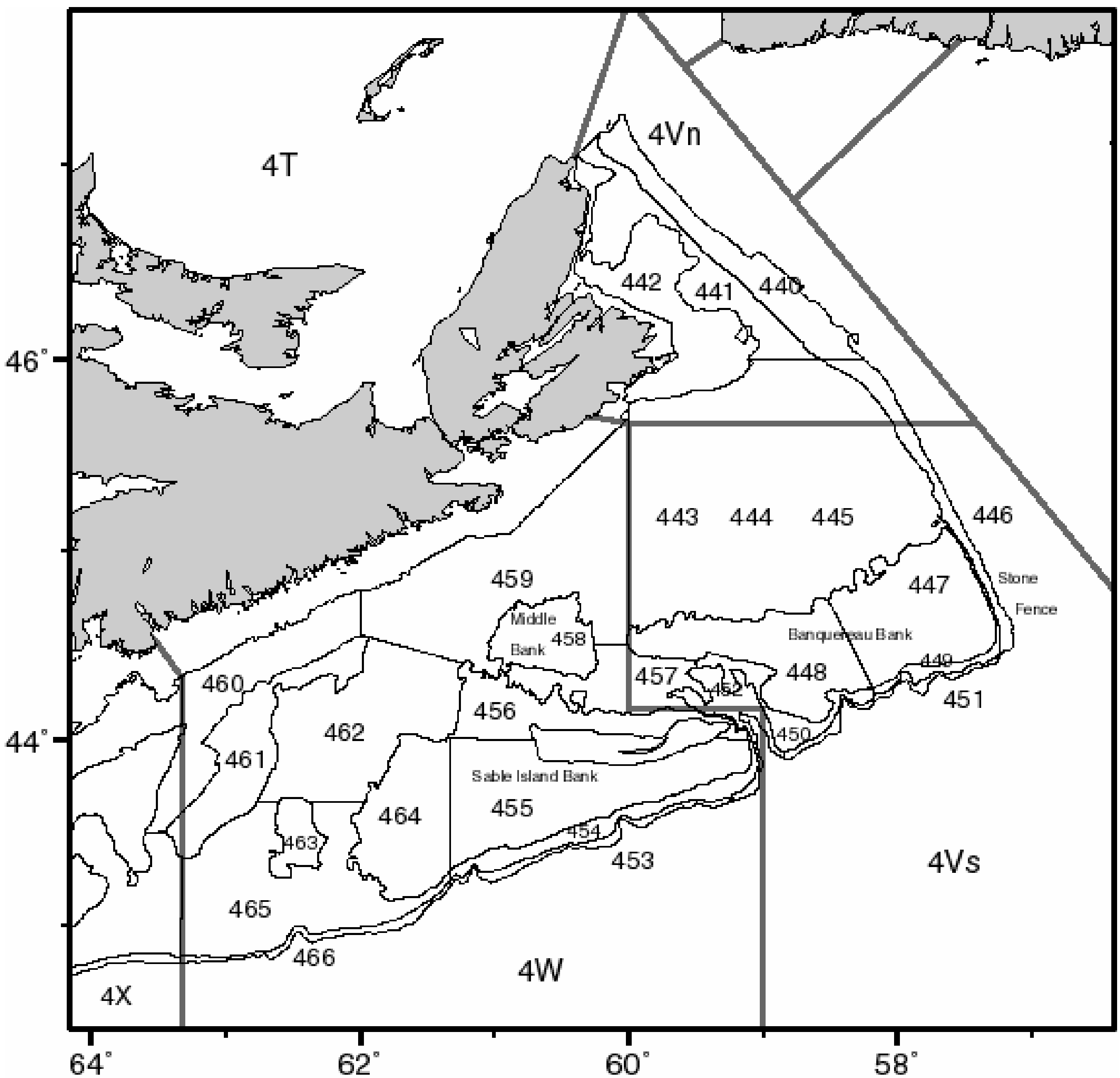


Figure 13a. Stratification scheme used in the July RV survey. Strata 440-466 were used in analyses of 4VW winter skate. Strata 446-458 were sampled in the joint industry/science skate surveys.

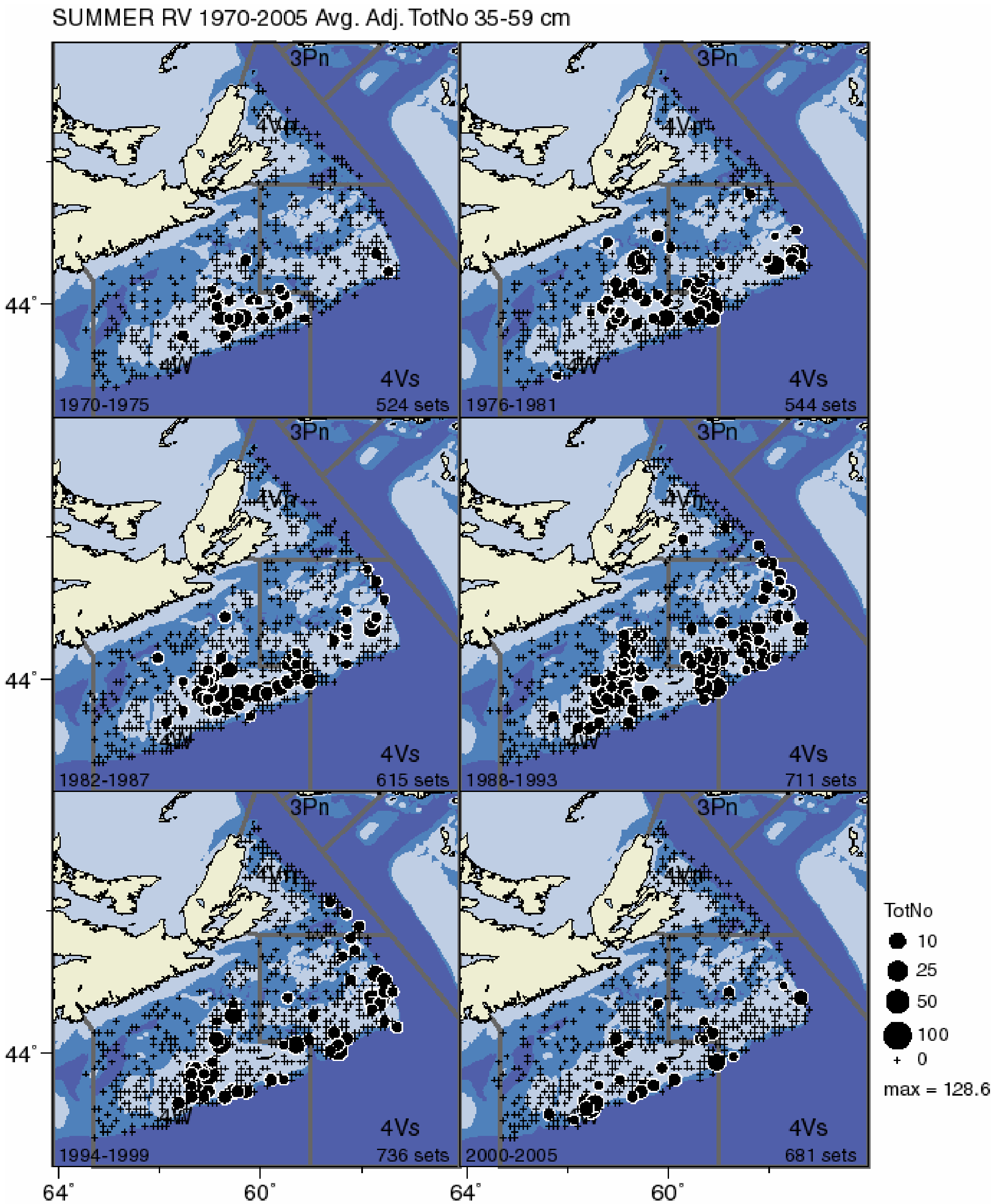


Figure 13b. Distribution of winter skate 35-59 cm from the summer RV survey in Div. 4VW aggregated in 6 year blocks.

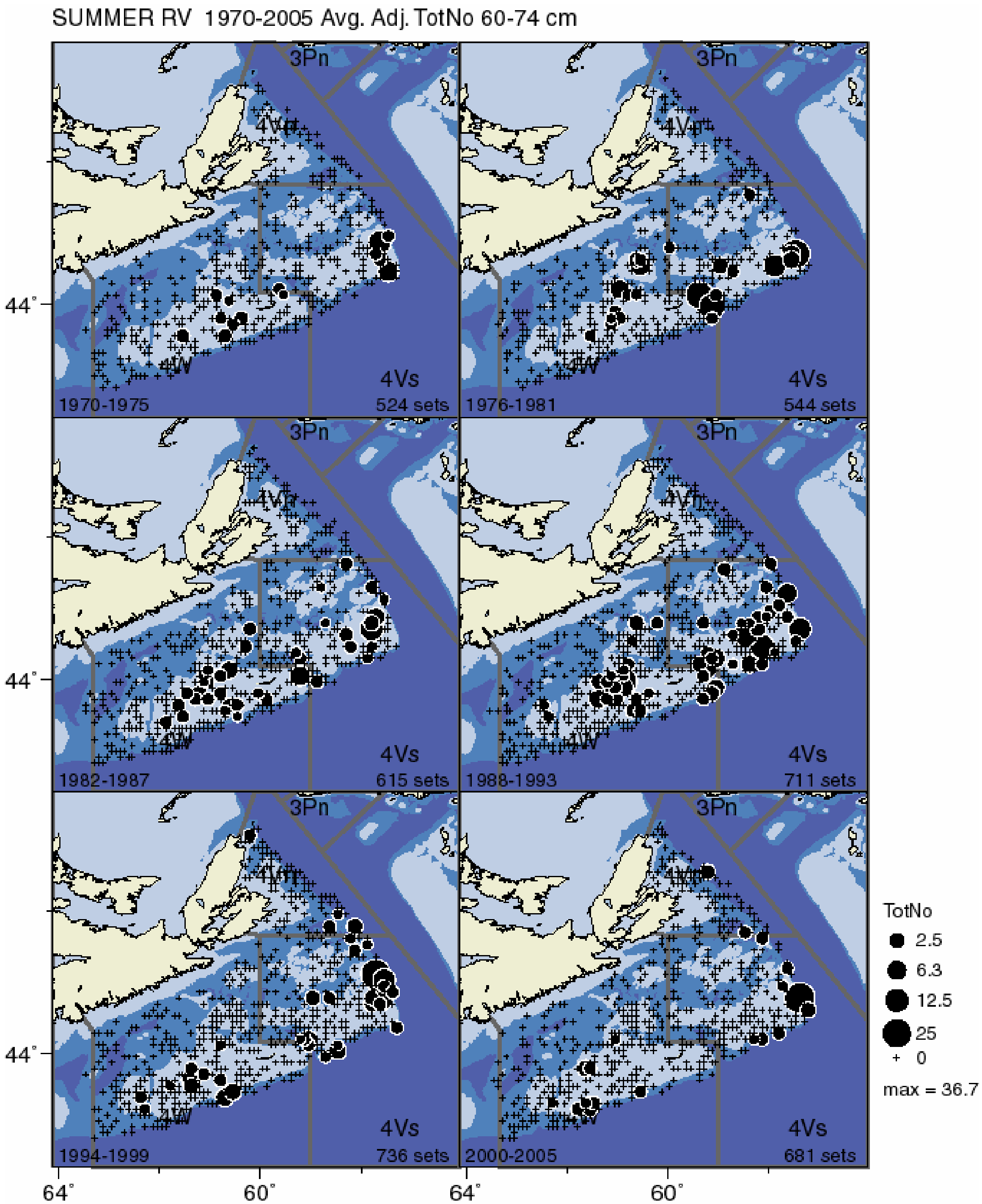


Figure 13c. Distribution of winter skate, 60-74 cm, from the summer RV survey in Div. 4VW aggregated in 6 year blocks.

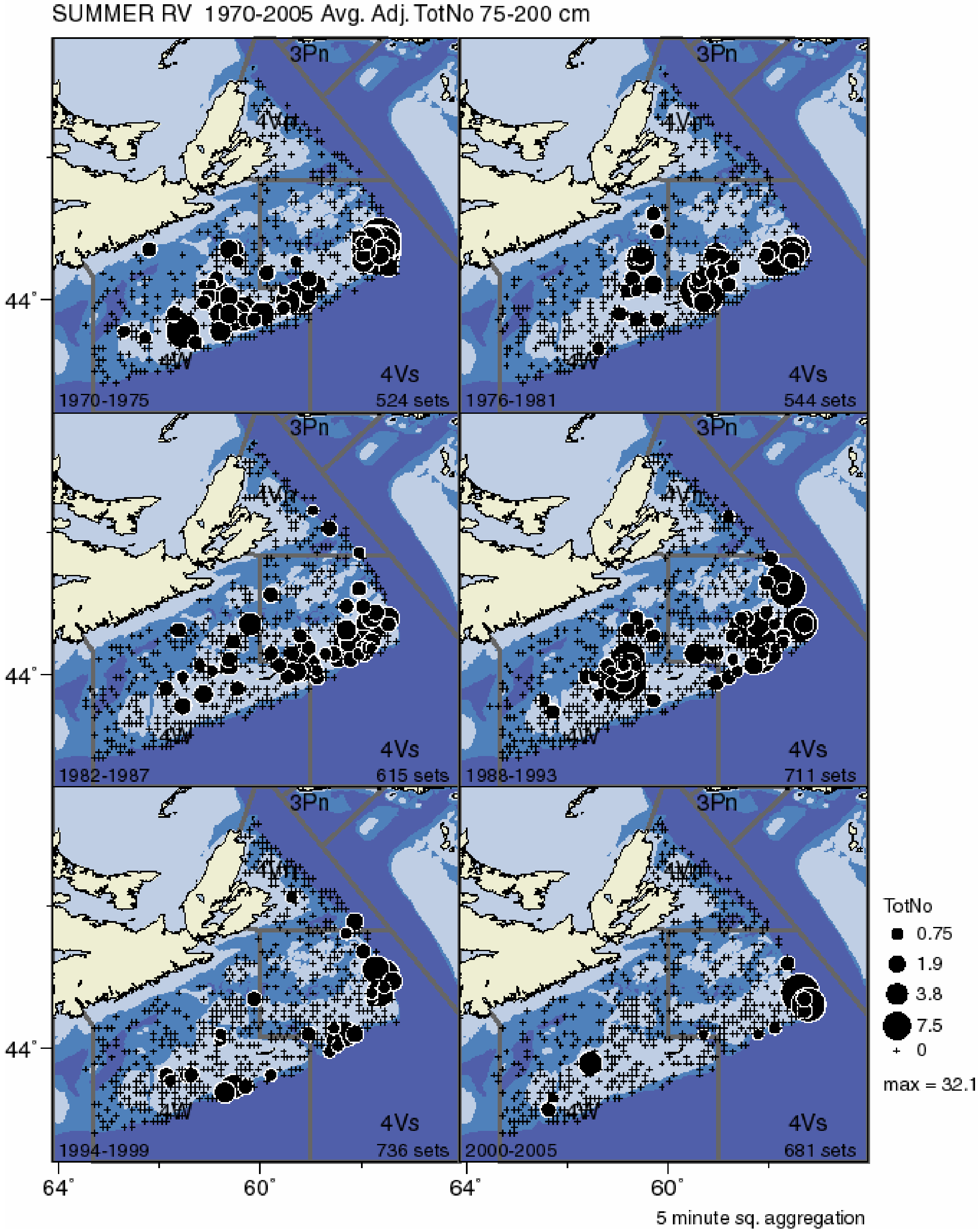


Figure 13d. Distribution of winter skate 75+ cm from the summer RV survey in Div. 4VW aggregated in 6 year blocks.

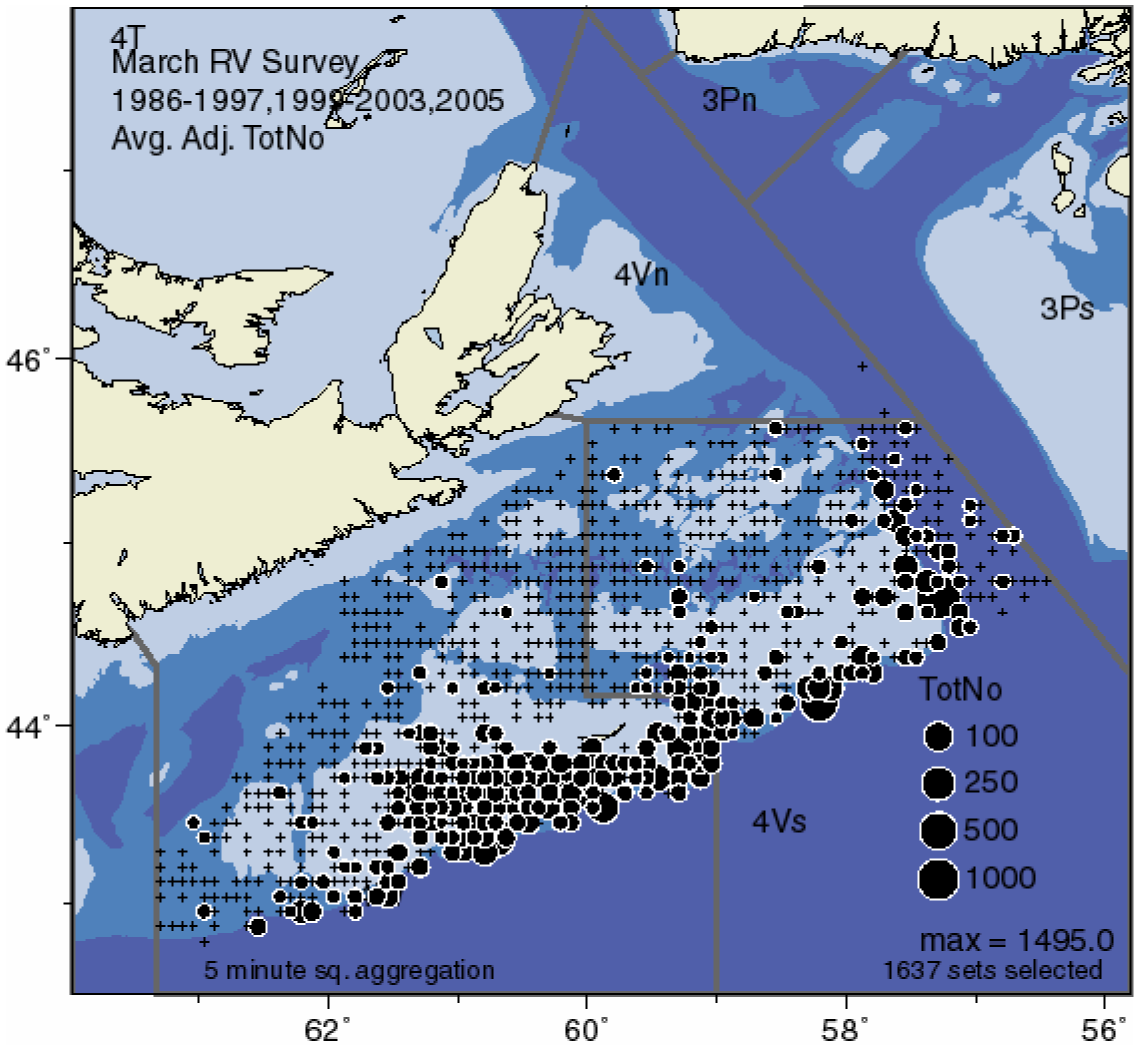


Figure 13e. Distribution of winter skate from the March RV survey in Div. 4VsW. Crosses indicate tows where no winter skate were captured.

.

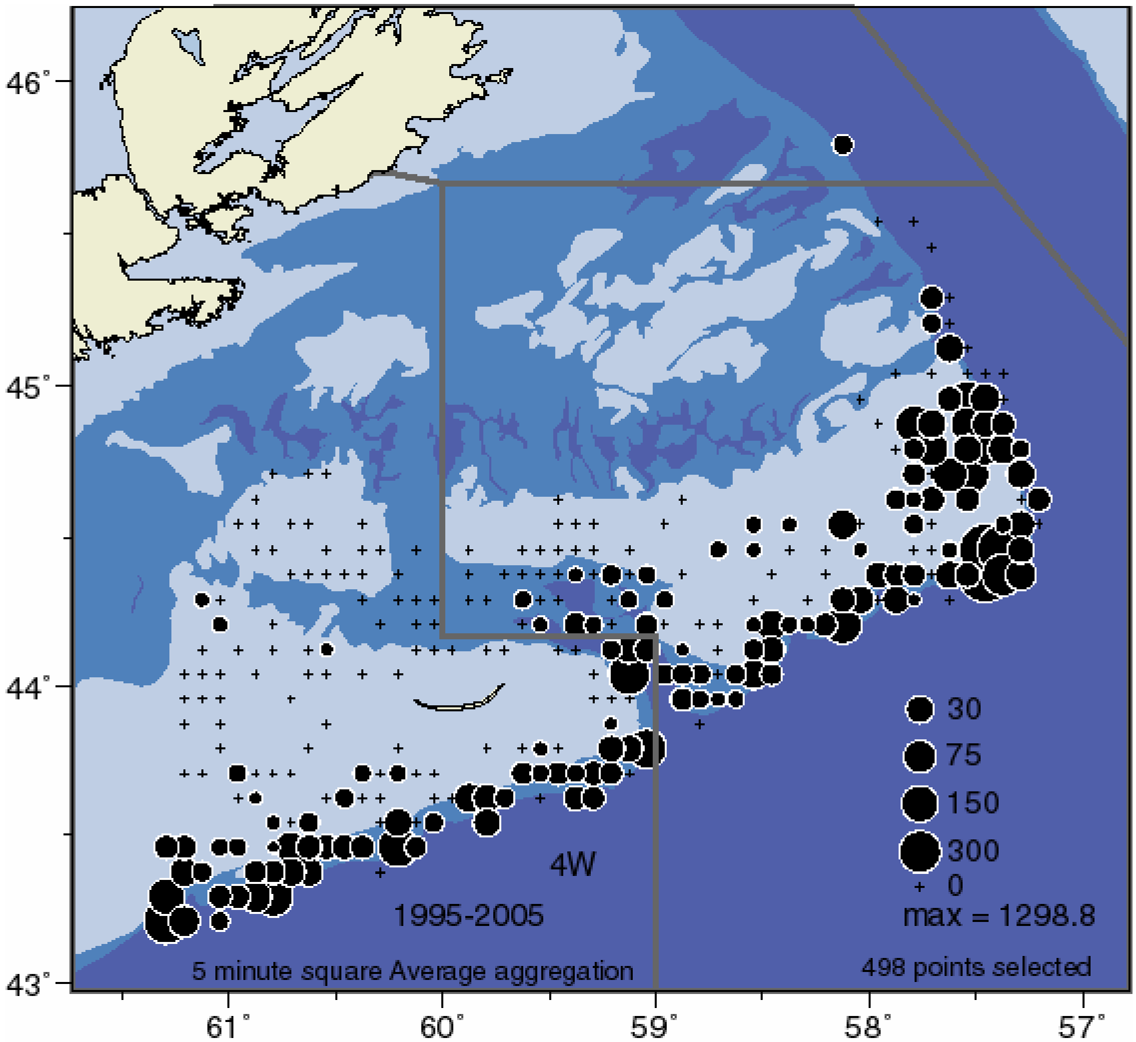


Figure 14. Distribution of winter skate from the spring industry survey, 1995-2005.

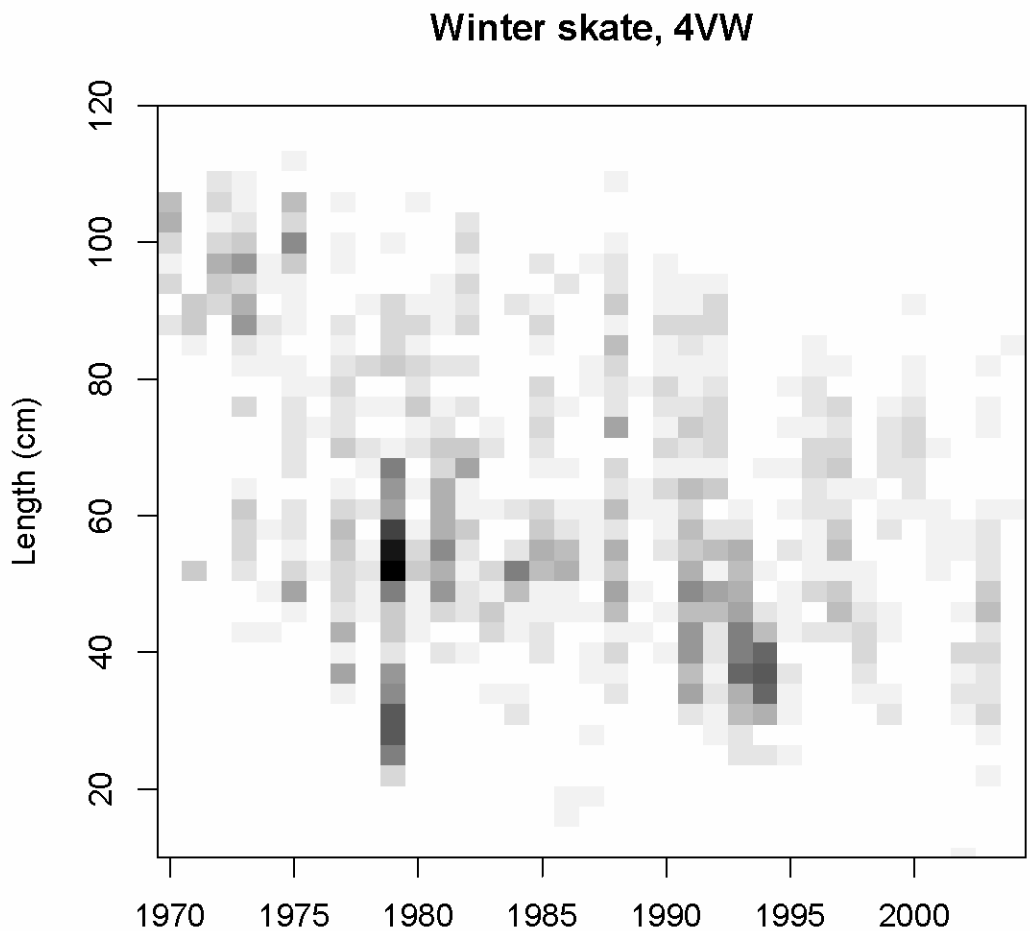


Figure 15. Catch rates (fish/tow) of winter skate by 3-cm length class in the July survey of the eastern Scotian Shelf, 1970-2004. Darker shading indicates a higher catch rate.

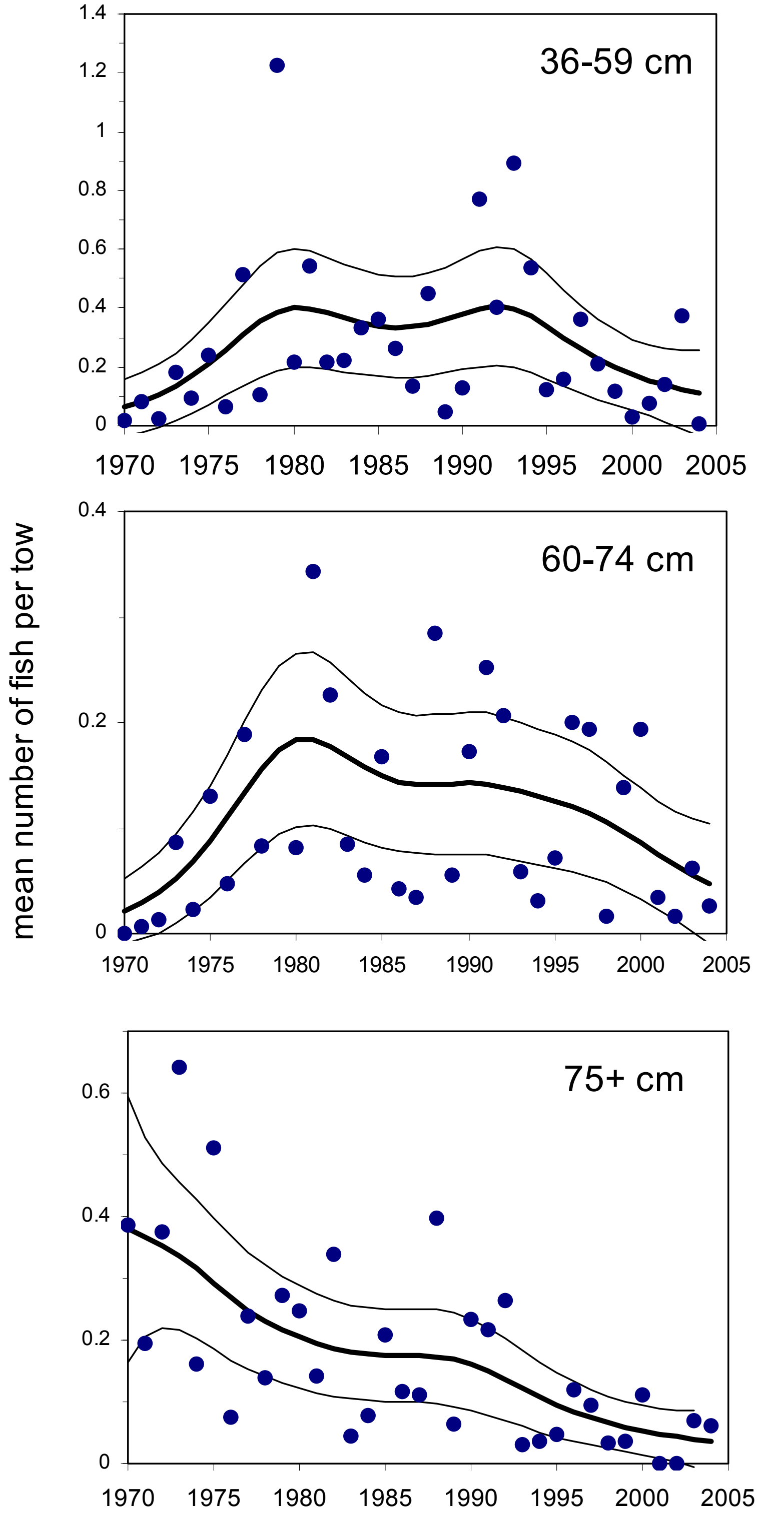


Figure 16. Catch rates of three size classes of winter skate in the July survey of the eastern Scotian Shelf. Heavy lines show the fit of a generalized additive model (GAM) to the time trend in catch rates, and light lines show approximate 95% confidence intervals around the fitted line. The GAMs used a log link and a Poisson error distribution allowing for overdispersion.

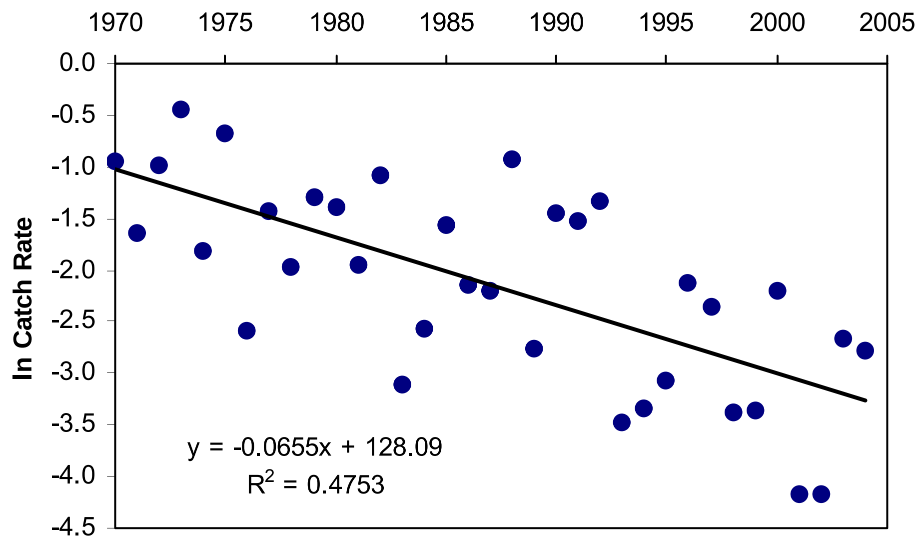
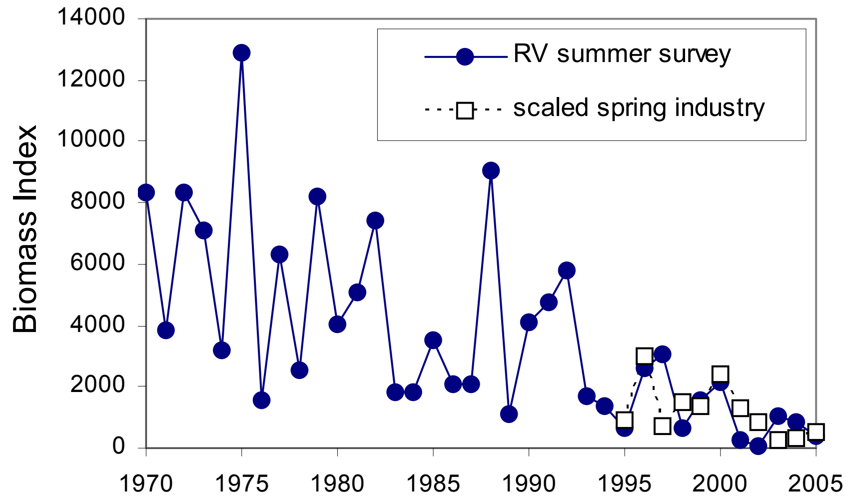


Figure 17. Log_e catch rates of adult winter skate (i.e., skate 75 cm or longer) in the July survey of the eastern Scotian Shelf. Zeros in 2001 and 2002 were replaced by one-half the minimum observed non-zero value before log-transformation.



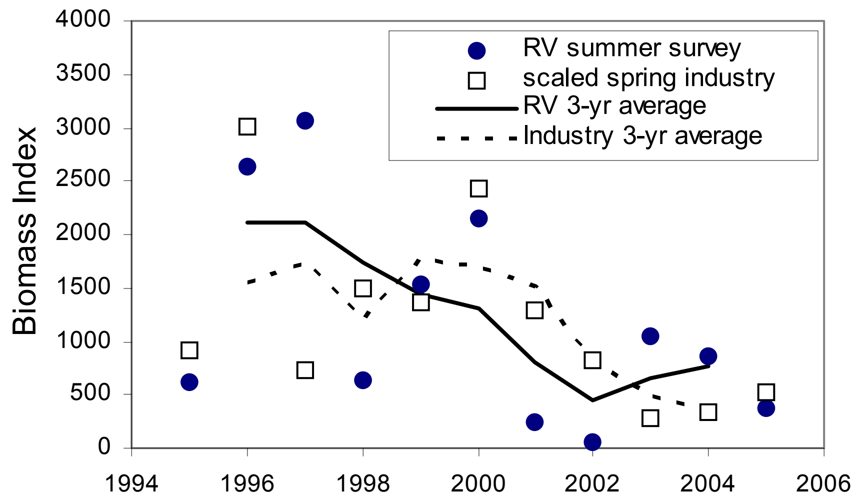


Figure 18. Comparison of trends in catch rate between the July RV and spring industry surveys. Data from the July RV survey are restricted to strata in the area covered by the industry survey (strata 446-458). Catch rates in the industry survey are scaled to have the same average value as the RV survey in the 1995-2005 period. (The average biomass index in the industry survey was 6.8 times the average in the RV survey in the 1995-2005 period.)

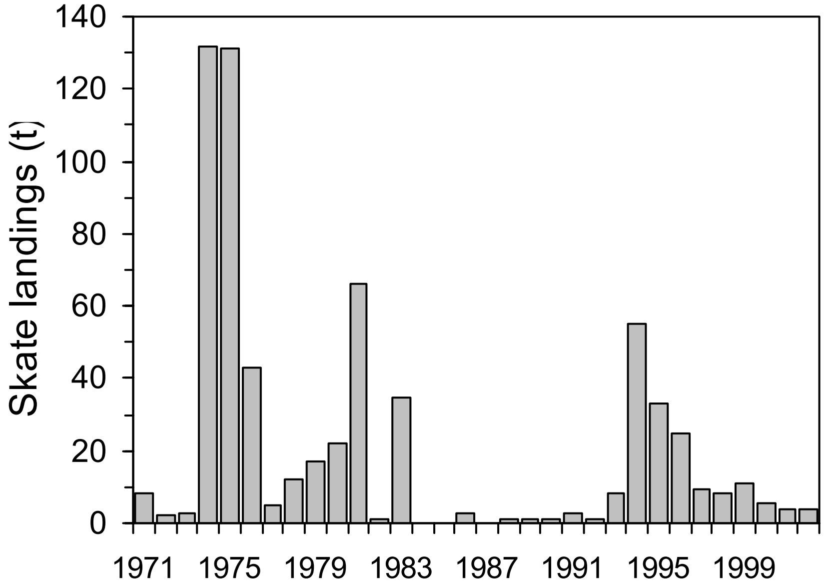


Figure 19. Reported landings (t) of skates in the southern Gulf of St. Lawrence, 1971-2002.

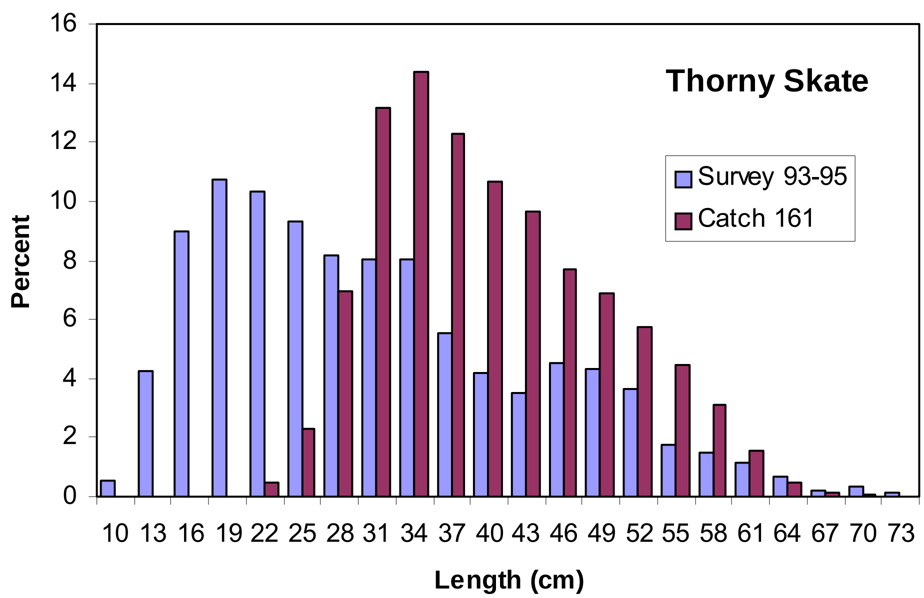


Figure 20. Length frequencies of thorny skate caught by 161-mm mesh otter trawls in the 1994 fishery in the southern Gulf of St. Lawrence and in the 1993-1995 RV surveys of the southern Gulf.

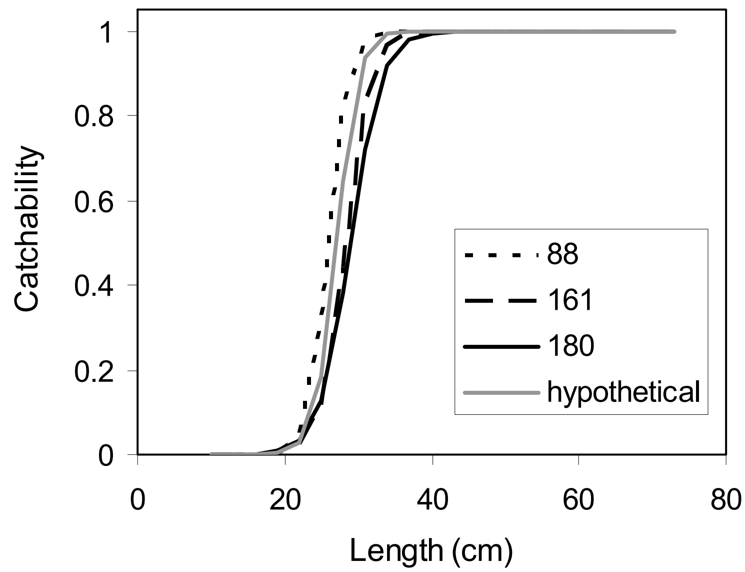


Figure 21. Estimated retention curves for thorny skate by mesh size (mm). An intermediate hypothetical curve is also shown.

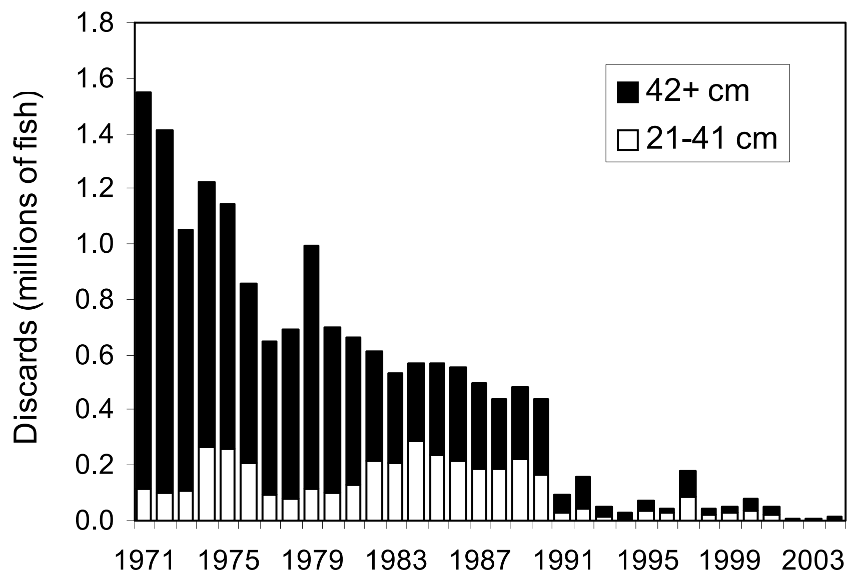


Figure 22. Median estimated discards of winter skate by groundfisheries in the southern Gulf of St Lawrence, by size class (juveniles, 21-41 cm; adults, 42+ cm).

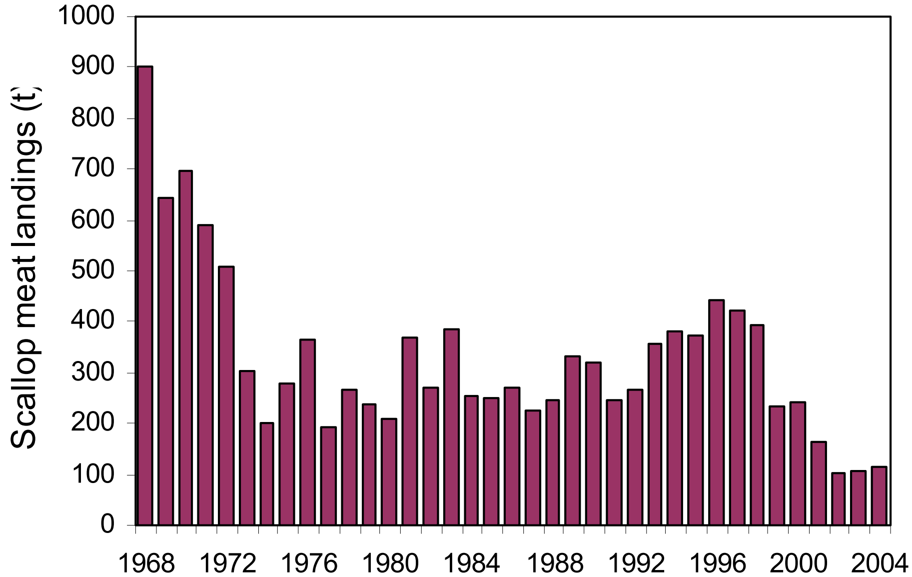


Figure 23. Scallop landings in the southern Gulf of St. Lawrence.

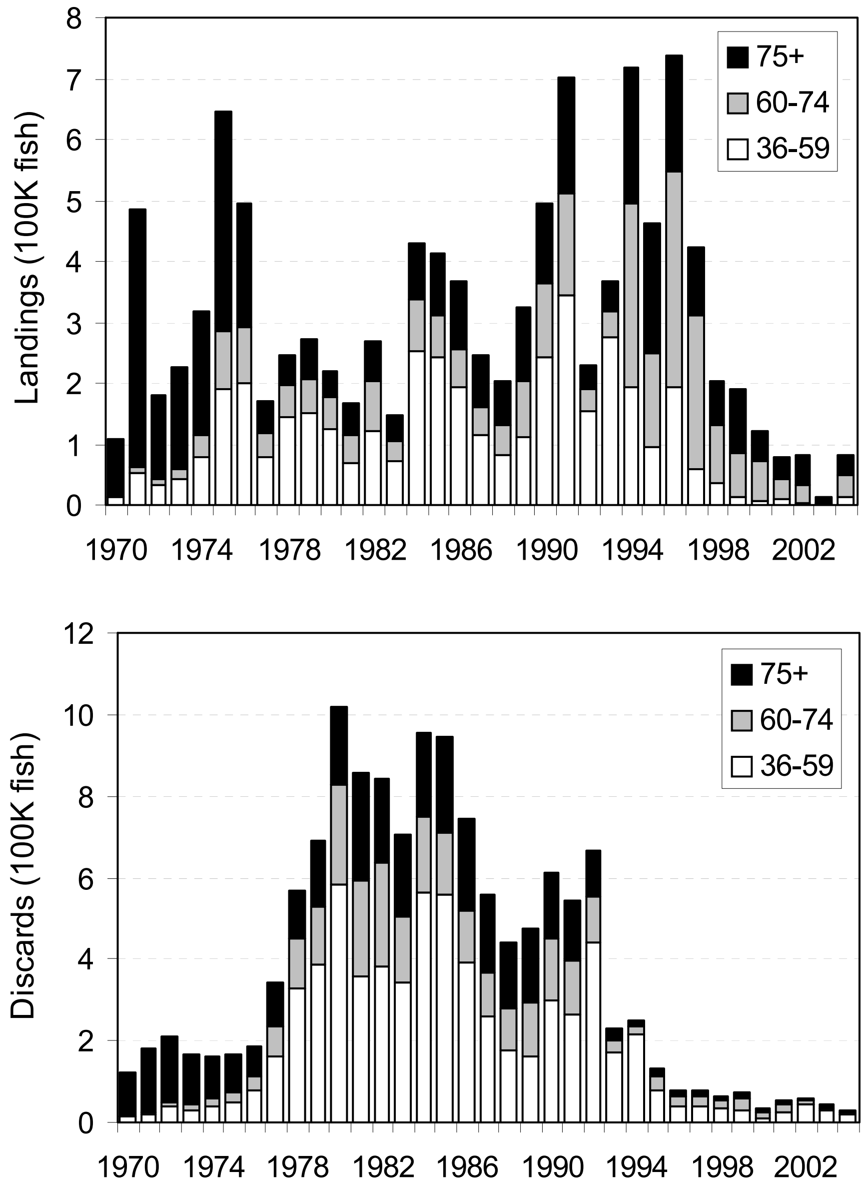


Figure 24. Estimated landings and discards of winter skate on the eastern Scotian Shelf (4VW) by size class (cm).

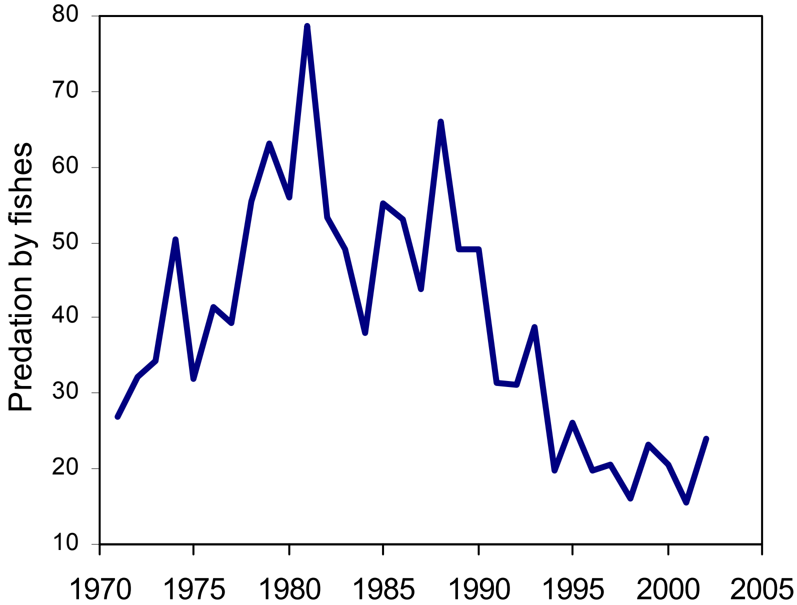


Figure 25. Index of predation by fishes on prey in the 10-32 cm length range in the southern Gulf of St. Lawrence (H. P. Benoît, unpublished analyses).

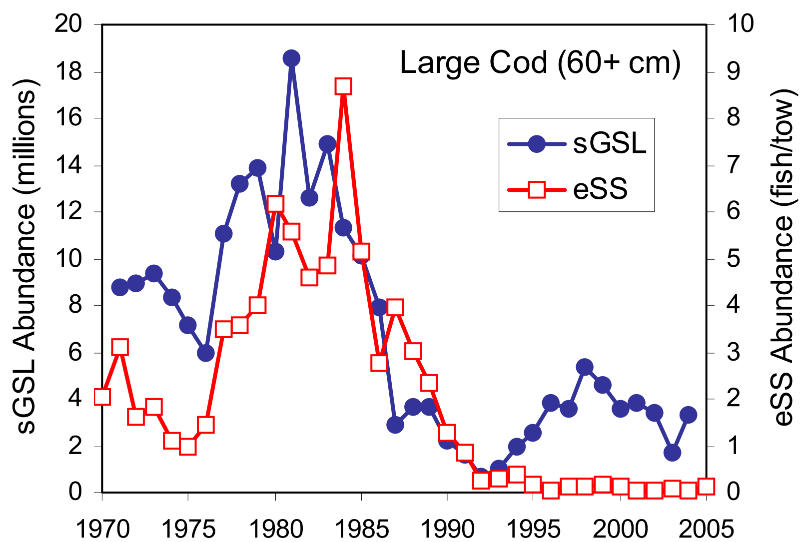


Figure 26. Abundance of large cod (60 cm or more in length) in the southern Gulf of St. Lawrence (sGSL) and eastern Scotian Shelf (eSS) populations. Indices are based on survey catch rates, either expanded to the survey area (sGSL) or unexpanded (eSS).

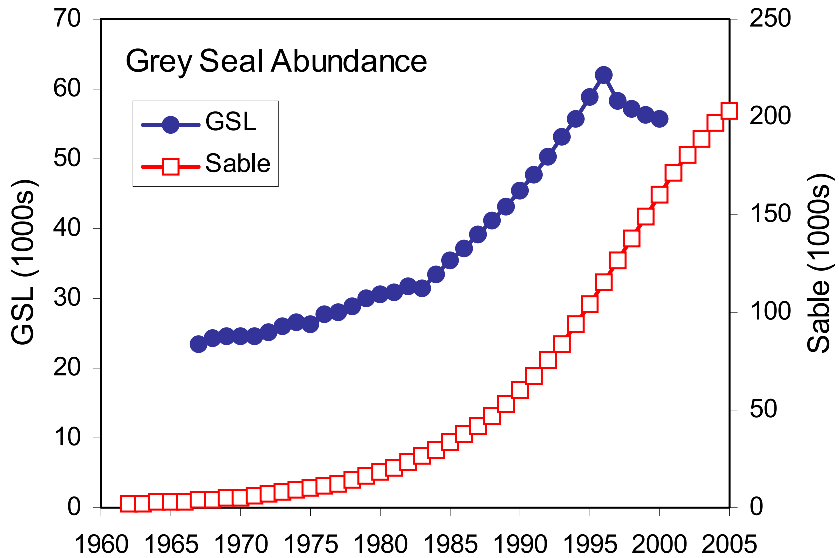


Figure 27. Abundance of grey seals in the Gulf of St. Lawrence and on Sable Island.

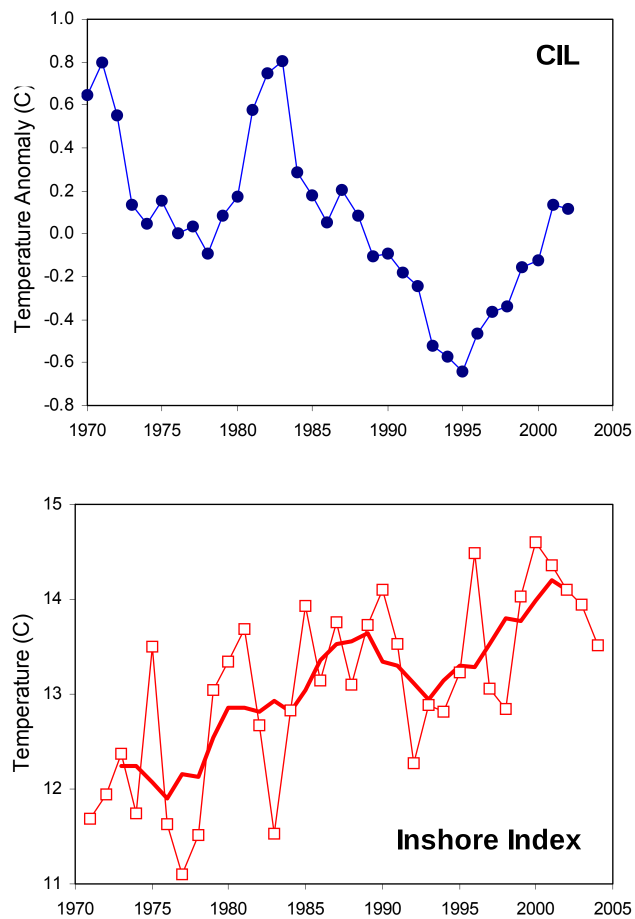


Figure 28. Water temperature indices for the southern Gulf of St. Lawrence.

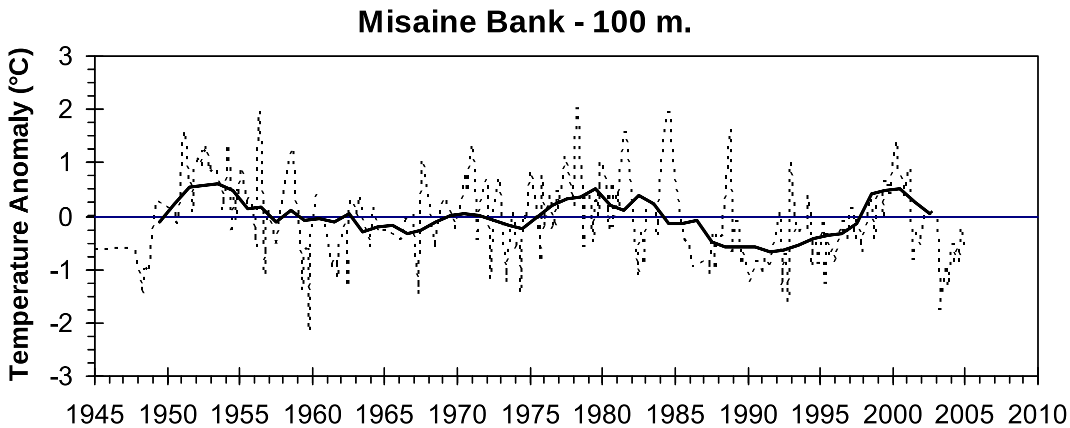


Figure 29. Temperature index at 100 m on Misaine Bank.

Appendix A: Alternative survey indices for winter skate in the southern Gulf of St. Lawrence

1. Inshore strata

Three inshore strata were added to the southern Gulf survey in 1984: 1) 401, along the north shore of PEI, 2) 402, in the Northumberland Strait (only the eastern half of this stratum can be fished in September due to the lobster fishery), and 3) 403, in St. Georges Bay. These strata were not included in the indices analyzed here, in order to avoid biasing the 1984-2004 indices relative to the 1971-1983 indices. Because of the inshore distribution of winter skate in September, these strata would be expected to be important for winter skate. However, abundance trends are virtually identical including or excluding these strata (Fig. A1).

2. Day-night adjustment

Fishing was conducted only during daylight hours (07:00-19:00) in the period 1971-1984, but done throughout the 24 hr day since 1985. Winter skate have higher catchability at night than in day, and the diel difference in catchability is greater at small lengths than at large lengths. In the analyses presented here, night catches were adjusted to be equivalent to day catches using length-dependent factors so that the data since 1985 would not be biased relative to the pre-1985 data. Nonetheless, the trends reported here would be biased if these adjustment factors are inaccurate. As a check on the effectiveness of our day-night adjustments, abundance indices calculated using only day tows were compared to those calculated using all tows, with night catches adjusted to day catchability. Trends in abundance were remarkably similar in both cases (Fig. A2), even though sample size was reduced by roughly 50% in the “day-only” index. This confirms the accuracy of the day-night adjustments used here.

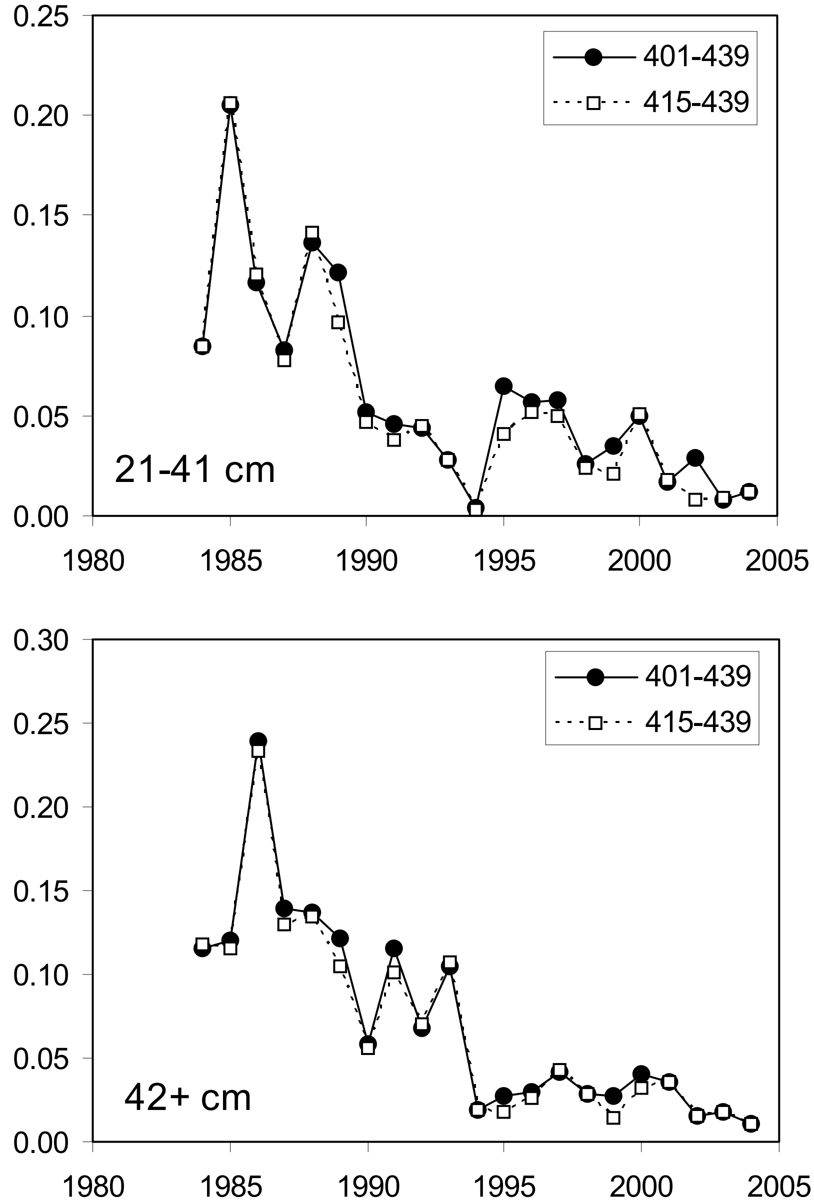


Figure A1. Catch rates (fish/tow) of two size classes of winter skate in the September survey of the southern Gulf of St. Lawrence, including (401-439) or excluding (415-439) three inshore strata.

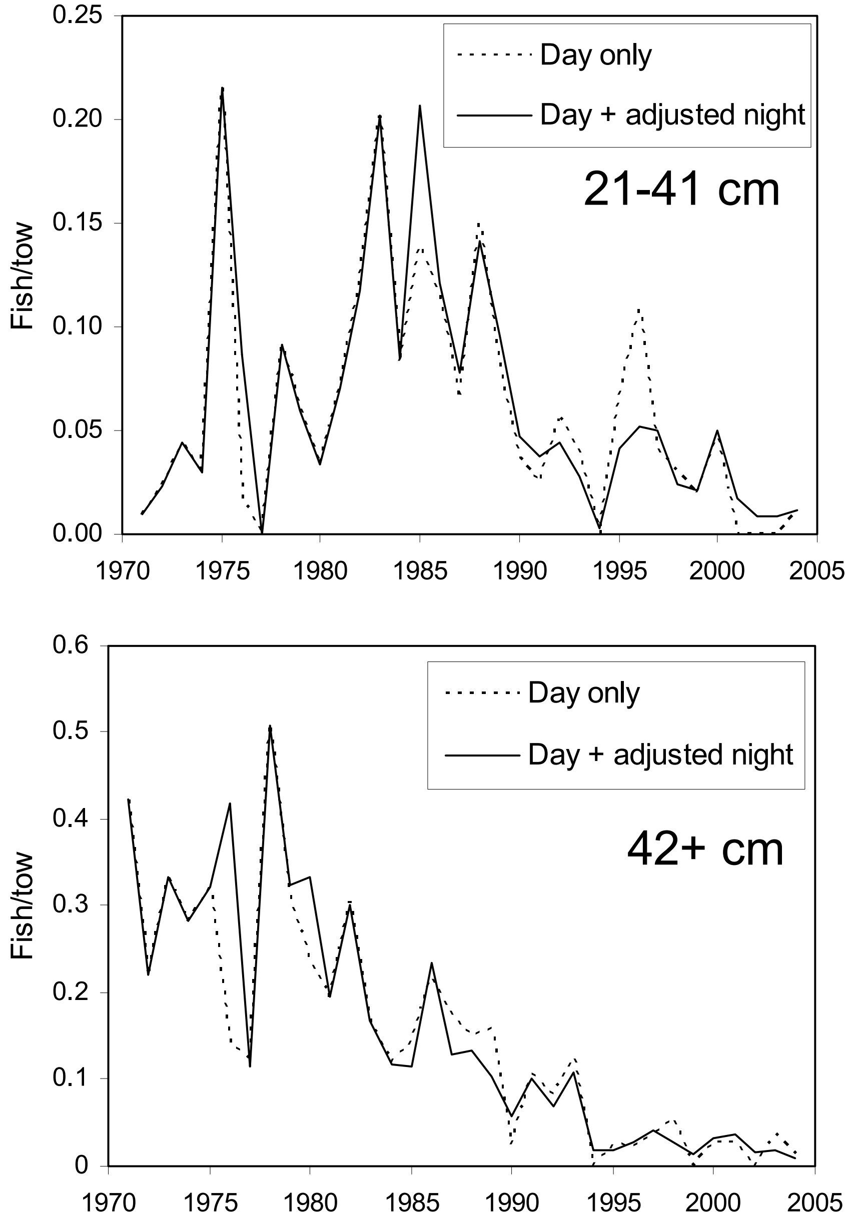


Figure A2. Average catch rates (fish/tow) of two size classes of winter skate in the September survey of the southern Gulf of St. Lawrence, using only daytime tows or using both day and night tows, with night tows adjusted to daytime catchability (after 1984).

Appendix B: Scaling survey abundance indices to the level of absolute abundance

A. September survey of the southern Gulf of St. Lawrence

1. Adjustment for catchability to the gear

We first attempted to adjust for size selectivity of the gear. No estimates of the size-selectivity of research survey gear for skates were available. Thus, we attempted to adjust for size selectivity using the flatfish (plaice) curve estimated by Harley and Myers (2001). We set γ to 1 (i.e., at this stage, we attempted to adjust small and large individuals to the same relative catchability, but not to 100% catchability). Using the standard ("day-catchability") indices, this adjustment increased the average survey catch rate for skates 21 cm and over by a factor of 1.78.

Edwards (1968) argued that the catchability of skates to survey trawls is very low. This reflects a tendency by skates to remain on the bottom rather than to rise up off the bottom as the trawl approaches. Thus, given the large rollers on the foot gear of traditional survey trawls, these trawls tend to pass over rather than capture the skates in their path. Edwards suggested that catchability to survey trawls is about 10% for most skate species, though he argued that winter skate catchability is about 20%. This suggests that RV catch rates should be multiplied by 5 to adjust for catchability. On the Scotian Shelf, catch rates by commercial rockhopper gear are about 6 times those by the RV gear, with both adjusted to the same swept area (J.E. Simon, pers. comm.). This suggests that RV catch rates should be multiplied by a factor greater than 6 (because even commercial rockhopper gear likely does not catch all of the skate in the path of the trawl). As a compromise between these two estimates, we assumed that RV catch rates should be multiplied by 6 to adjust to 100% catchability.

Adjustment for size selectivity increased survey catch rates by a factor of 1.78. To complete the adjustment for catchability, survey catches were further multiplied by 3.37 (i.e., 6/1.78).

2. Adjustment for availability within strata 415-439

Given a number of assumptions, we estimated that 38% of the winter skate in the southern Gulf of St. Lawrence are within strata 415-439 in September (Appendix C). Thus,

$$\frac{(J_{in} + A_{in})}{(J_{out} + A_{out})} = \frac{0.38}{0.62} = C_0 \quad \text{.....(1)}$$

where J_{in} is the number of juveniles inside the survey area, and A_{out} is the number of adults outside of the survey area, etc.

After adjustment for size selectivity, the ratio of juveniles to adults is 2.301221 (C_1) inside strata 415-439, and 3.83456 (C_2) outside the survey area (based on the size distribution in the Northumberland Strait survey). Thus,

$$\frac{(C_1 A_{in} + A_{in})}{(C_2 A_{out} + A_{out})} = C_0 \ldots\ldots(2)$$

Re-arranging equation 2 gives: A_{out} = 1.114A_{in}. Thus, adult abundance within strata 415-439 should be multiplied by 2.114 to account for total adult abundance in the southern Gulf. Following a similar approach for juveniles yields: J_{out} = 1.865J_{in}, suggesting that juvenile abundance within strata 415-439 should be multiplied by 2.856 to account for total juvenile abundance in the southern Gulf.

3. Expansion from swept area to survey area

Multiply the mean catch per tow by the number of "trawlable units" in strata 415-439 (1729346).

4. Adjustments using survey indices adjusted to night catchability

Adjustments were the same as for the standard "day-adjusted" indices, with the following exception. Adjustment for size selectivity increased survey catch rates by a factor of 2.28. To complete the adjustment for catchability, survey catches were further multiplied by 2.63 (i.e., 6/2.28).

B. July survey of the eastern Scotian Shelf

Adjustments were similar to those applied to the southern Gulf survey data except:

1) There was no adjustment for availability; the entire population was assumed to occur within the survey area.
2) Adjustment for size selectivity increased survey catch rates by a factor of 1.23. To complete the adjustment for catchability, survey catches were further multiplied by 4.878 (i.e., 6/1.23).
3) The mean catch per tow was multiplied by 2667322 to expand from swept area to survey area.

References

Edwards, R. L. 1968. Fishery resources of the North Atlantic area, pp. 52-60 *In* D. W. Gilbert (ed.) The Future of the Fishing Industry of the United States. Univ. Wash. Publ. Fish. N.S. 4.

Harley, S.J., and Myers, R.A. 2001. Hierarchical Bayesian models of length-specific catchability of research trawl surveys. Can. J. Fish. Aquat. Sci. 58: 1569-1584.

Appendix C: The proportion of winter skate available within the September survey area

We estimated the proportion of winter skate in the southern Gulf that occur within the standard strata 415-439 of the September RV survey as follows:

1. The western Northumberland Strait has been sampled by a summer survey since 2000. The area swept by a standard tow is 9000 m^2 (9 m wingspread $\times$ 1000 m tow length). The catch rate in strata 1-4 of this survey averaged 1.453 skates per 10,000 m^2 in 2000-2002. Based on length frequencies of survey catches, 93.8% of these were 21 cm and longer. Thus, the average catch rate for the size classes used in our analyses was 1.363 skates per 10,000 m^2.

2. The area swept by a standard tow in the September survey is about 40,512.5 m^2 (12.5 m wingspread $\times$ 3241 m tow length). The catch rate in strata 415-439 averaged 0.013222 skates per 10,000 m^2 in 2000-2002 for the 21+ cm length class.

3. The Northumberland Strait survey uses rockhopper gear. Based on comparisons on the Scotian Shelf, the fishing efficiency of this gear for winter skate is about 6 times the efficiency of the Western IIA gear used in the September survey. A second estimate of relative efficiency can be obtained by comparing catch rates in the Northumberland Strait survey to catch rates in the September survey at depths under 30 m. This suggests a relative efficiency of 8.66, comparable to the estimate from the Scotian Shelf. The higher ratio obtained in the southern Gulf comparison may partly reflect spatial variation in skate densities. Winter skate densities in many of the shallow (<30 m) areas covered by the September survey appear to be lower than those in the western Northumberland Strait area. Thus, we assumed that the Northumberland Strait survey gear was 6 times as efficient as the September survey gear. Based on this assumption and the 2000-2002 catch rates in the two surveys, average winter skate density in strata 1- 4 of the Northumberland Strait survey is about 18.3 times the average density in strata 415-439 of the September survey.

4. A trawl survey of inshore areas around the Magdalen Islands was conducted in summer in 1999 – 2001. Average catch rates of winter skate in this survey were 0.0397 skates per 10,000 m^2. This survey also used rockhopper gear. Adjusting for the difference in fishing efficiency, this suggests that winter skate density in the area of this survey averaged 0.5 that in strata 415-439 of the September survey.

The above calculations lead to the following estimates of relative abundance:

Area	Trawlable Units	Relative Density	Relative Abundance	Proportion
N. Strait	109960[1]	18.30000	2012268	0.488533
415-439	1729346	1.00000	1729346	0.419846
401-403	57903	5.93944	343908	0.083493
Magdalen Is.	66914[2]	0.50039	33483	0.008129
Total			4119005	

[1]Correcting for 20% overlap with strata 415-439.
[2]Correcting for 25% overlap with strata 415-439.

The above calculations suggest 42% of southern Gulf winter skate occur within strata 415-439 of the September survey. However, while the above areas comprise most of the surface area of the southern Gulf, inshore areas shallower than about 20 m along the coast of New Brunswick north of the Miramichi River and in Chaleur Bay are not covered. Some winter skate are expected to occur in these uncovered waters. The proportion of the population occurring in strata 415-439 depends on the percent occurring in these uncovered waters:

% not covered	Total Relative Abundance	Proportion in 415-439
0%	4119005	0.419846
5%	4335795	0.398853
10%	4576672	0.377861
15%	4845888	0.356869

In most analyses conducted here, we have assumed that strata 415-439 cover about 38% of the winter skate population in the southern Gulf.

Appendix D: Landings and discards in 4VW

J. E. Simon

Removals of winter skate in Div. 4VsW

To estimate the total removals of winter skate in 4VW we examined landings information from the area, observations of skate bycatch from various fisheries from the observer program (IOP) and used the summer RV survey to determine species composition of skate. We examined foreign as well as Canadian data to estimate bycatch and discards of winter skate from these fisheries, as well as results from the directed fishery for skate that has been conducted in 4VsW since 1994.

Past

Skate was not a regulated species on the Scotian Shelf prior to 1994. In 1994 a directed skate fishery began in 4VsW, but even then there were no bycatch limits on other fisheries or requirement to record discards. Landings data exist since 1961; however the data is not separated by species and only represent a fraction of the actual removals since there was no requirement to report discards.

Foreign Fisheries: 1970-1976

Prior to the extension of jurisdiction by Canada, reported landings of skate by foreign countries were as high as 6,100t in Div. 4Vs, 16,000t in Div. 4W. The validity of these high catches has been questioned due to the way in which they were calculated (pers comm. Ralph Halliday, DFO Dartmouth). In the case of the USSR, an exploratory 'research trawler'would be assigned to scout out fishing areas. Vessels were free to fish anywhere in the zone outside of the 12 mile limit. The scout vessels catch was collated by species and the proportion of each species was prorated to the annual catch of the fleet. There is no way to determine how representative the scout vessels catch was for the entire fleet and therefore there is a high level of uncertainty in this data.

The foreign catch was reported as skate unspecified. Without any other information available, we examined the summer RV survey conducted by DFO in 4VsW from 1970-1976 to determine the percentage of winter skate in the total catch of skate. The foreign catch was primarily by large otter trawlers while the summer RV survey used a Yankee 36 otter trawl. For this time period winter skate was 20% of the total skate catch and this percentage was applied to the reported skate catch by the foreign fleet. Catches of winter skate were estimated to range from approximately 800 to 3500 t.

Foreign Fisheries: 1977-2005

Subsequent to the extension of jurisdiction by Canada in 1977 foreign countries were restricted to the shelf edge primarily in Div. 4W. The main species caught were silver hake and squid. These vessels retained other species including skate which were processed into fish meal. The catch information was reported to NAFO and this formed the basis of the catch information from 1977 to 1999. From 1999 to present the data comes from the IOP.

In 1977, the observer program (IOP) began in Canada to monitor the catch by foreign vessels. Given the focus of the program on commercially important species like cod and haddock, skate were not consistently separated by species. Skate identification improved in 1994 due to the more detailed requirements of the directed skate fishery and this information has allowed us to summarize skate bycatch and discards by species.

Observer reports indicate that winter skate made up 70% of all skate catches from 1995-2005. This percentage was applied to all reported skate catches from 1977-2004. From 1977- 1987, observer coverage was low and a mean estimate of 1.1% winter skate bycatch was applied to the NAFO reported silver hake landings. From 1988- 2004, observer coverage was sufficient to calculate annual bycatch levels of winter skate. These ranged from less than 1% to 3%. Winter skate catches averaged 725 t from 1977-1993, peaking in 1991 at 1683 t. As the effort by the foreign fisheries has been reduced, winter skate bycatch has been generally less than 100 t since 1994 and has been close to zero since 2000.

Canadian Fisheries in 4VsW

The primary fisheries in 4VsW are halibut, redfish, flatfish and Cod, Haddock, Pollock (CHP). Div. 4Vn was excluded from these analyses because very few winter skate were observed there in the summer RV survey. Landings of each species and species group were extracted from NAFO (1970-85), ZIF (1986-2002) and MARFIS (2003-2004) databases. Observer reports from each fishery where skate were caught were extracted to determine the level of bycatch of all species of skate in each fishery.

Halibut

Observer reports from 1993 to 2005 indicated that winter skate bycatch was 1.2% of the total halibut landings in 4VsW. This percentage was applied to halibut catches from 1970 to present. Halibut landing in these areas peaked in the mid 1980’s at less than 1200 t and have remained below 500 t since 1993. This resulted in a winter bycatch of less than 15 t over the entire time period.

Redfish

The same methods used for the halibut fishery were used to determine redfish landings and bycatch estimates for this fishery. Observer reports were available from 1995–2005. This yielded a winter skate bycatch of 1.6% in the redfish fishery. This percentage was again applied to redfish catches from 1970 to present with winter skate catches peaking at 250 t in the early 1970s. Since 1982 winter skate bycatch has been generally less than 100 t.

Flatfish

Total landings of all species of flatfish in 4VsW and observer reports were calculated in a similar manner as the halibut and redfish fisheries. IOP information from 1995 to present indicates that winter skate made up 5.4% the flatfish fishery. This is much higher than the other fisheries examined so far but flatfish are generally caught in the same area as the skate fishery and used gear more likely to pick up skate. Previous stock assessments had attempted to estimate the amount of skate discarding based on interviews with fishermen who directed for both flatfish and skate in this area. These interviews indicated that skate discards made up to 25% of the flatfish landings in the area. The 1970-2005 summer RV survey indicates that overall winter skate made up 25% of all skate caught in the area, resulting in a 5% discard rate for winter skate, similar to the observer reports.

Flatfish landings averaged 7100 t from 1970-1985. From 1986 to 2002, landings fell from 5000 t to close to 1000 t. In the last couple of years, landings have fallen to 300 t. Winter skate discards have therefore fallen from a high of 500 t in 1971 to 30 t or less in the 2000s.

Cod Haddock Pollock (CHP)

Total landings of cod, haddock and pollock were calculated in the same manner as the previous Canadian fisheries. Observer reports for these fisheries since 1995 did not consistently record skate by species and was felt to be unrepresentative. To estimate discards in this fishery the total skate observed was calculated from 1978-2002 and then the percentage of winter skate in the summer RV survey was calculated for the same time period. Skate bycatch was estimated to make up 9% of the total landings of CHP. The summer RV survey indicated that 23% of these skate, for this time period, were winter, resulting in an estimated winter skate bycatch of 2.1%. This factor was applied to CHP landings from 1970-2004.

Winter skate discards were estimated to be less than 1000t prior to extension of jurisdiction. As Canadian effort increased in the 1980s, discards increased to between 1100t and 1900t. In 1993 the cod and haddock fisheries were closed and landings were much reduced. Winter skate discards fell to below 50t in 1994 and recently have been below 10t. Misreporting of total catch in these fisheries was a problem prior to the cod and haddock closure in 1994 and all estimates should be considered minimum values.

Canadian Reported Skate Landings, 1970-1993

Skate landings were recorded by Canada from 1970-1993 on the NAFO and ZIF databases but not by species. Again the summer RV survey was used to estimate that 25% of these skate would have been winter skate. In most years landings were less than 30t although there are reports of landings greater than 100t in 1976 and 1977.

Canadian Directed Skate Fishery

The history of the current directed skate fishery on the eastern Scotian Shelf and the rationale for the harvesting plan have been reviewed in Simon and Frank (1995, 1996, and 1998). In the first year of the fishery, the species composition was unknown due to lack of DFO port samples or observer reports. Observers were placed on each vessel and it became apparent that there was a problem with species identification by some observers. Limited DFO port sampling indicated that winter skate was the primary species landed with a bycatch of larger thorny skate. In 1995, the species identification problem was resolved and with increased port sampling both data sources indicated that winter skate made up approximately 95% of the skate caught in this fishery.

A progressive quota reduction on the fishery has resulted in the landings falling from over 2000t in the first year to less 300t since 2001. The low 2003 value was due to market conditions and the timing of the fishing year.

Summary

The total removals of winter skate are a combination of directed fisheries, bycatch, and estimated discards in other fisheries. The fisheries examined are not a complete inventory but do encompass the majority of landings in this area. These landings are probably an underestimate due to misreporting and therefore discards should be considered minimum estimates.

As the foreign fisheries effort was replaced by Canadian effort in 1977, total removals of winter skate remained relatively constant from 1970-1997, averaging 2400t. The 1971 and 1975 estimates are driven by the anomalous Soviet reports of skate. Since 1998 total winter skate removals have not exceeded 800t and in 2003 were estimated to be less than 100t. Most of this tonnage has come from the directed skate fishery which has had an annual quota of 200t since 2002.

References

Simon, J.E., and Frank, K.T. 1995. An assessment of the skate fishery in Division 4VsW. DFO Atl. Fish. Res. Doc. 95/71.

Simon, J.E., and Frank, K.T. 1996. Assessment of the Division 4VsW skate fishery. DFO Atl. Fish. Res. Doc. 96/105.

Simon, J.E., and Frank, K.T. 1998. Assessment of the winter skate fishery in Division 4VsW. DFO Can. Stock Assess. Sec. Res. Doc. 98/145.

Table D1. Total winter skate removals from Div. 4VsW.

Year	Foreign All fisheries [1] 20%	Foreign silver hake [2] 70%	Cdn halibut [3] 1.21%	Cdn CHP [4] 2.10%	Cdn Flatfish [5] 5.40%	Cdn Redfish [6] 1.61%	Cdn Reported skate [7] 25%	Cdn Skate Fishery [8] 95%	Total Removals
1970	774		5	405	339	123	7		1652
1971	3498		6	570	494	255	3		4827
1972	1047		4	500	483	243	0		2277
1973	1338		4	468	389	138	1		2338
1974	1686		3	304	434	124	15		2565
1975	3234		3	324	381	135	1		4078
1976	1574		3	278	285	108	191		2438
1977		359	3	416	387	139	109		1412
1978		535	6	778	379	146	34		1879
1979		586	7	1064	364	109	22		2152
1980		439	8	1534	465	125	18		2589
1981		476	7	1888	434	152	2		2959
1982		697	10	1727	362	82			2877
1983		398	11	1478	354	83	2		2327
1984		860	12	1473	373	57	4		2780
1985		874	14	1684	225	85	2		2884
1986		955	13	1719	168	44	3		2902
1987		714	8	1320	264	66	11		2384
1988		624	7	1128	171	54	2		1986
1989		1016	8	1157	225	93	3		2501
1990		1153	7	1070	254	100	0		2583
1991		1683	7	1007	149	139	3		2988
1992		407	7	946	183	43	1		1586
1993		547	6	157	166	24	18		918
1994		9	6	46	122	97		2045	2324
1995		118	4	36	89	74		1454	1775
1996		188	4	43	65	44		1571	1915
1997		71	4	31	58	47		995	1207
1998		46	4	44	48	14		500	655
1999		32	4	48	52	45		592	773
2000		1	4	15	31	28		358	436
2001		1	6	14	19	69		235	344
2002		0	5	7	18	42		278	350
2003		0	6	3	21	29		39	98
2004		0	6	5	10	29		233	283
2005									

Notes: Observers coded skate prior to 1994 primarily as species unknown.

[1] Based on the percentage of winter skate of the total skate catch from the 1970-76 summer RV survey in 4VsW.
[2] Based on observer reports that 70% of all skate reported in 4VsW from the silver hake fishery(1995-2005) were winter skate.
[2] 1977-87- averaged observed bycatch of skate *0.7
[2] 1988-2004 annual observed bycatch of skate *0.7
[3] Percentage based on 1993-2005 observer reports that winter skate bycatch was 1.21% of directed halibut catches.
[4] Observers reported that there was a 9% bycatch of skate in the directed CHP fishery from 1978-93.
Winter skate were estimated to make up 23% of the skate bycatch based on the summer RV survey for the same time period.
[5] Percentage based on 1995-2004 observer reports that winter skate bycatch was 5.4% of directed flatfish catches.
[6] Percentage based on 1995-2005 observer reports that winter skate bycatch was 1.6% of directed redfish catches.
[7] Based on the percentage of winter skate of the total skate catch from the 1970-93 summer RV survey in 4VsW.
[8] Percentage based on approximate estimates from DFO commercial samples.
[9] Other fisheries did not have sufficient information to make even broad estimates of discarding.

Appendix E: Relative availability of juveniles and adults within strata 415-439 of the September survey

Juvenile winter skate appear to have a more inshore distribution than adults in September in the southern Gulf. In this case, the proportion of individuals unavailable to the survey will be greater for juveniles than for adults. We accounted for this in the population models by adjusting the catchability of juveniles to reflect their reduced availability within the survey area. We calculated the amount of adjustment required as follows.

In recent years (1998-2002), the ratio of juveniles (21-41 cm) to adults (42+ cm) within strata 415-439 of the September survey has been 2.3012. The ratio in the summer survey of the Northumberland Strait is 3.8346. In both cases, these ratios are based on length frequencies adjusted for size selectivity using the flatfish curve from Harley and Myers (2001). We assumed that this ratio was representative of that outside of the survey area. The catchability adjustment required to correct the juvenile/adult ratio within the survey area to be equal to that for the entire population depends on the proportion of the population outside of the survey area:

Proportion Outside	Population Ratio	Relative availability inside (J/A)
0.50	3.0679	0.750
0.55	3.1446	0.732
0.60	3.2212	0.714
0.62	3.2519	0.708
0.64	3.2826	0.701
0.65	3.2979	0.698
0.70	3.3746	0.682
0.75	3.4512	0.667
0.80	3.5279	0.652

Based on our estimate that about 38% of 4T winter skate occur within strata 415-439 in September (Appendix C), we assumed that availability of juveniles to the survey was 70% that of adults.

References

Harley, S.J., and Myers, R.A. 2001. Hierarchical Bayesian models of length-specific catchability of research trawl surveys. Can. J. Fish. Aquat. Sci. 58: 1569-1584.