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Gulf and Quebec Regions

Canadian Science Advisory Secretariat
Science Advisory Report 2016/059

RECOVERY POTENTIAL ASSESSMENT OF WINTER SKATE (*LEUCORAJA OCELLATA*): GULF OF ST. LAWRENCE POPULATION

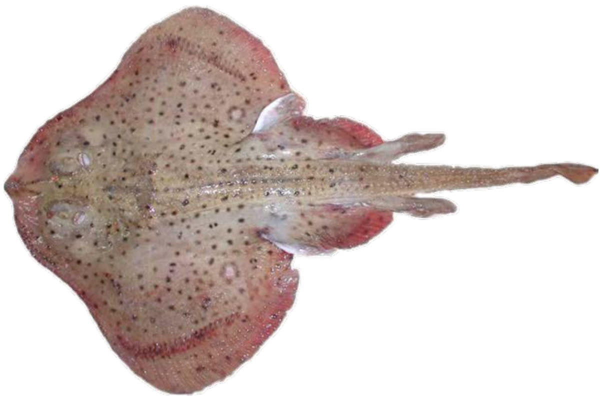

Photo courtesy of Eric Parent

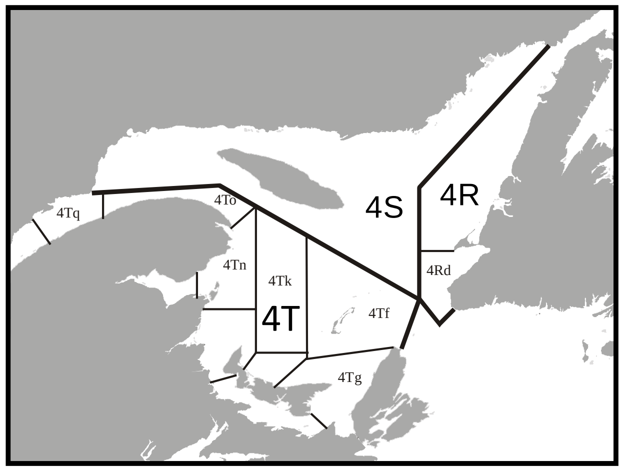

Figure 1. Revised geographic boundaries of the Winter Skate Gulf of St. Lawrence population defined by NAFO Div. 4T.

Context:

In its second assessment of Winter Skate (Leucoraja ocellata Mitchill 1815) in Canadian waters, conducted in April 2015, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-assessed the species as three populations or Designatable Units (DU): the Gulf of St. Lawrence population (GSL; endangered), the Eastern Scotian Shelf and Newfoundland population (ESSN; endangered), and the Western Scotian Shelf population (not at risk).

When a species is assessed as Threatened or Endangered by COSEWIC, Fisheries and Oceans Canada (DFO) undertakes a number of actions required to support implementation of the Species at Risk Act (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery. This advice has typically been developed through a Recovery Potential Assessment (RPA). In support of listing recommendations for Winter Skate by the Minister, DFO Science was asked to undertake an RPA, based on the national RPA Guidance. The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, to aid in the development of a recovery strategy and action plan, and to support decision making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of SARA. The advice in the RPA may also be used to prepare for the reporting requirements of SARA s.55. The advice generated via this process will update and/or consolidate any existing advice regarding Winter Skate in the GSL DU.

This Science Advisory Report is from the January 19 to 21, 2016 science peer review meeting of the Recovery Potential Assessment of Winter Skate in eastern Canada. Participants at the review included personnel from DFO (Gulf, Maritimes, Newfoundland and Labrador, and Quebec Regions) Ecosystems and Science Branch, Fisheries and Aquaculture Management, Species at Risk, Policy and Economics, and invited experts from the US National Marine Fisheries Service (NOAA) and University of New England (USA).

SUMMARY

Biology, Abundance, Distribution and Life History Parameters

- Winter Skate is endemic to shelf waters of the northwest Atlantic. Winter Skate in the Gulf of St. Lawrence (GSL) DU are characterized by maturation at a much younger age and smaller size than Winter Skate elsewhere.
- The early-maturing type of Winter Skate, characteristic of the GSL DU, does not appear to occur in the northern Gulf of St. Lawrence. This RPA considers the GSL DU to be restricted to Northwest Atlantic Fisheries Organization (NAFO) Division 4T. Within Division 4T, Winter Skate appear to be largely confined to the southern Gulf of St. Lawrence (sGSL), though there are rare reports in the St. Lawrence Estuary.
- Based on catches in the annual September Research Vessel (RV) survey, adult (≥42 cm total length) abundance of Winter Skate has declined by 99% since 1982.
- The RV biomass index for Winter Skate, all sizes combined, has declined by an estimated 99% between 1980 and 2014 (35 years, 3 generations). The biomass index from the Northumberland Strait survey, available since 2000, has declined by 78% over 15 years.
- Adult abundance estimated from a population model was high in the 1970s, at an average of 7.7 million fish, but declined to the lowest level on record in 2014 at 0.2 million fish, 3% of the average level in the 1970s.
- There has been an important contraction in the size distribution of adult Winter Skate. The average proportion of adults > 50 cm in length was 72% in the 1970s and 45% during 1995 to 2010.
- Estimates of natural mortality (*M*) from an age-structured model indicate that there has been a large increase in *M* of adults, from a median value of 10% annually during 1971 to 1977 to 63% annually during 1992 to -1998 and remaining high at 57% since 1999.
- Recruitment rates of Winter Skate have fluctuated without any trend, averaging 10.4 recruits per female spawner. Juvenile *M* has also fluctuated without trend around an average value of 57.6% annually.

Habitat and Residence Requirements

- During the summer, adult Winter Skate were widely distributed in shallow (< 50 m) coastal waters of the sGSL during the 1970s and 1980s but their geographic range contracted beginning in the late 1980s. For adults, the habitat occupied in summer has declined by 94%. During the winter, adult Winter Skate are broadly distributed on the Magdalen Shallows and the slope of the Laurentian Channel (approximately 40 to 200 m depth), however, there is no information available on possible changes over time in the winter distribution.
- Winter Skate distribution during the summer has now contracted to the western portion of the central Northumberland Strait, the only important area where Winter Skate is now detectable in the sGSL.

Threats and Limiting Factors to the Survival and Recovery of Winter Skate

- There has been no directed fishing for skates in the southern Gulf of St. Lawrence. However, skates, including Winter Skate, are incidentally captured in commercial fisheries directed at other species. Currently, all bycatch of skates must be released.

- The estimated fishing mortality of juveniles was below 0.1% annually in all years since 1971, averaging 0.006% annually over the last five years. For adults, estimated fishing mortality declined from an average of only 1.8% annually during 1971 to 1993 to 0.1% since 2011.
- Elevated adult *M* is the main cause of the on-going decline in abundance in this DU. The weight of evidence supports the hypothesis that predation by grey seals is the largest contributor to this high adult natural mortality.
- The summer distribution of Winter Skate is now concentrated in a small coastal area of the Northumberland Strait where predation risk appears to be relatively low. This area may therefore presently constitute a refuge for Winter Skate.

Recovery Targets

- Candidate recovery targets for survival, size structure, distribution, and abundance are proposed. The survival target is defined in terms of the intrinsic rate of population increase (*r*) or an equivalency in terms of natural mortality (*M*). In terms of *M*, the population would increase and the risk of extinction become negligible if current adult *M* (*M* = 0.85, 57% annually) was reduced by 80% (i.e., to *M* = 0.17, 16% annually).
- The size structure, distribution, and abundance targets cannot be realized until the natural mortality on adult Winter Skate has been substantially reduced.

Projections

- Assuming current productivity conditions and even with no fishery related losses, the Winter Skate population is expected to continue to decline rapidly and is almost certain to be extinct by mid-century.

Scenarios for Mitigation of Threats and Alternatives to Activities

- The lack of recovery and on-going decline of sGSL Winter Skate is due to the exceedingly high *M* of adult skate. If this high *M* persists, any additional measures to further reduce the already low fishing mortality will be ineffective in promoting recovery and reducing the high risk of extinction. Only actions which reduce the high *M* of adults are likely to be effective in reducing extinction risk. Reductions in grey seal predation on Winter Skate would be expected to reduce adult *M*.
- Possible mitigation measures to reduce harm to Winter Skate from fishing include: continued prohibition of retention of any skate species, priority be given to sorting and rapidly discarding skate catches to enhance post-release survival rates, and reduced fishing effort in areas and times with the highest potential of intercepting Winter Skate.

Allowable Harm Assessment

- The losses of juvenile and adult Winter Skate due to fishing were estimated to average 0.006% and 0.1% respectively over the last five years. Based on projections, fishing losses of these levels have negligible consequences for population trajectory, probability of recovery and risk of extinction.

INTRODUCTION

Winter Skate (*Leucoraja ocellata* Mitchill 1815) is a commercially exploited species endemic to shelf waters in the northwest Atlantic.

COSEWIC (the Committee on the Status of Endangered Wildlife in Canada) first assessed the status of Winter Skate in Canada in May 2005. In that assessment, four Designatable Units (DU) were identified, including the Southern Gulf of St. Lawrence (sGSL) DU. This DU was assessed as Endangered. The Recovery Potential Assessment (RPA) of the sGSL DU concluded that the population was expected to steadily decline even in the absence of any fishery removals (including bycatch) and that no recovery of the population could be expected without a decrease in adult natural mortality (DFO 2005).

In its 2015 re-assessment, COSEWIC concluded that Winter Skate in Canadian waters was comprised of three DUs: the Gulf of St. Lawrence (GSL) population, the Eastern Scotian Shelf and Newfoundland (ESSN) population, and the Western Scotian Shelf population. The GSL population of Winter Skate was reassessed as Endangered. Reasons for this designation included an estimated 99% decline in the abundance of mature individuals since 1980, with abundance now at a historically low level, and a severe reduction in range size, also now at a historical low. COSEWIC (2015) concluded that if current trends continue, this population is in danger of imminent extinction. COSEWIC noted that the species has a slow rate of population growth, and the main threat appears to be unsustainably high non-fishing mortality, possibly due to predation by Grey Seal.

Biology

Winter Skate in the sGSL (NAFO Div. 4T) differ from Winter Skate elsewhere, maturing at a much younger age and smaller size, and more closely resemble Little Skate (*L. erinacea)* in terms of life history characteristics.

Ageing information using thin sections of vertebrae was collected from 582 samples of sGSL Winter Skate (Fig. 2). The asymptotic length was estimated to be 77 cm, larger than the largest fish aged (67 cm) and near the largest Winter Skate captured in the surveys (an 80 cm skate captured in 1985). Estimated age at 50% maturity is about five years. These are much lower than those reported for Winter Skate elsewhere (75 cm, 11 to 13 years). Assuming that the rate of adult natural mortality is normally about 0.15, generation time of Winter Skate in the sGSL is normally about 12 years.

Winter Skate are oviparous, depositing a single egg in a horny capsule or purse. Average annual fecundity has been reported to be 50 eggs for Winter Skate outside the Gulf and 30 for Little Skate. The egg purse has adhesive mucus which helps to maintain bottom contact by attaching to substrate materials. The structure and function of the egg capsule is most similar to that of a bird or reptile egg shell. 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. Gestation time within the purses for sGSL Winter Skate is assumed to be similar to that of Little Skate at 6 to 9 months. Length at hatching from the purses is about 10 to 15 cm total length (Scott and Scott 1988). Reported predators after hatching include sharks, other skates and grey seals.

In the sGSL, Winter Skate occur in shallow inshore areas in summer and move offshore in winter. Based on the historic distribution of Winter Skate, physical environments suitable to Winter Skate are widespread throughout the shallow coastal zone of the sGSL in summer and the Magdalen Shallows in winter.

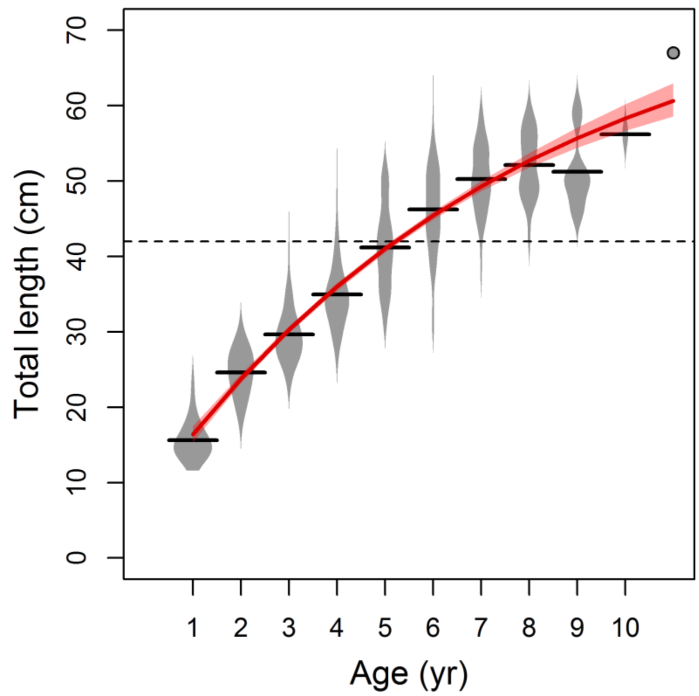

Figure 2. Total length (cm) at age of Winter Skate in the southern Gulf of St. Lawrence. Shading shows the distributions of length at age and black lines the mean lengths at age. The red line shows the predicted length at age based on a von Bertalanffy model (95% confidence bands given by the red shading). The dashed line shows the length (42 cm) at the start of the adult stage. The dot in the upper right corner is a single observation for an estimated age of 11 years.

Designatable Unit

COSEWIC (2015) revised the population structure of Winter Skate from that of the 2005 assessment. A new Gulf of St. Lawrence DU was established, composed of the former Southern Gulf of St. Lawrence population and the northern Gulf portion of the former Northern Gulf - Newfoundland population.

The northern Gulf of St. Lawrence (nGSL) appears to be outside the normal range of the southern Gulf of St. Lawrence type of Winter Skate. Winter Skate have been reported in only 38 of 7,148 (0.5%) fishing tows and in 12 of 31 years of the nGSL RV survey. New information presented at the RPA indicated that the majority of Winter Skate records from this survey were very likely mis-identified Thorny Skate, Round Skate, and Smooth Skate. To date, the only confirmed Winter Skate collected on this survey was captured in 2008 off western Newfoundland in NAFO Div. 4R. The large specimen had biological characteristics indicative of the typical late-maturing type of Winter Skate found in the Atlantic, and not that of the early-maturing sGSL type (Gauthier and Nozères 2016). The only other confirmed occurrences of Winter Skate in the nGSL are about ten individuals captured in Bonne Bay, a fjord in western Newfoundland (Gauthier and Nozères 2016). Maturity was identified for a single specimen, a 54 cm immature male, indicating that these Winter Skate also did not belong to the early-maturing sGSL type.

The COSEWIC (2015) report alludes to the southern Gulf of St. Lawrence as NAFO Div. 4T, which consists of both the sGSL and the St. Lawrence Estuary (Fig. 1). Observations of Winter Skate in the Estuary are restricted to three individuals collected prior to 1953 and a single individual collected in 1988 (Gauthier and Nozères 2016). The latter individual was an adult male of 50 cm, indicating that it was the early-maturing type of Winter Skate characteristic of the sGSL population.

This RPA considers the GSL DU to be restricted to the area encompassed by NAFO Division 4T, including the Estuary. However, the rarity of observations of Winter Skate in the estuary portion of NAFO Div. 4T suggests that this area may be outside the normal range of Winter Skate. Virtually all Winter Skate collected from NAFO Div. 4T were obtained from the sGSL.

ASSESSMENT

Abundance, Distribution and Life History Parameters

Species abundance

Indices of abundance and biomass are available from a research vessel (RV) survey conducted each September since 1971 in the southern Gulf of St. Lawrence (Fig. 3A), and a bottom-trawl survey of the Northumberland Strait (NS) conducted in late July and early August since 2000 (Fig. 3B).

The RV survey uses a stratified random design, with stratification based on depth and geographic region. Survey coverage was expanded in 1984 with the addition of three inshore strata (401-403). With this exception, survey timing and area have remained constant since 1971. No differences in fishing efficiency for Winter Skate were detected between vessels or gears based on comparative fishing experiments conducted whenever these changed (Benoît and Swain 2003; Benoît 2006). Winter Skate are estimated to be more catchable at night than in the day, consequently night catches were adjusted to be equivalent to day catches (Benoît and Swain 2003). The survey gear was a Yankee 36 otter trawl up to1985 and a Western IIA trawl since then.

The NS survey used a No. 286 otter trawl with rockhopper footgear except in 2010 and 2011; these two years are omitted from the analyses. Fishing was conducted during daylight hours. The survey area was divided into 9 “blocks” or strata (1-3, 5-10; Fig. 3B), though not all strata were sampled every year. Abundance and biomass indices were calculated based on strata 1-3 and 5 (sampled in all years) or strata 3 and 5 (the areas not covered by the standard September survey strata 415-439).

Abundance indices are presented for two size classes: 42 cm total length (TL) and longer roughly corresponding to the adult portion of the population, and 21 to 41 cm TL, roughly corresponding to juveniles two years of age and older. Winter Skate below 21 cm TL were very rare in September survey catches but are reported from the NS survey.

The percent change of indices was estimated by regression of the natural logarithm of survey catch rate against year. Percent change in abundance was calculated as $100*(\exp(b*\Delta t)-1)$ where b is the log-linear regression slope and Δt is the change in time (years).

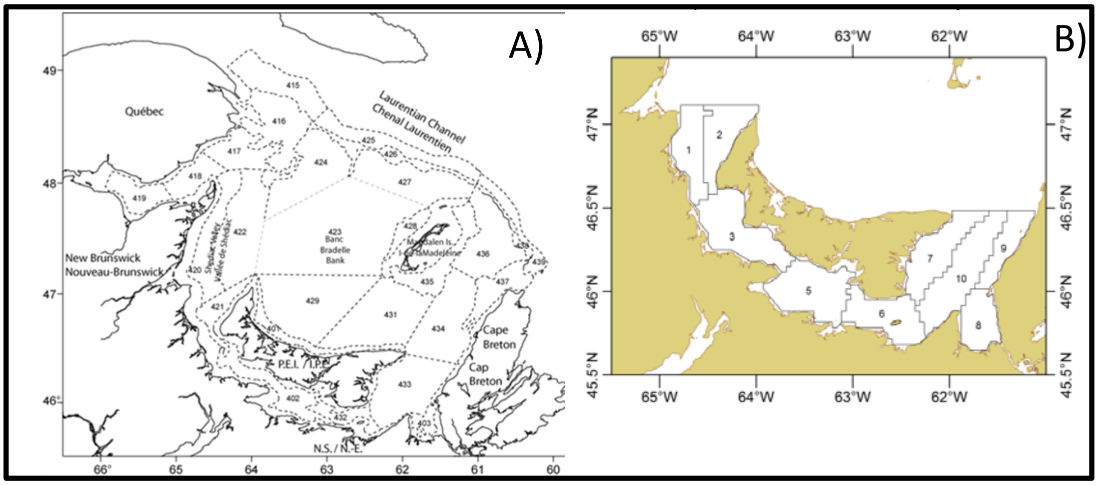

Figure 3. Stratification scheme for the southern Gulf of St. Lawrence September trawl survey. (A; left panel) and for the Northumberland Strait Survey (B; right panel). For the RV survey strata depths are as follows: < 50 fathoms: 401-403, 417-424, 427-436; 51-100 fathoms: 416, 426, 437-438; >100 fathoms: 415, 425, 439.

Research vessel indices

Adult abundance has been in decline since the late 1970s or early 1980s, corresponding to a 99% decline since 1982 (Fig. 4a, 4d). Trawlable abundance (mean catch per standard tow expanded to the survey area) of mature Winter Skate in strata 415-439 averaged 580,000 fish during 1971 to 1980, 29,000 during 2000 to 2009, and 5,000 during 2010 to 2014. No mature Winter Skate were caught in strata 401 to 439 in 2013, and only a single mature individual was caught in stratum 402 in 2014.

Winter Skate are now rarely detected in the RV survey area but persist in portions of the Northumberland Strait now covered by the NS survey. Estimated annual decline rates based on catch rates in the NS survey were lower (10%) than those of the RV survey (21%) over the same period (2003 to 2014) (Table 1). Based on strata 1 to 5, the decline in adult abundance in the Northumberland Strait was 66% over this 11-year time period (Fig. 4b, 4e), compared to 90% in the RV survey (Table 1). Trawlable abundance of adults in strata 3 and 5 of the NS survey averaged 148,000 fish during 2003 to 2009, and 88,000 fish during 2012 to 2014.

Mean catch rates in the NS survey are much higher than those in the RV survey over the same time period (2000 to 2014; Figs. 4 to 6). This largely reflects the much higher proportion of habitat suitable for Winter Skate in the NS survey compared to the RV survey (in which much of the area surveyed is at depths greater than those used by Winter Skate in summer and early fall). The much higher catchability of Winter Skate to the NS survey gear than to the RV gear also contributed to this difference (Swain and Benoît 2016).

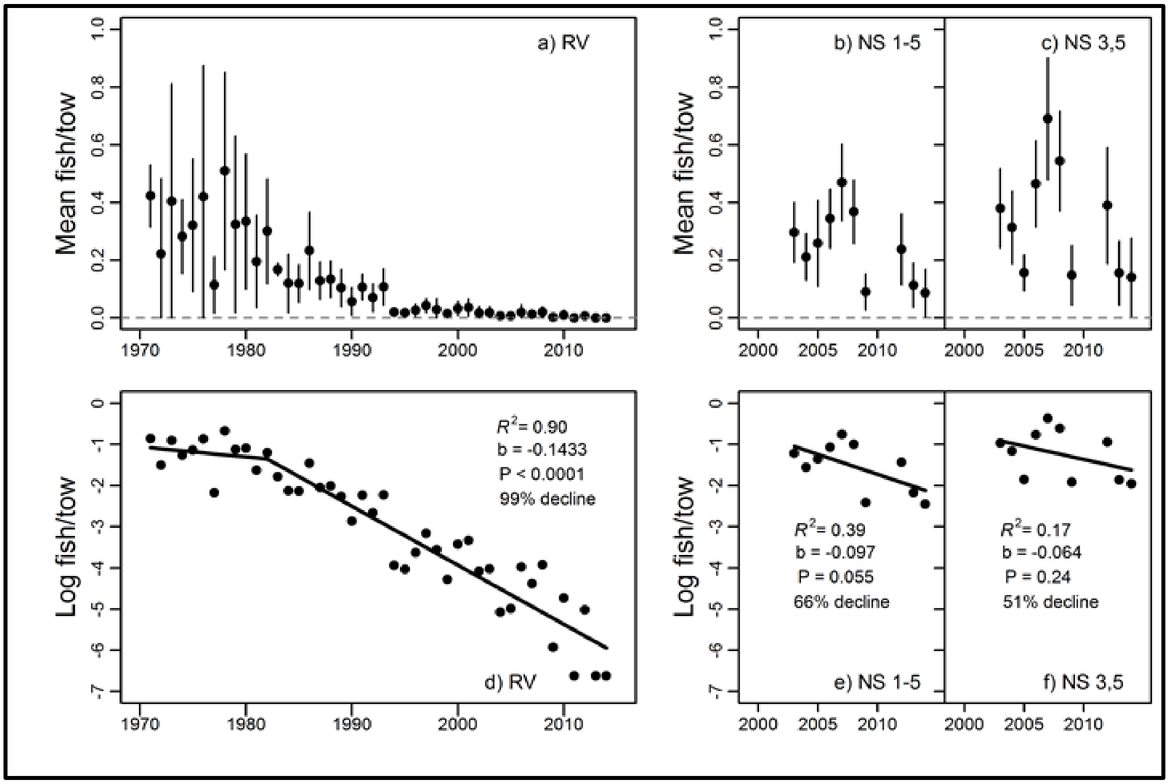

Figure 4. Abundance indices for adult Winter Skate (≥42 cm) in the September RV survey (panel a, RV) and the Northumberland Strait survey (panels b and c, NS). Symbols are the mean values and vertical lines show ± 2 SE. The 24 strata fished since 1971 (415 to 439) are used for the RV survey and strata 1 to 5 (the strata fished since 2000) or strata 3 and 5 (the region not covered by the standard RV strata) are shown for the NS survey. A segmented regression is used in panel d to accommodate a change in the time trend; the estimated breakpoint was in 1982. In panels d to f, R^2 is the proportion of variation in log catch rates explained by the regression model, P is the significance level of the model, and b is the estimated slope (since 1982 in panel d).

Table 1. Estimated percent change (negative is a decline) in juvenile and adult abundance and biomass (all sizes) of Winter Skate, based on catch rates in the September research vessel survey (RV) and the Northumberland Strait survey (NS) (Figs. 3 to 5). The number of years over which the change is calculated is shown in parentheses. Rates of change not statistically significant from zero (p > 0.05) are denoted by "ns".

Size group	Survey	Period	Instantaneous rate of change	Percent change (number of years)
adult	RV survey	1982 - 2014	-0.143	-99% (32)
		2003 – 2014	-0.206	-90% (11)
	NS survey	2003 – 2014	-0.097	-66% (11)
juvenile	RV survey	1986 - 2014	-0.1697	-99% (28)
		2003 – 2014	-0.263	-92% (11)
	NS survey	2003 – 2014	-0.100^{ns}	-67% (11)
all sizes	RV survey	1980 - 2014	-0.136	-99% (34)
		2000 – 2014	-0.168	-91% (14)
	NS survey	2000 – 2014	-0.109	-78% (14)

RV survey catch rates of juvenile Winter Skate were low in the early 1970s, then increased nearly 9-fold to the mid-1980s but decreased sharply afterward, resulting in a 99% decrease between the mid-1980s and 2014 (Fig. 5; Table 1). Trawlable abundance of juveniles in strata 415 to 439 of the RV survey averaged 46,000 during 1971 to 1974, 183,000 during 1975 to

1985, 16,400 during 2003 to 2009 and 2,400 during 2010 to 2014. Only one was caught in each of 2013 and 2014, from stratum 402 in both years.

Juvenile catch rates in the NS survey were relatively high during 2005 to 2008 and low since 2009 (Fig. 5; Table 1). However, the decline in juvenile catch rates was not significant over this short period. Trawlable abundance of juveniles in strata 3 and 5 averaged 188,000 during 2003 to 2009 and 83,000 during 2012 to 2014.

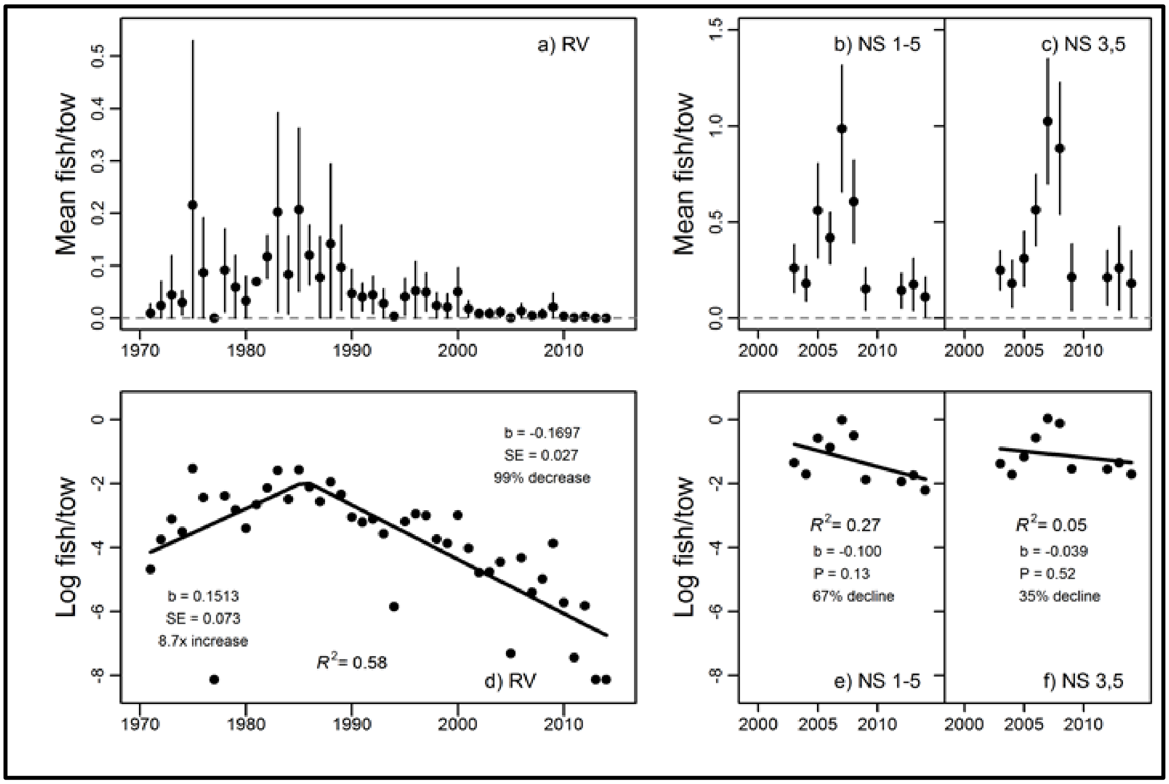

Figure 5. Abundance indices for juvenile Winter Skate (21 to 41 cm) in the September RV survey (panel a, RV) and the Northumberland Strait survey (panels b and c, NS). Vertical lines show ±2SE. A segmented regression is used in panel d to accommodate a change in the time trend; the estimated breakpoint was in 1986. In panel d, slopes (b) are shown for the regressions ending or starting in 1986. In panels d to f, R^2 is the proportion of variation in log catch rates explained by the regression model, P is the significance level of the model, and b is the estimated slope, and SE is the standard error.

The biomass index for Winter Skate, all sizes combined, from the September RV survey (strata 415 to 439) was stable at a high level in the 1970s but has steadily declined since 1980 (Fig. 6). The index has declined by an estimated 99% between 1980 and 2014. No Winter Skate were caught in strata 415 to 439 in 2013 and 2014. Over the 2000 to 2014 period, the mean biomass index in the NS survey was 20 times the mean in the RV survey (despite a smaller swept area in the NS survey). Although this is partly due to the higher catchability of Winter Skate to the trawl used in the NS survey, it also reflects the prevalence of preferred habitat of Winter Skate within the Northumberland Strait compared to the RV survey area. Over a 15-year time period, the index of biomass from the NS survey has shown a highly significant decline of 78% (Fig. 6).

Habitat selection by marine fishes is typically density-dependent, with distribution expanding into marginal habitat as population abundance increases and contracting into optimal habitat as it declines (MacCall 1990). The only long-term survey monitoring Winter Skate in the sGSL is the RV survey. Winter Skate appear to have vanished from the RV survey area (strata 415 to 439) but persist in portions of the Northumberland Strait not covered by the RV survey. It may be important to take this contraction in distribution to areas outside of the RV survey into account when estimating the rate and extent of decline in this population. Composite indices incorporating both the RV and NS surveys (strata 415 to 439 and strata 3 to 5, respectively) were constructed assuming that habitat selection by Winter Skate conformed to the ideal free distribution, a hypothesis from behavioural ecology that predicts the distribution of individuals and fitness between areas (Swain and Benoît 2016). Based on these composite indices, total Winter Skate biomass and adult abundance declined by 98% since 1979 or 1980 (e.g. Figs. 6 and 7), respectively, close to the 99% declines estimated using the RV data alone.

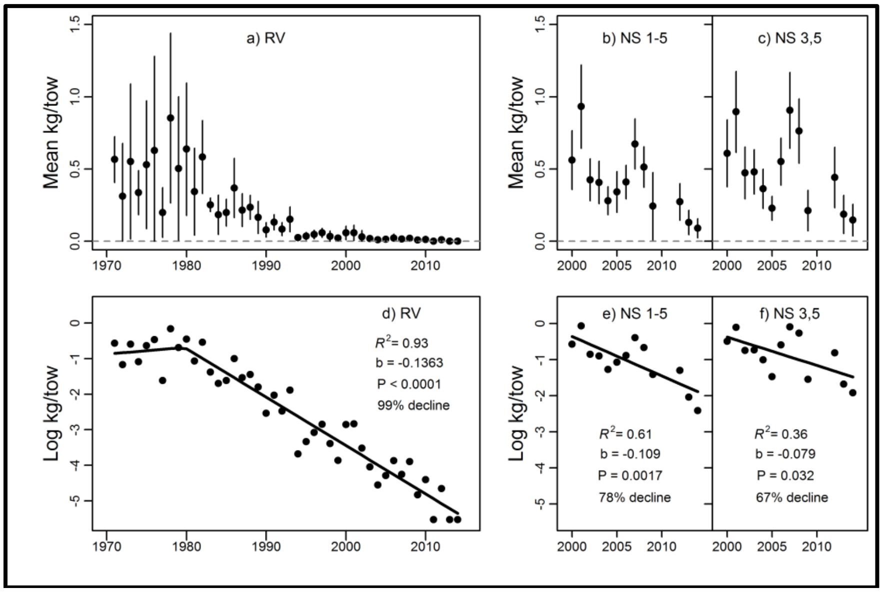

Figure 6. Biomass indices for Winter Skate (all lengths) in the September RV survey (panel a, RV) and the Northumberland Strait survey (panels b and c, NS). Vertical lines show ±2SE. The 24 strata fished since 1971 (415 to 439) are used for the RV survey and strata 1 to 5 or strata 3 and 5 are shown for the NS survey. The exponential declines in biomass are estimated in panels d to f based on the regression of log biomass versus year. A segmented regression with a breakpoint in 1980 is used in panel d. Explanations of other labels in the panels are provided in Figure 4.

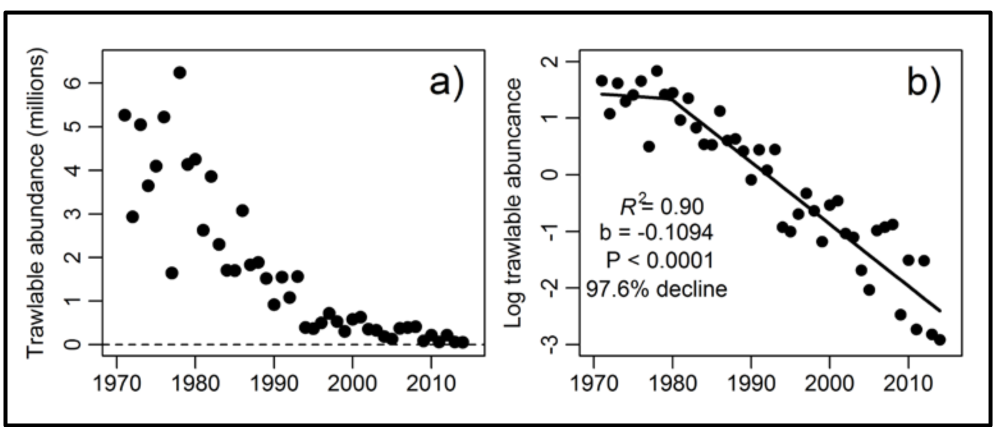

Figure 7. Composite index of abundance (millions) for adult Winter Skate in the RV and NS surveys (panel a) and fit of a segmented regression (1980 break point) to log abundance (panel b). See Figure 4 for further details.

Population model estimates

Two types of population models were examined: 1) stage-structured state-space models, the type of model used in the previous RPA of Winter Skate (Swain et al. 2006), and 2) an age-structured length-based model. The stage-structured model was fit to either the RV indices or the composite indices. Results were similar in both cases, except that the increased rate of decline in recent years evident in the fit to the RV indices alone, was not evident when fit to the composite indices. This increased rate of decline in the RV indices alone reflected the shift in distribution into the Northumberland Strait, which was accounted for in the composite indices.

The age-structured model was fit to the composite indices. The model spanned ages 2 to 9+ years (9 years and older) and 1971 to 2014. Natural mortality (*M)* was estimated separately for two age groups (ages 2 to 4 years and ages 6 to 9+ years; *M* of 5-year olds was assumed to be the average of *M* for ages 2 to 4 and 6 to 9+ in the same year) and was allowed to vary between six time blocks (five 7-yr blocks and a final 9-yr block).

Based on the age-structured model, juvenile abundance fluctuated around a relatively high value (56 million fish) in the 1970s and 1980s and progressively declined beginning in the late 1980s, reaching the lowest level on record in 2014 (estimated to be 3 million fish, 5.6% of the mean level in the 1970s and 1980s) (Fig. 8a). Adult abundance was at a high level in the 1970s, when estimated abundance averaged 7.7 million fish, but has been in decline since the late 1970s. Adult abundance in 2014 is estimated to be the lowest on record (0.2 million individuals), 3% of the average level in the 1970s (Fig. 8c). Estimated juvenile and adult biomass show similar trends (Fig. 8b, 8d). Adult biomass is estimated to have declined by 98% since 1971 and 81% since 2004 (when the previous RPA was conducted).

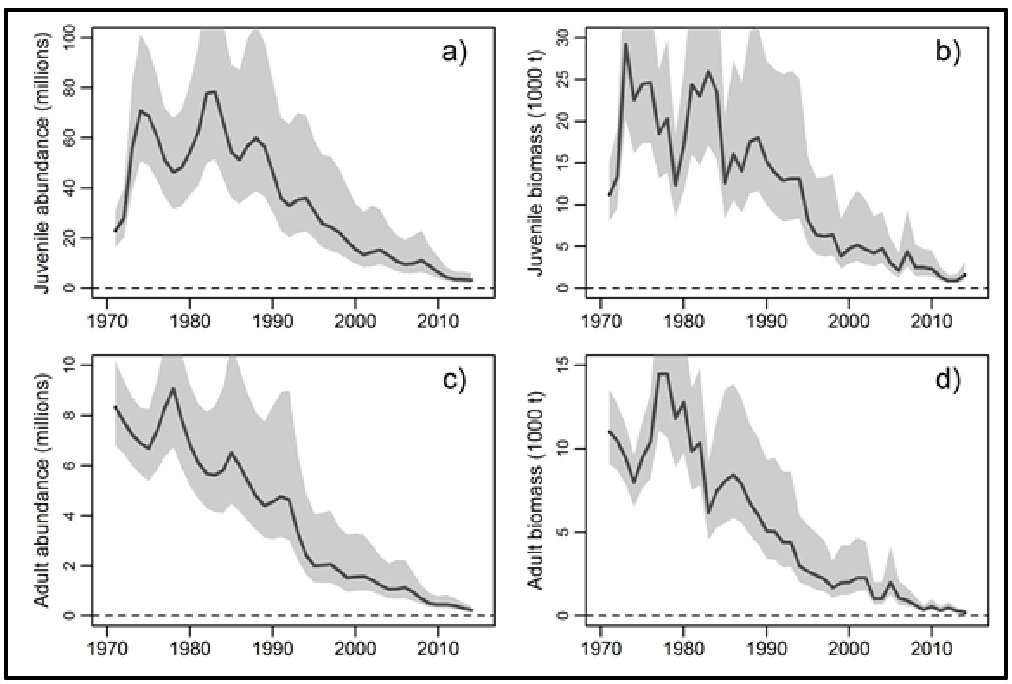

Figure 8. Estimated abundance (millions, panels a and c; left column) and biomass (1000 t, panels b and d; right column) of juvenile (panels a and b, top row) and adult (panels c and d, bottom row) Winter Skate in the southern Gulf of St. Lawrence, based on the age-structured model.

Species distribution

In the sGSL, Winter Skate occur in shallow coastal waters in summer and early fall. The median temperature occupied by Winter Skate caught in the September RV survey is about 9°C, and median depths occupied vary between 24 m for skates under 33 cm TL and 32 m for those over 50 cm TL (Swain et al. 2006). In the Northumberland Strait survey, the median depths and temperatures occupied were 12 m and 16.5°C, respectively (Kelly and Hanson 2013). In winter, these fish move offshore (Darbyson and Benoît 2003). 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).

Changes in distribution

Adult Winter Skate were widely distributed in shallow (< 50 m) coastal waters of the sGSL in the 1970s and 1980s (Fig. 9). By the late 2000s and early 2010s, catches of adult Winter Skate were very rare. Geographic distribution was similar for juveniles, though they were less widely distributed than adults. An index of geographic range (D95, the area accounting for 95% of the catches) indicated sharp contractions in range for both juvenile and adult Winter Skate (Fig. 10). For adults, D95 averaged 6,500 km^2 in the mid-1980s but had declined to 377 km^2 in 2012, a 94% decline. The D95 index for juveniles was low in the early 1970s, averaging 800 km^2 during 1971 to 1975. It then increased to a peak in the early to mid-1980s (3,400 km^2) before declining to low values in the late 2000s and early 2010s (775 km^2, 2007 to 2012), an 89% decline. Both juveniles and adults were absent from the standard survey area in 2013 and 2014.

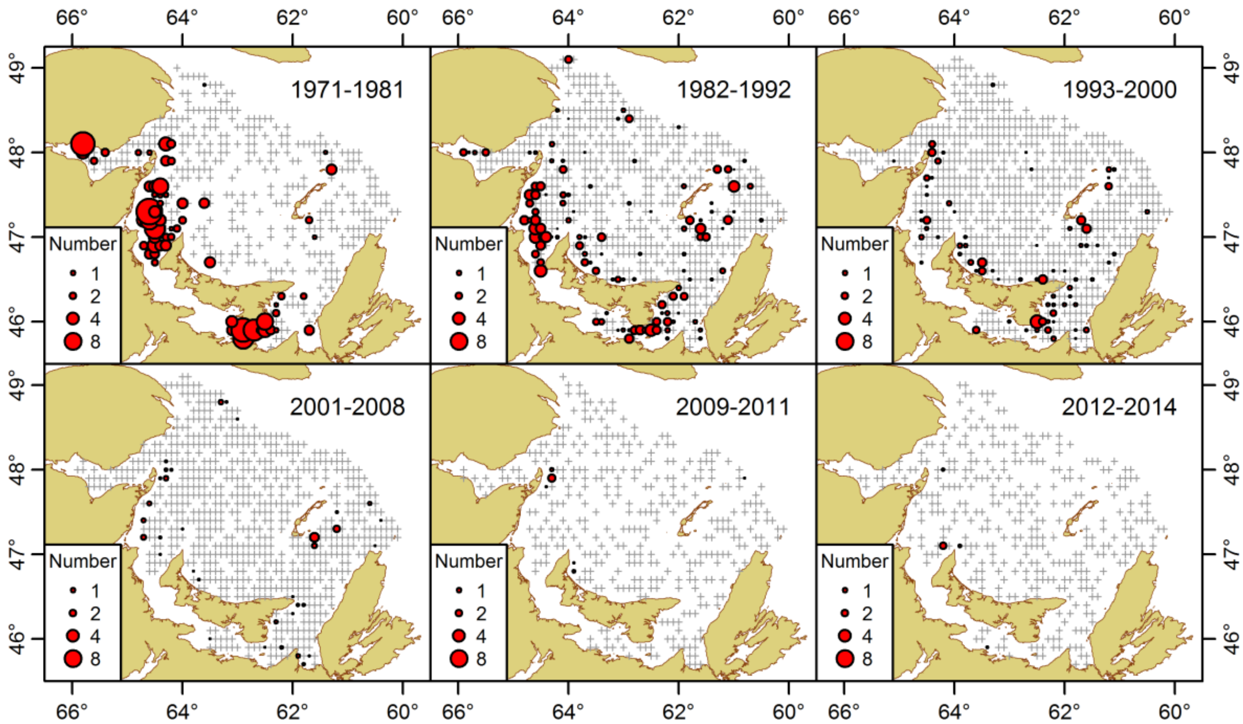

Figure 9. The geographic distribution of catches of adult Winter Skate (≥ 42 cm TL) in the September bottom-trawl survey of the southern Gulf of St. Lawrence by time period. Catches were aggregated on a 0.1°W x 0.1°N grid and averaged within time periods. Crosses indicate locations that were fished without catching Winter Skate. Circle area is proportional to catch rate (number per tow).

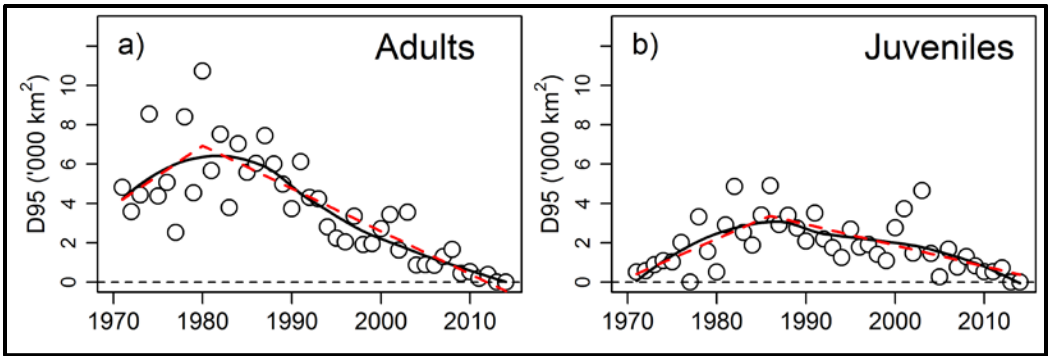

Figure 10. An index of geographic range for adults (≥42 cm TL; left panel a) and juveniles (21 to 41 cm TL; (right panel b) of Winter Skate in the southern Gulf of St. Lawrence. D95 is the estimated minimum area containing 95% of the population. Circles show the annual estimates. Solid lines describe the temporal trend based on a locally-weighted smoother (loess). The dashed lines in each panel show a segmented regression fit to the data.

Winter Skate have been primarily caught in the western portion of Northumberland Strait since the start of the NS survey in 2000, even though historically they were once common in the RV survey samples of the eastern portion of the strait (Figs. 9 and 11). Geographic distribution within the strait was similar between juveniles and adults, though the distribution of adults tended to be slightly more concentrated than that of juveniles. Catches were infrequent by 2012. In the 2014 survey, catches of adults were restricted to a small region of Stratum 3, whereas the few tows catching juveniles were more widely distributed throughout Strata 3 and 5. Catches of recruits (< 21 cm) were largely restricted to Stratum 3.

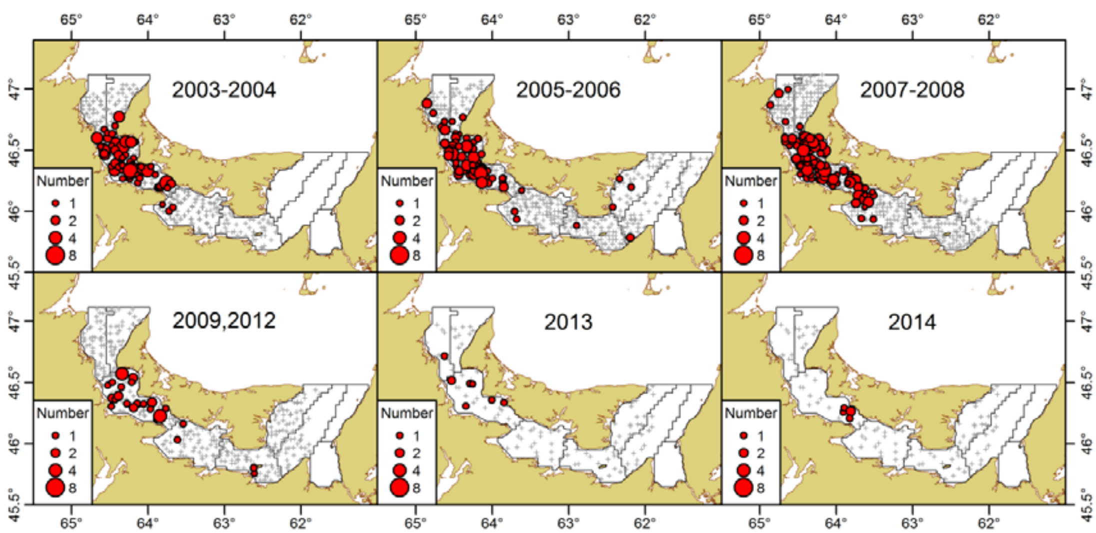

Figure 11. Distribution of catches by time period of adult Winter Skate (≥ 42 cm TL) in the July to August bottom-trawl survey of the Northumberland Strait. Circle area is proportional to catch rate (number per standardized tow). Crosses indicate locations that were fished but no skate were caught.

Current or recent life-history parameters

Size distribution

The size distribution of Winter Skate in the sGSL has contracted beginning in the 1990s (Fig. 12). The proportion of adult skate > 50 cm TL averaged 75% (61 to 90%) in the 1970s and early 1980s, declining to 55% in the 1990s and 40% in the 2000s.

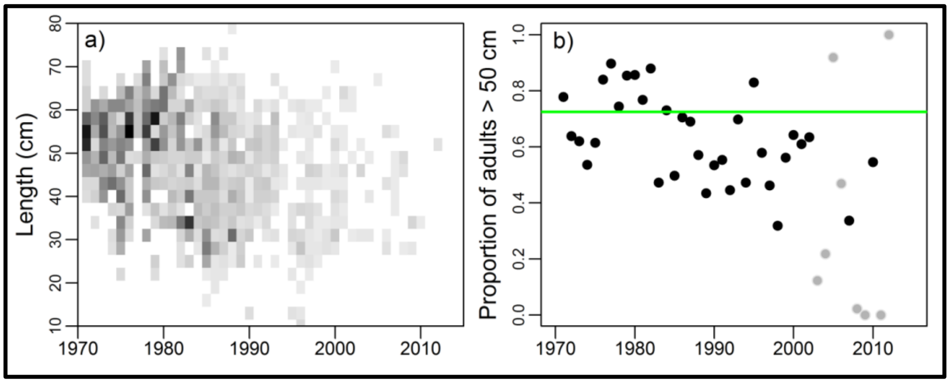

Figure 12. Size structure (length) of Winter Skate in the September RV survey of the southern Gulf of St. Lawrence, 1971 to 2014. In panel a (left panel) the relative abundance in terms of fish per tow is shown by 3-cm length class with darker shading indicating a higher catch rate. In panel b, the proportion of adults of TL greater than 50 cm is shown by year. The grey symbols are for years with observations in fewer than five length classes. The solid green line indicates the average proportion in the 1970s (0.72).

Weight and condition at age

Winter Skate measuring 42 cm TL have a predicted mean weight of 0.58 kg, whereas an adult skate measuring 60 cm has a predicted mean weight of 1.81 kg (Fig. 13). Condition (expressed as the ratio of measured weight to predicted weight) is highly variable within year and there is no trend in condition over years. The condition index was at its highest value in 2010 and lowest value in 2013, but recent values are based on very small sample sizes (e.g., 12 samples in 2010, 1 sample in 2013).

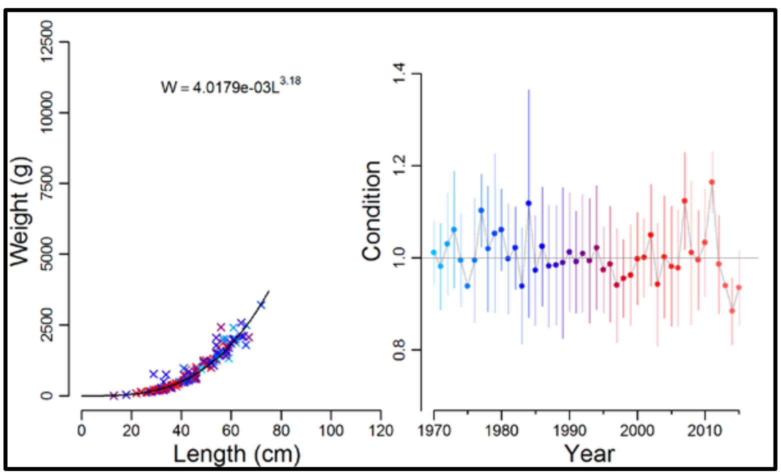

Figure 13. Length (cm) to weight (g) relationship (left panel; symbols are observations)) and condition (right panel; expressed as observed weight divided by predicted weight from the length to weight relationship) for Winter Skate from the southern Gulf of St. Lawrence, 1970 to 2014. Dots represent average condition value and vertical lines the 95% confidence interval range. The colour shading can be used to reference the sampling year of the individual observations shown in the left panel.

Mortality rates

Estimates of natural mortality (*M*) from the age-structured model indicated relatively minor trends in the *M* of juveniles (Fig. 14), with the median estimate fluctuating around an average value of 0.94 (i.e., an annual mortality of 61%). In contrast, there was a strong change in estimated *M* of adults over time (Fig. 14), steadily increasing from a median estimate of 0.11 (10% annually) during 1971 to 1977 to 1.0 (63% annually) during 1992 to 1998. Estimated adult *M* has remained high since then, with the median estimate averaging 57% since 1999.

The strongly elevated adult natural mortality estimated here for Winter Skate in the sGSL is also seen in other large demersal fish (i.e. adults of Atlantic Cod, American Plaice, Thorny Skate, White Hake, and other fish species) in the sGSL ecosystem. This high natural mortality rate has been hypothesized to reflect a “predator pit” or predation-driven Allee effect, resulting from the depleted abundance of these fishes and the high and increasing abundance of grey seals, an important predator of these fishes (Swain and Benoît 2015).

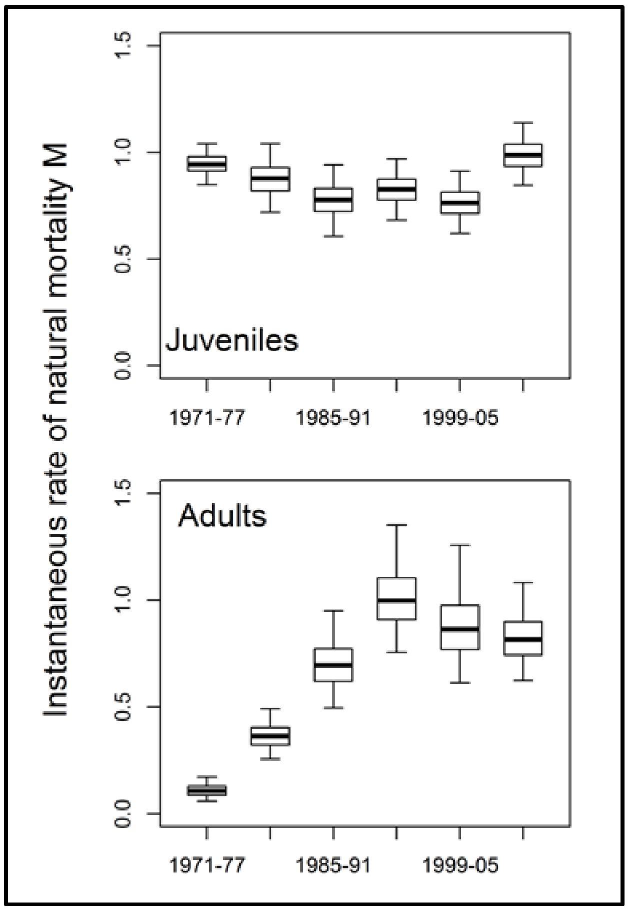

Figure 14. Estimated instantaneous natural mortality (M), in 7- or 9-year blocks, for juvenile (ages 2 to 4 years) and adult (ages 6+ years) Winter Skate from the age-structured model. Horizontal lines are the median estimates, boxes the 25th to 75th percentiles and vertical lines the 95% confidence intervals.

Recruitment and recruitment rates

Estimated recruitment rates (the number of age-2 recruits produced per female spawner) of Winter Skate show no temporal pattern, fluctuating without any long-term trend for the 1971 to 2012 cohorts (Fig. 15). The average recruitment rate was estimated to be 10.4 recruits per female spawner.

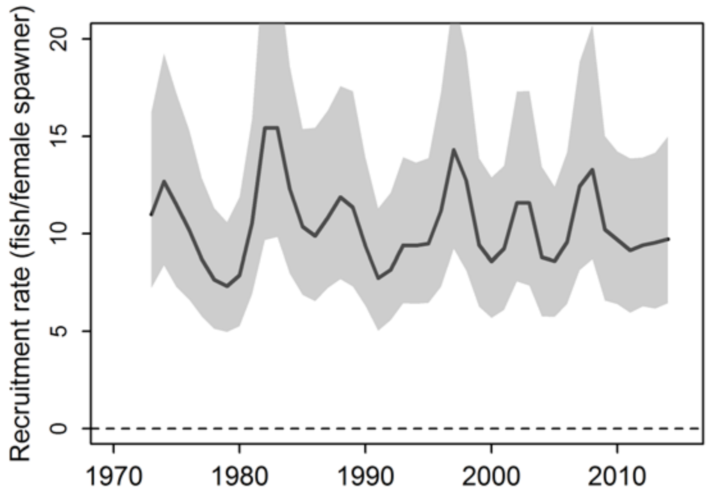

Figure 15. Estimated recruitment rate (number of age-2 recruits produced per female spawner) plotted against year of recruitment at age 2. The median estimates are indicated by the line and their 95% confidence intervals by the shading.

Habitat and Residence Requirements

Habitat properties

The median temperature occupied by Winter Skate caught in the September RV survey is about 9°C, and median depths occupied vary between 24 m for skates under 33 cm TL and 32 m for those over 50 cm TL. In the Northumberland Strait survey, the median depths and temperatures occupied were 12 m and 16.5°C, respectively. In winter, these fish move offshore and are broadly distributed on the Magdalen Shallows (40 to 100 m depth) and along the slope of the Laurentian Channel (100 to 200 m depth).

Spatial extent of the habitat areas

Adult Winter Skate were widely distributed in shallow (< 50 m) coastal waters of the sGSL during the summer in the 1970s and 1980s (Fig. 9). Densities were highest in Chaleur Bay, off the New Brunswick coast from Miscou to PEI, and between southeastern PEI and Nova Scotia in the Northumberland Strait. Adult Winter Skate also occurred in shallow water east of the Magdalen Islands and along the north coast of PEI. Geographic distribution was similar for juveniles, though they were less widely distributed than adults. The optimal habitat of sGSL Winter Skate appears to be concentrated in the Northumberland Strait.

Based on the historic distribution of Winter Skate, physical environments suitable to Winter Skate during the summer are widespread throughout the shallow coastal zone of the sGSL. The physical characteristics of these habitats (depth, temperature, salinity) are still available to Winter Skate and there has been no apparent change in the spatial extent of this suitable habitat.

Presence and extent of spatial configuration constraints

Winter Skate were once widely distributed in shallow coastal waters of the sGSL in summer, but their distribution has now contracted to the western portion of the Northumberland Strait. Within the Northumberland Strait, total biomass and the abundance of all life-history stages of Winter Skate (recruits, juveniles and adults) are highest in the area extending from Cape Tormentine in the east to Buctouche NB and West Point PEI, in the west. All the Winter Skate caught in the 2014 Northumberland Skate survey were caught in this region. Based on the now severely contracted Winter Skate distribution, this area appears to be the only important refuge remaining for Winter Skate in the sGSL.

The features contributing to the importance of this area are uncertain. Physical environmental factors such as temperature and depth do not appear to be involved. Physical environments suitable to Winter Skate are widespread throughout the shallow coastal zone of the sGSL. This suggests that biological interactions, such as predation or foraging, may be involved. The abundance of the grey seal (*Halichoerus grypus)* has increased by an order of magnitude in the sGSL since the 1960s. Depths greater than 50 m do not appear to be suitable for sGSL Winter Skate in summer. Risk of predation by grey seals is not estimated to be as high in the western Northumberland Strait as it is in other inshore areas in summer. This may account for the persistence of Winter Skate in this area. However, Winter Skate abundance has recently declined even in this area, suggesting that even here predation rates may be too high to permit survival of this species (see section on predation by grey seals).

Concept of residence for Winter Skate

The SARA 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” (s.2(1)).

Winter Skate do not have life history characteristics or behaviour that would be characterized as having features of a residence. In accordance to the DFO June 2013 policy statement on the “Application of Species at Risk Act Section 33 (Residence) to Aquatic Species at Risk” the concept of residence does not apply to Winter Skate.

Threats and Limiting Factors to the Survival and Recovery

Threats

COSEWIC (2015) indicated that although there is no commercial fishery for this Winter Skate population, declines in the 1970s and 1980s may have been due to an unsustainable rate of mortality from bycatch in fisheries targeting other groundfish species. COSEWIC noted that the species has a slow rate of population growth, and that the main threat appeared to be unsustainably high non-fishing mortality, possibly due to predation by grey seals. The source and consequence of exceedingly high non-fishing mortality are discussed in the section “Natural factors that limit survival and recovery”. The existing sources of mortality on Winter Skate resulting directly from human activities are presented below.

Fishing

There has been no directed fishing for skates in the sGSL. However, skates, including Winter Skate, are incidentally captured in commercial fisheries directed at other species. Most of these skates are discarded, though a small proportion is landed annually (Benoît 2013a). Winter Skate are incidentally captured in the commercial scallop fishery as a result of considerable spatial-temporal overlap in their respective distributions (DFO 2010). Winter Skate are also captured in groundfish fisheries, most notably those directed at the coastal flatfish species (Winter Flounder, *Pseudopleuronectes americanus;* Yellowtail Flounder *Limanda ferruginea)* (Benoît 2006, 2013a). Though the distribution of the southern Gulf lobster fishery overlaps with that of Winter Skate, the current lobster trap design likely precludes the incidental capture of skates.

Estimating fishing-induced mortality of Winter Skate historically and currently presents a number of challenges that were addressed as part of the RPA.

- Landings of skate are not identified to species. In addition, skates are also not routinely, and in some instances not reliably, identified to species even by fisheries observers.
- At sea observer programs can suffer from non-random deployment of observers and changes in harvester behaviour when an observer is present.
- The size composition of both landed and discarded skates is not available, except in the scallop fishery in the mid -2000s.
- Because the majority of incidentally captured skate are discarded, a discard mortality rate is required to estimate losses.
- Sufficient at-sea observer data to estimate annual Winter Skate discards are only available since 1991. Assumptions are required to derive estimates for prior years.

Estimated discards of Winter Skate in the scallop fishery declined from over 100 t during 1971 to 1972, to around 70 t annually from the mid-1970s to mid-1980s, to 25 t annually in the 1990s and one to two tonnes annually since 2005. Changes in the gear used in the fishery and in particular, the introduction of closed areas in the mid-2000s, likely contributed to the very low catches of Winter Skate since then. Based on empirical data, a 90% survival rate was estimated for Winter Skate discarded from the sea scallop fishery. Though the estimates for the mid-2000s may be biased, the fishing mortality rates are estimated to be sufficiently low that discard mortality in the scallop fishery is unlikely to be a significant component of Winter Skate mortality (DFO 2010).

Estimates of Winter Skate annual landings from the groundfish and shrimp fisheries for 1991 to 2014 were variable with landings generally less than 500 kg in the 2000s (Fig. 16). Prior to 1991, estimated Winter Skate landings were highest in 1974 and 1975 at around 20 t, declining slightly before peaking again at 10 t in 1981 and then declining to <500 kg annually up to 1990.

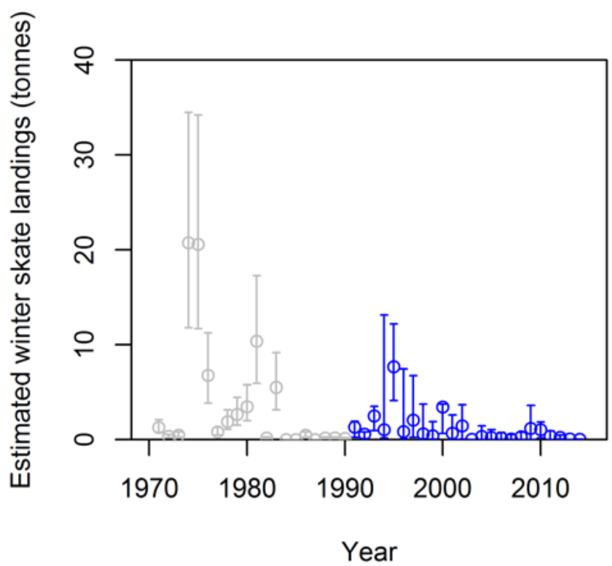

Figure 16. Estimated Winter Skate landings (with 95% confidence intervals) in the sGSL based on reported skate landings and either annual at-sea observer reports (blue) or a fixed proportion of Winter Skate in skate catches based on the 1991 to 2014 average (grey).

Estimated annual Winter Skate discards in fisheries directing for groundfish averaged about 700 t during 1971 to 1976, and around 300 t from 1977 to the early 1990s, but declined to between 10 and 50 t annually during the 1990s and early 2000s, and to less than five tonnes annually since 2008 (Fig. 17).

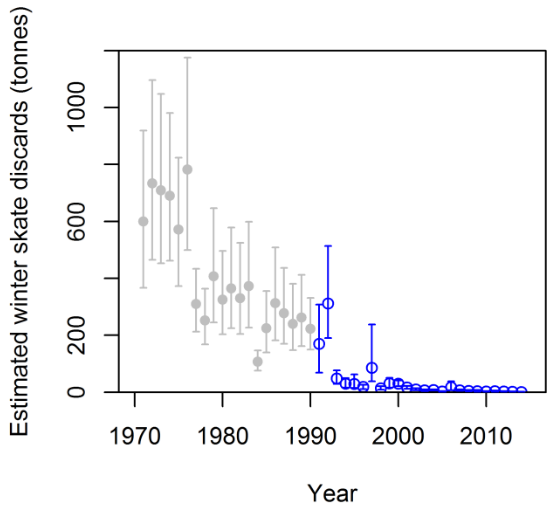

Figure 17. Estimated total discards of Winter Skate (mean and 95% confidence intervals) in commercial and sentinel fisheries for groundfish. The estimates for 1991 to 2014 (blue) are annual estimates based on fisheries observer reports, while the estimates for 1971 to 1990 are derived for the three main fisheries capturing Winter Skate, adjusted for catches in other fisheries.

Estimated mortality of Winter Skate discarded in sGSL mobile gear fisheries covered by at-sea observers was highest in 1991, at around 40%, but averaged 22% from 1992 to 2006 and 5% thereafter (Fig. 18). These are short-term survival estimates that do not account for possible enhanced predation mortality on discarded skates. Estimated discard survival was lowest in the cod mobile gear fishery and similar in flatfish fisheries. Overall Winter Skate discard mortality of around 25 to 35% was estimated for most of the 1971 to 2001 period and declined during the 2000s to around 5%. This decline reflects a higher proportion of Winter Skate discards originating from fisheries that are predicted to involve conditions that are favorable for survival such as lower handling times due to smaller catch amounts.

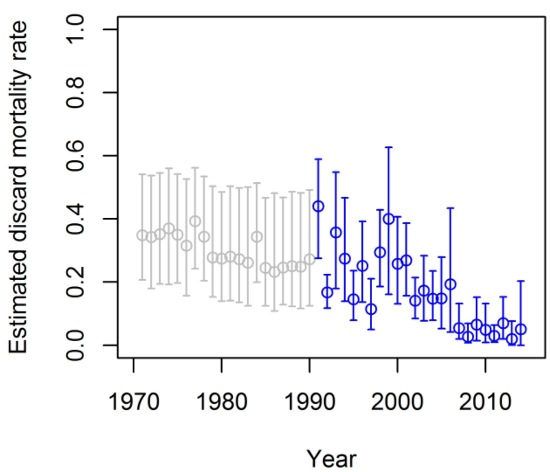

Figure 18. Estimated Winter Skate discard mortality rate (with 95% confidence interval) for groundfish and shrimp fisheries. Blue symbols represent estimates derived in large part using annual fisheries observer data, while grey symbols represent estimates derived using mean values for the 1990s.

Based on the median estimates of fisheries related losses, consisting of landings and discarded catch that did not survive, the instantaneous rate of fishing mortality (*F*) was estimated to be very low (Fig. 19). The estimated fishing mortality of juveniles (a weighted average of ages 2 to 4 years) was below 0.1% annually in all years, and averaged 0.006% annually over the last five years. Although higher for adults (a weighted average of ages 6 years and older), estimated fishing mortality averaged only 1.8% from 1971 to 1993 (when the cod fishery was first closed), 0.9% from 1994 to 2000, 0.3% during 2001 to 2010 and 0.1% since 2011 (Fig. 19). Even using the upper percentile of the estimated catch or a lower discard survival rate, the estimated *F* remained very low in all years with a similar trend of declining *F*.

There are no recreational or aboriginal food, social and ceremonial (FSC) fisheries on Winter Skate.

Catches of Winter Skate have occurred in a number of scientific programs in the southern Gulf of St. Lawrence including the RV and NS surveys, the snow crab bottom trawl survey, and the sea scallop RV survey. Although catches of Winter Skate in the RV survey were more important in the past when abundance was higher, total catches of Winter Skate in in the RV survey have averaged nine individuals annually in the past five years. In the NS survey, total catches declined from 37 individuals in 2012 to 14 in 2014.

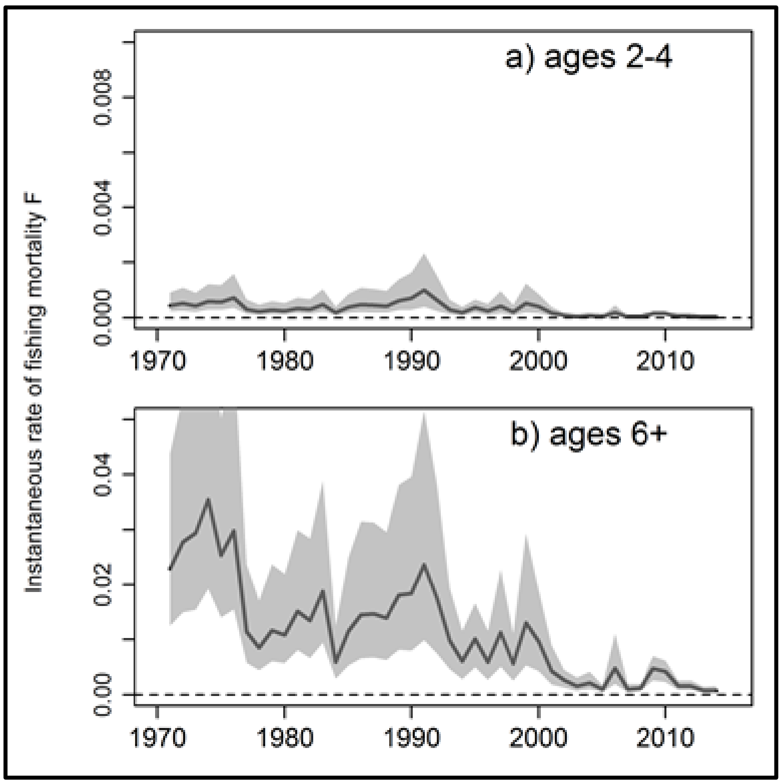

Figure 19. Estimates of the instantaneous rates of fishing mortality (F) for Winter Skate aged 2 to 4 years (upper panel a) and 6+ years (lower panel b) from the age-structured population model. Lines show the median estimates and shading their 95% confidence intervals.

Activities most likely to damage or destroy the habitat properties

Bottom-contacting mobile fishing gear can reduce habitat complexity, alter seafloor structure and alter the relative abundance of benthic species. Winter Skate may be vulnerable to such effects given its benthivorous diet and behavior and possible habitat-specific requirements for the successful development of embryos in egg cases.

The scallop (*Placopecten magellanicus*) fishery and certain mobile-gear groundfish fisheries occur in Winter Skate habitat in the sGSL. The possible short and long term impacts of scallop dredging on the coastal benthic community in the sGSL was studied and little to no evidence for an effect of dredging on the benthic invertebrate community was found. The nearshore demersal invertebrate communities in the sGSL are likely adapted to physical disturbance, including that caused by dredging, since these habitats are physically dynamic, being characterized by strong wave action and by ice scouring in winter. The results of LeBlanc et al. (2015) suggest that any effect of scallop dredging on Winter Skate via food web alteration is therefore likely to be small to undetectable.

Fishing effort has declined considerably in all the mobile groundfish fisheries in the sGSL particularly since the mid to late 1990s and any impacts are therefore likely to have been more pronounced in the past. Because scallop dredges have generally been found to produce more pronounced changes in benthic communities compared to bottom trawls, effects of mobile groundfish fishing on Winter Skate habitat are also expected to be small.

Natural factors that limit the survival and recovery

The 2005 recovery potential assessment for sGSL Winter Skate identified elevated adult natural mortality (*M*) as the main demographic rate contributing to the DU's decline (DFO 2005; Swain et al. 2006). Winter Skate in the sGSL are projected to rapidly decline to extinction at current levels of adult *M*.

In an analysis of possible hypotheses for the causes of the increased and high adult *M*, the weight of evidence indicated that predation by grey seals appeared to be the largest contributor to high *M* (Benoît et al. 2011a). Among the evidence cited was the steep rise over time in the number of grey seals that occur in the sGSL and the high degree of spatial overlap in the summer distributions of Winter Skate and grey seals which makes Winter Skate particularly vulnerable to predation by seals. In a more recent analysis, Benoît et al (2011b) reported that predation by grey seals could account for all of adult Winter Skate *M* even if Winter Skate comprise no more than 0.6% of the diet of the grey seals that overlap spatially with them, and no more than 0.2% of the average grey seal diet. Sampling prior to the 1990s, when skates were more abundant, found skates in approximately 30% of the seal stomachs examined in the sGSL and skates were considered a regular diet item (Benoit and Bowen 1990). Interannual changes in the distribution of grey seals from July to October have recently been estimated by Swain et al. (2015). Over time the presence of grey seals has particularly intensified in the Shediac Valley, at the eastern and western ends of the Northumberland Strait and between the Magdalen Islands and Prince Edward Island, regions which were historically important areas of Winter Skate distribution in the summer. The summer distribution of Winter Skate is now concentrated in a small region where predation risk appears to be low. Changes in distribution associated with risk of predation also appear to underlie long term changes in the distributions of adult Atlantic Cod, White Hake and Thorny Skate in the sGSL (Swain et al. 2015).

Recovery Targets

Candidate abundance and distribution targets for recovery

Candidate recovery targets for survival, size structure, distribution, and abundance are proposed.

Survival target

The survival target is defined in terms of the intrinsic rate of population increase (*r*) from a surplus production model or an equivalency in terms of adult *M* from an age-based model. Based on life history characteristics including a growth model, length-weight relationship, recruitment rate, maturity at age, and natural mortality, the value of *r* which would allow the population to grow and reduce the risk of extinction has a median value of 0.053. At that *r* value, the probability of extinction (biomass < 50 t) by 2039 is 4% relative to a probability of 93% under current conditions with a negative intrinsic rate of increase (-0.16).

In terms of *M*, the population would increase and the risk of extinction within 25 years become low (2%) if current *M* (0.85; 57% annual mortality) was reduced by 80% to a value of 0.17 (16% annual mortality).

Size structure target

High natural mortality has resulted in a contraction of the adult size structure. In the 1970s and early 1980s, there were abundant catches of adult (≥ 42 cm TL) Winter Skate greater than 50 cm TL in the RV survey, ranging from 43% to 90% of the adults caught (Fig. 12). Since 2006, the number of Winter Skate greater than 50 cm TL captured in the annual RV survey has varied between 0 and 5 individuals. Recovery of this Winter Skate population would require a return to the size structure of Winter Skate observed in RV survey catches during the higher abundance period of the 1970s and 1980s. This size structure target would not be realized until the natural mortality on adult Winter Skate was substantially reduced.

Distribution target

Adult Winter Skate were widely distributed in shallow (< 50 m) coastal waters of the sGSL in the 1970s and 1980s (Fig. 9). A summer distribution of Winter Skate in the inshore waters of the sGSL corresponding to the distribution during the 1980s and early 1990s is proposed as a distribution target for recovery. The D95 index (habitat occupied by 95% of the catches) for that time period averaged 6,500 km^2. This distribution target is unlikely to be realized until such time that natural mortality is substantially reduced, abundance increased, and the factors that contributed to the range contraction of the species, plausibly predation risk by grey seals, are mitigated.

Abundance Target

Abundance is not expected to increase from low levels until natural mortality on adult Winter Skate is substantially reduced.

A candidate recovery target corresponding to 40% of the biomass producing maximum sustainable yield (B_{MSY}) is proposed as the “abundance” target. This target is consistent with the Precautionary Approach framework for a limit reference point (LRP) which delimits the critical zone from the cautious zone; the critical zone is a state in which the population is considered to be suffering serious harm to its productivity (DFO 2009). A population above this abundance target is expected to be at reduced risk of extinction.

A surplus production model was used to estimate B_{MSY}, the biomass producing maximum sustainable yield (MSY). The B_{MSY} value is 0.6481 of the adult biomass estimated for 1971 by the surplus production model. Using this proportion and fitting with the age-structured model, the recovery target in terms of adult biomass is estimated to be 7,158 t (Fig. 20). The probability that annual adult biomass was below the recovery target was about 0% in the 1970s increasing to 100% since about 1995 (Fig. 20). In the most recent five years, adult biomass has declined from 8% to 3% of the recovery target.

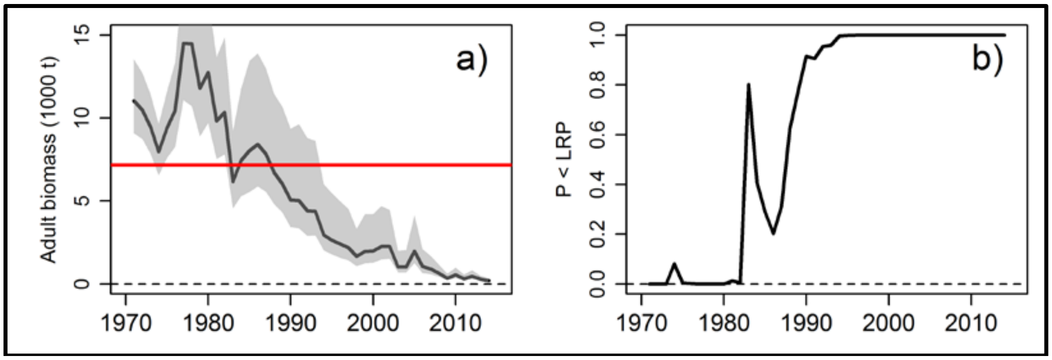

Figure 20. Adult biomass (1000 t; left panel a) from the age-structured model and probability that biomass is below the abundance recovery target of 7,158 t (LRP; right panel b). In panel a, the black line is the median estimate of adult biomass, the shading its 95% confidence interval, and the horizontal red line the recovery target.

Expected population trajectories

Using the age-structured model, the population was projected forward 50 years assuming current productivity conditions and at various lower levels of adult *M*. In initial projections, fishery removals were assumed to be nil. Under current conditions, the population is expected to continue to decline rapidly (Fig. 21a). There is a 95% probability that the population will be below 50 t by 2030, below 10 t by 2042 and below 2 t by 2054 (Fig. 22a). It is almost certain that this population would be extinct by mid-century if the current level of adult natural mortality were to persist, even with no fishery removals. This assumes no changes in juvenile natural mortality or average recruitment rates. Both these components of productivity have shown no trend over time according to this model.

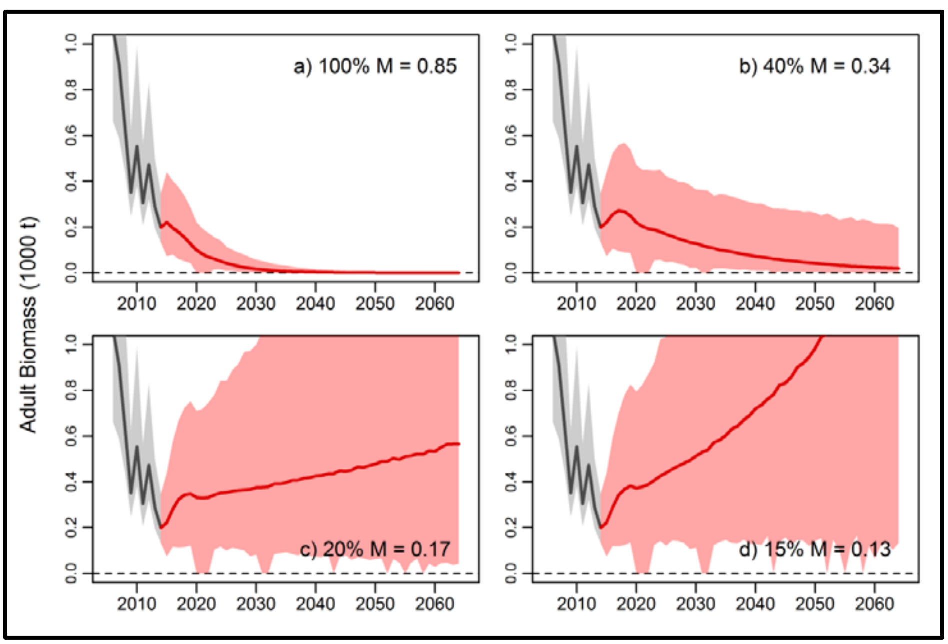

Figure 21. A 50-year projection of adult biomass (1000 t) of Winter Skate from the GSL DU based on the age-structured model assuming that productivity conditions remain at the current level (panel a) or increase to higher levels (panels b to d). Productivity changes reflect changes in adult natural mortality (M). Lines show the median estimate and shading the 95% confidence interval. Black line denotes observed years and red denotes projection years.

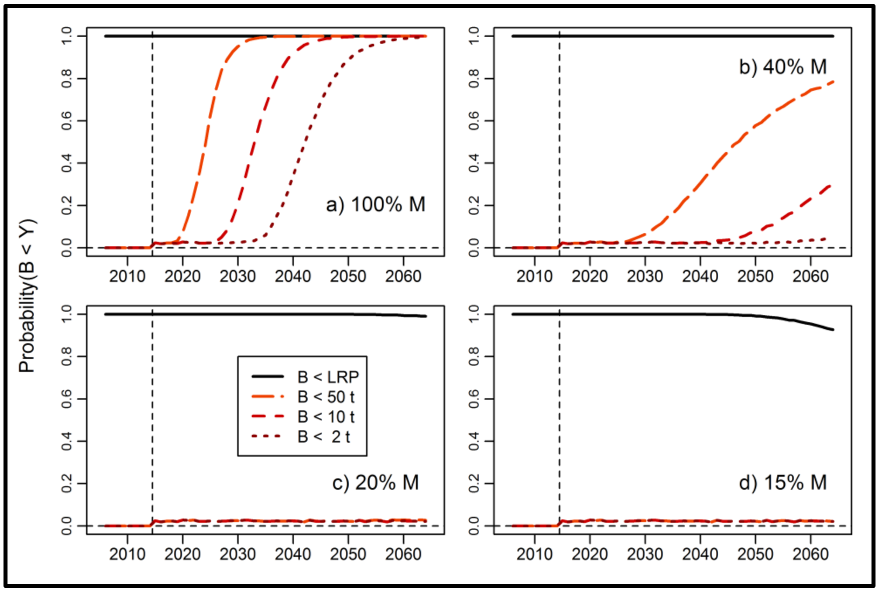

Figure 22. Probability that adult biomass of Winter Skate from the GSL DU falls below various levels (Y = LRP, 50 t, 10 t or 2 t) during the projection based on the age structured model and under different M scenarios.

Supply of suitable habitat at present and when the species reaches the potential recovery target(s)

Based on their historical distribution, depths greater than 50 m do not appear to be suitable for sGSL Winter Skate in summer. However, Winter Skate were once widely distributed in shallow coastal waters of the sGSL in summer. Their summer distribution has now contracted to the western portion of the Northumberland Strait. Physical environmental factors such as temperature and salinity do not appear to be involved. Based on the historic distribution of Winter Skate, suitable physical environments are widespread throughout the shallow coastal zone of the sGSL. The physical characteristics of theses habitats (temperature, salinity) are still available to Winter Skate and there has been no apparent change in the spatial extent of this suitable habitat. However, most of this habitat no longer appears to be available to Winter Skate in summer due to a high risk of predation by grey seals. It is unlikely that Winter Skate will return to the broader inshore areas until predation risk in these areas is substantially reduced.

Probability of achieving potential recovery targets with different mortality and productivity parameters

Projections were conducted at reduced levels of *M* using the same methods and model described above.

If adult M were reduced by 60% from its current level (i.e., to *M* = 0.34), the population would be expected to continue to decline at a slow rate (Fig. 21b). At the end of the 50-year projection, there is a 78% probability that adult biomass would be less than 50 t, a 30% probability that it would be below 10 t, and a 5% probability that it would be below 2 t (Fig. 22). Thus, even with no fishery removals, the population would be expected to decline to extinction; it just would take longer.

If adult *M* were reduced by 80% from its current level, adult biomass would be expected to slowly increase (Fig. 21c). The median estimate of biomass at the end of the 50-yr projection is 565 t, about three times the 2014 estimate but only 5% of the 1971 level. The probability that biomass would reach the LRP in 50 years is estimated to be 1% (Fig. 22c). Although it is not expected that the proposed abundance recovery target would be achieved in that time frame, the risk of extinction would be reduced to a very low level (2%).

A reduction in adult *M* by 85% of its current level would result in a relatively rapid increase in adult biomass (Fig. 21d). The probability that biomass would reach the LRP in 50 years is estimated to be 7%. The median estimate of adult biomass in 50 years is about 8 times the 2014 level and 14% of the 1971 level. The risk of extinction within 50 years would be low (Fig. 22d).

Scenarios for Mitigation of Threats and Alternatives to Activities

Inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat

Fisheries

There has been no directed fishing for skates in the sGSL. Skates, including Winter Skate, are incidentally captured in commercial fisheries directed at other species.

The offshore mobile-gear fisheries for American Plaice and Witch Flounder have contributed 10 to 20% of estimated Winter Skate discards in almost all years, and the cod fisheries produced up to 40% of the discards in a number of years prior to 2003 (Fig. 23). Most Winter Skate discards were estimated to have originated in the coastal flatfish mobile-gear fishery; generally around 50% of the discards during the 1990s, rising to over 80% in the 2010s. Fixed-gear fisheries other than that directed at cod produced an average of about 8% of estimated Winter Skate discards for the 1991 to 2000 period and a lower proportion since then.

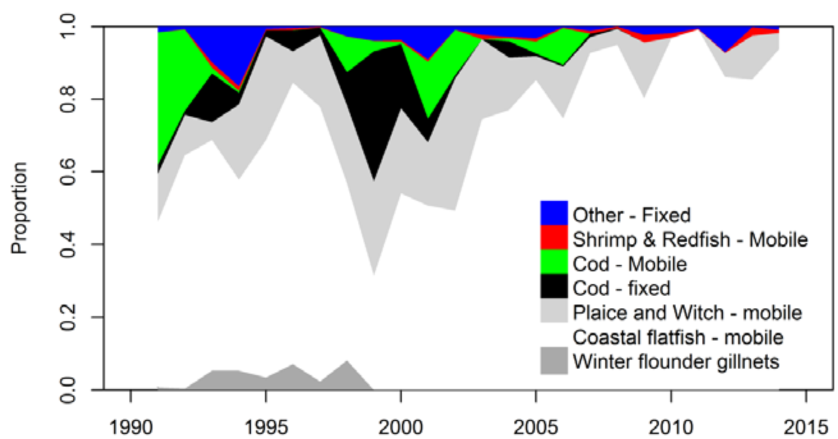

Figure 23. Annual estimates of the contribution of the various groundfish commercial fisheries and the shrimp commercial fishery to the discards of sGSL Winter Skate. Coastal flatfish mobile-gear fisheries are those that target Winter Flounder and Yellowtail Flounder.

Retention of any skate has been prohibited in NAFO Div. 4T since 2013.

Potential additional measures to further reduce fisheries related losses of Winter Skate in scallop, groundfish and shrimp fisheries and their expected effectiveness include:

- Maintained prohibition of any retention of any skate species (Thorny, Smooth, Winter) in all commercial fisheries in the southern Gulf of St. Lawrence.
- Regulations or licence conditions that ensure priority be given to sorting and rapidly discarding skate catches when they occur since there is potential for a very high post-release survival rate for discarded Winter Skate.

- Reduced fishing effort in commercial fisheries in areas and times with the highest potential of intercepting Winter Skate.

Other potential measures associated with improved information and monitoring of Winter Skate catches include:

- Increased at-sea observer coverage in the commercial fisheries in the southern Gulf of St. Lawrence. Presently there is no observer coverage in the scallop fishery.

Inventory of activities that could increase the productivity or survivorship parameters

The lack of recovery and on-going decline of sGSL Winter Skate is due to the exceedingly high natural mortality of adult skate. If this high natural mortality persists, any additional measures to further reduce the already low fishing mortality will be ineffective in promoting recovery and reducing the high risk of extinction. Elevated levels of adult natural mortality are widespread among large-bodied demersal fishes in the sGSL (Swain and Benoît 2015), and are thought to be due to the high and increasing abundance of grey seals, an important predator of these fishes. If so, activities to reduce the abundance of grey seals foraging in the sGSL may increase the survivorship of Winter Skate.

Feasibility of restoring the habitat to higher values

Physical habitat characteristics are not considered to have been degraded and be limiting to Winter Skate nor to be contributing to the high risk of extinction. On the other hand, access to much of this habitat appears to be restricted by the very high risk of predation by grey seals that now exists in inshore areas in summer (Swain et al. 2015a). Historically, the majority of adult Winter Skate utilized these inshore areas in summer, but it is unlikely that they will resume use of these areas until predation risk is reduced.

Reduction in mortality rate expected by each of the mitigation measures or alternatives and the increase in productivity or survivorship associated with each measure

A reduction of adult *M* to approx. 20% of its current high value (i.e., from 0.85 to 0.17) would be required to prevent extinction of the species (Fig. 22). Based on the energy requirements of grey seals and their spatial overlap with sGSL Winter Skate, Benoît et al. (2011b) estimated that predation by grey seals could explain all of adult Winter Skate *M* even if Winter Skate comprise no more than 0.6% of the diet of the grey seals that overlap spatially with them, and no more than 0.2% of the average grey seal diet.

Expected population trajectory (and uncertainties) and time to reach recovery targets, given reduced mortality rates and increased productivities

If adult *M* were reduced by 80% from 0.85 to 0.17, the population would be expected to slowly increase with only a 1% chance of reaching the LRP within 50 years. A reduction by 85% in adult *M* to 0.13 would be expected to result in a more rapid population increase with a 7% chance of reaching the LRP within 50 years. These projections assume that other components of productivity (e.g., recruitment rate, individual growth rate, juvenile *M*) would remain at their current levels (see section Expected population trajectories).

Parameter values for population models for additional scenarios analyses

Models for assessing trajectories for Winter Skate from the sGSL population have been described, reviewed and accepted as appropriate for assessing management scenarios associated with recovery and survival (see section Expected population trajectories).

Allowable Harm Assessment

Winter Skate are intercepted and discarded in a number of commercial fisheries in the southern Gulf of St. Lawrence. Losses of Winter Skate in scallop fisheries were estimated in the past to be on the scale of 5 to 15 t, much less important than losses from groundfish and shrimp fisheries combined (200 t annually during early 1970s) (Fig. 24). During 2005 to 2014, estimated fishing related losses in scallop commercial fisheries averaged 0.11 t (annual range 0.08 to 0.17 t). For the same period, total fishing related losses of Winter Skate in groundfish and shrimp commercial fisheries averaged 0.8 t (annual range of 0.04 to 3.51 t**)** (Fig. 24; Table 2). Most Winter Skate losses from groundfish fisheries were estimated to have originated in the coastal flatfish mobile-gear fishery during the 1990s, rising to over 80% of the losses in the 2010s, with estimated annual average losses of 0.13 t during 2005 to 2014 (Table 2).

Losses of Winter Skate in recreational as well as aboriginal groundfish fisheries in the sGSL are unknown but assumed to be near zero (Table 2).

Four scientific surveys in the sGSL have captured Winter Skate (Table 2). The September multi-species RV survey caught between 1 and 27 Winter Skate during 2005 to 2014 (Table 2). The research survey in Northumberland Strait has captured the most Winter Skate of all scientific surveys ranging between 14 and 292 individuals since its inception over the 2000 to 2015 period (Table 2). The snow crab survey occurs from July to October in depths and areas outside the normal range of Winter Skate and for the years where catches have been identified to species, total Winter Skate catches have numbered annually from 2 to 28 (2012 to 2015) (Table 2). The directed sea scallop survey has annually sampled a different scallop fishing area in the sGSL during 2012 to 2015. For those years, total catches of Winter Skate have been 0 to 7 Winter Skate annually.

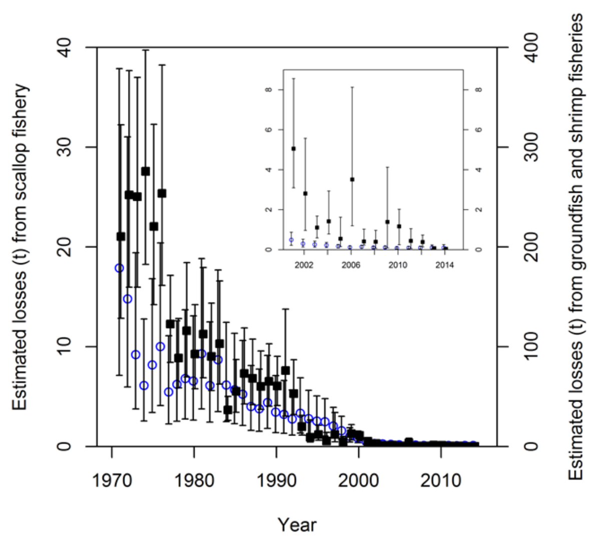

Figure 24. Estimated fisheries related losses (t; mean with 95% confidence interval error bars) of Winter Skate in the groundfish fisheries and the shrimp fishery (black squares) and the scallop fishery (open circles) of the southern Gulf of St. Lawrence, 1971 to 2014. The inset figure shows the time period for 2001 to 2014. Note the difference in scale for losses from scallop fisheries (0 to 40 t) and from groundfish fisheries (0 to 400 t) in the full time series panel.

Table 2. Estimated catches (t; median annual) and estimated losses (t; post-discard mortalities) of Winter Skate from the commercial, recreational, and aboriginal fisheries and scientific fishing activities in NAFO Div. 4T, 2005 to 2014. The coastal flatfish fishery includes Yellowtail and Winter Flounder. For scientific activities, values reported are in numbers of Winter Skate rather than in weight. This table excludes retained catches that were landed since landings of skates are no longer permissible in the sGSL.

Fishery type	Principal species	Estimated annual catches (t) mean (range)[3]	Estimated losses (t; post-discard mortality) mean (range)[3]
Fixed gear	Winter Flounder	0	0
	Other	0.07 (<0.01 – 0.17)	0.01 (<0.01 – 0.02)
Mobile	Coastal flatfish	3.79 (0.53 – 13.04)	0.13 (0.01 – 0.69)
	American Plaice and Witch Flounder	0.40 (<0.01 – 2.50)	0.08 (<0.01 – 0.43)
	Other	0.21 (<0.01 – 1.80)	0.04 (<0.01 – 0.34)
Mobile	Scallop	1.10 (0.80 – 1.70)	0.10 (<0.10 – 0.20)
Recreational	Groundfish	unknown	assumed 0
Aboriginal	Groundfish	unknown	assumed 0
Scientific surveys	Multi-species RV (Western IIA)	< 0.01 (< 0.01 – 0.02) 15.5 (1 – 27)[1]	< 0.01 (< 0.01 – 0.02) 15.5 (1 – 27)[1]
	Multi-species NS (rock hopper) [2]	0.07 (0.01 – 0.18) 126.6 (14 – 292)[1]	0.07 (0.01 – 0.18) 126.6 (14 – 292)[1]
	Snow crab (Nephrops trawl) [4]	11 (2 – 28)[1]	14 (3 – 28) [1]
	Scallop (drag) [4]	3 (0 – 7)[1]	3 (0 – 7) [1]

[1] Expressed as number of Winter Skate
[2] For the Northumberland Strait (NS) survey, 2010 and 2011 (when a Nephrops trawl was used) are excluded
[3] This is the range in annual estimates.
[4] For the years 2012 to 2015

The instantaneous rate of fishing mortality (*F*) of juveniles (a weighted average of ages 2 to 4 years) was estimated to average 0.006% over the last 5 years. The estimated fishing mortality rate on adults was estimated at 0.1% since 2011 (Fig. 19).

The low level of fishing mortality has a negligible impact on the population trajectory (Fig. 25). Based on projections, fishing mortality at levels observed since 2001, and more so since 2011, has negligible consequences for population trajectory, probability of recovery, and risk of extinction. In all cases, the probability of extinction (biomass < 50 t) is almost 100% by 2035 (Fig. 25). This is a consequence of the extremely high level of natural mortality currently experienced by this population. These projections are constant effort scenarios, not constant catch scenarios. As Winter Skate abundance declined in the projections, these levels of *F* would have resulted in progressively smaller annual losses due to fishing.

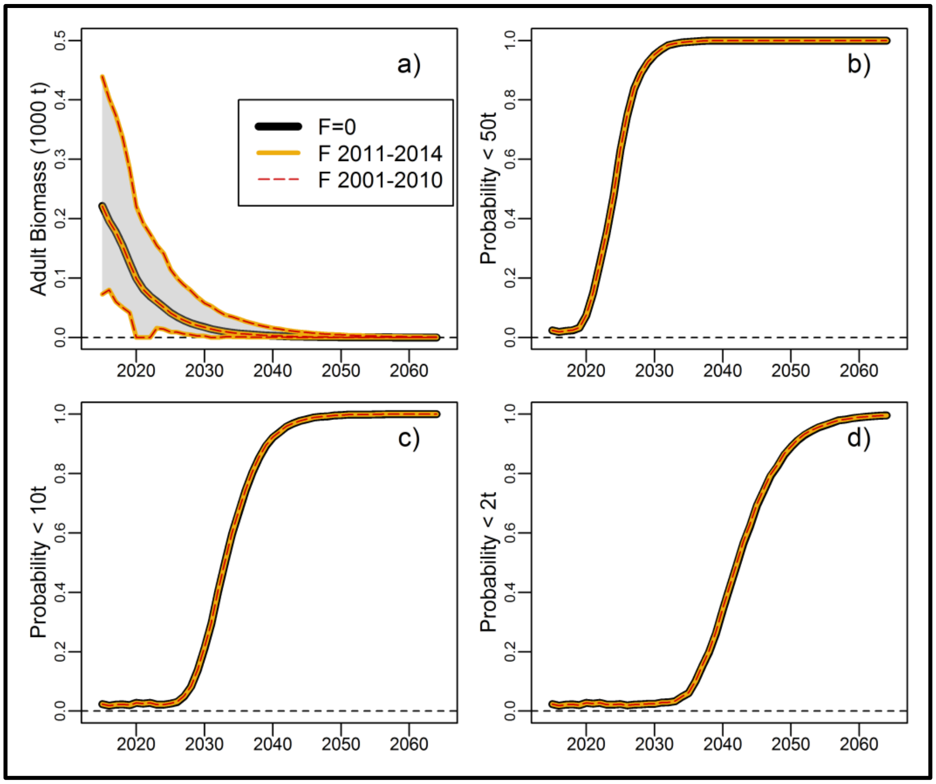

Figure 25. Projected adult biomass (1000 t, panel a, upper row on the left) and probabilities of annual biomass being < 50 t (panel b; top right), < 10 t (panel c, bottom left) and < 2 t (panel d; bottom right) for fishing rates of F = 0, at average fishing mortality rates of the 2001 to 2010 time period (0.0001 for juveniles, 0.003 for adult Winter Skate), at average fishing mortality rates of the 2011 to 2014 time period (0.00004 for juveniles, 0.001 for adult Winter Skate). Projections are from the age-based state space model with non-fishing productivity rates (M, mean weight) estimated for current conditions. The median and .5th and 97.5th percentiles of the projected abundance are indicated by the thick black line and grey shading for F = 0, and by the coloured lines for higher F values.

Sources of Uncertainty

Estimates of Winter Skate removals by fisheries are highly uncertain, especially prior to 1991. Nearly all of the Winter Skate catch in the sGSL is discarded at sea. Sufficient at-sea observer data to estimate catches is available only since 1991. Even since then, species composition of skate catches is often missing or unreliable and must be estimated, and a number of assumptions must be made to expand catches in observed trips to the total fishery catches. Estimates of discard mortality rates are required to estimate fishery removals associated with estimates of discarded catches. These mortality rates depend on a variety of technical (e.g., gear, handling), environmental (e.g., temperature gradients experienced during capture) and biological (e.g., size) factors. While it is possible to account for these effects to some extent, this becomes more difficult in early years when information on these covariates of mortality rates becomes more uncertain. Additional assumptions are required to obtain estimates of catch in years prior to 1991 when there was little or no observer coverage. The estimation methods used for the RPA incorporate and propagate these uncertainties, but it is possible that the level of uncertainty has been underestimated and that bias has been introduced by the assumptions required in the estimation. Uncertainties and bias are likely greatest in the estimates for the 1970s and 1980s.

The size composition of fishery removals is also highly uncertain. Except for the scallop fishery, there are no data on the size composition of Winter Skate catches in the sGSL. Size composition was estimated using observer data on the length distribution of Thorny Skate catches and RV survey data on length distribution of the Thorny Skate population available to the fishery.

While the level and length composition of fishery removals of Winter Skate are highly uncertain, it is nonetheless clear that there has been a large decline in the exploitation rate of Winter Skate over the 1971 to 2014 period. This is consistent with the large decline in fishing effort in the sGSL during this period.

Based on the RV survey index, adult abundance was high in the 1970s whereas juvenile abundance was very low. The cause of low juvenile abundance at a time of high adult abundance is unclear. One possibility is that catches of juvenile Winter Skate were much greater in the 1970s than estimated here.

Indices of relative abundance of Winter Skate are available from the September RV survey of the sGSL, conducted since 1971, and the Northumberland Strait survey, conducted since 2000. Winter Skate are now rarely detected in the RV survey but are still caught (in severely reduced numbers) in the NS survey. This suggests that the proportion of the Winter Skate population available to the RV survey declined as population abundance declined, consistent with the predictions of theories of density-dependent habitat selection. Consequently, an index combining the RV and NS surveys was constructed in order to obtain an unbiased index of relative abundance. This required the assumption that the parameters of density-dependent habitat selection estimated for the 2000 to 2014 period could be applied to earlier periods. Nonetheless, conclusions appeared to be robust to any violations of this assumption. Decline rates and population model results were similar using either the RV index or the combined index.

The population models provide estimates of “absolute” abundance. Normally the level of fishery catches has a strong influence on the estimate of the scale of absolute abundance in stock assessment models. In this case, fishery removals are estimated to be very low throughout the time series and provide limited information on the scale of population abundance.

The main cause of the decline, lack of recovery and high extinction risk of sGSL Winter Skate is elevated natural mortality of adult skates. Based on the available evidence, predation by grey seals appears to be an important cause of this elevated mortality. However, much of the evidence is indirect. More direct evidence on interactions between Winter Skate and grey seals is needed to better understand the impacts of changes in grey seal abundance on the abundance and productivity of Winter Skate. Given the very low abundance of Winter Skate and the difficulty in detecting Winter Skate in grey seal diets (e.g., due to their lack of bony parts), it will be difficult to obtain this additional information.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 19 to 21, 2016 meeting on the Recovery Potential Assessment – Winter Skate (*Leucoraja ocellata*), Gulf of St. Lawrence population and Eastern Scotian Shelf – Newfoundland population. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

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