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Science Advisory Report 2017/014

RECOVERY POTENTIAL ASSESSMENT FOR WINTER SKATE (*LEUCORAJA OCELLATA*): EASTERN SCOTIAN SHELF AND NEWFOUNDLAND POPULATION

Photo courtesy of Eric Parent

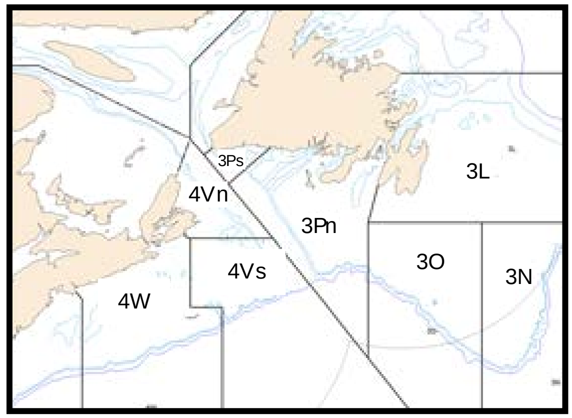

Figure 1. Geographic boundaries of the Winter Skate Eastern Scotian Shelf and Newfoundland population defined by NAFO Divisions 3LNOP and 4VW.

Context:

In its second assessment of Winter Skate (Leucoraja ocellata, Mitchill 1815) in Canadian waters from April 2015, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-assessed this 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, the Department of 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 and 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. Advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, development of a recovery strategy and action plan, and to support decision-making regarding issuance of permits or agreements, and formulation of exemptions and related conditions, as per sections 73, 74, 75, 77, 78, and 83(4) of SARA. Advice in the RPA may also be used to prepare for the reporting requirements of SARA s.55. Advice generated through this process will update and consolidate any existing advice regarding Winter Skate in the ESSN DU.

This Science Advisory Report is from the 19-21 January 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

- The Eastern Scotian Shelf – Newfoundland (ESSN) population structure of Winter Skate was revised by COSEWIC in 2015 to include the previous Eastern Scotian Shelf (ESS) population and the Newfoundland portion of the previously identified Northern Gulf and Newfoundland population. This new ESSN DU population was assessed as Endangered, due to an estimated decline in abundance of 98% since the early 1970s and a decrease in distribution range.
- ESSN DU Winter Skate mature at older ages and larger sizes than Winter Skate in the Gulf of St. Lawrence (GSL) DU, but at sizes and ages similar to Winter Skate elsewhere along the eastern seaboard of North America.
- The ESSN DU range consists of Northwest Atlantic Fisheries Organization (NAFO) Divisions 3LNOP and 4VW, with the majority of Winter Skates located in Divisions 4VW.
- Based on annual area-specific DFO research surveys, biomass indices of all sizes of Winter Skate declined over 1996 to 2014 by 90% in Div. 3LNOP, and 92% in Div. 4VW. In Div. 4VW, the observed decline began in 1970, with a decrease by 99% during 1970 to 2014.
- Estimated biomass indices for all size groups in this DU indicated a 98% decline from a peak value of 48.6 kt in 1970 to 1.2 kt in 2015.
- Winter Skate on the ESS was broadly distributed on shelf waters at depths < 110 m and on the offshore banks, with concentrations on Middle Bank, Sable Island Bank, and Banquereau Bank in the 1970s and 1980s. Beginning in the 1990s, the distribution shifted from the Sable Island area to edges of the ESS and the average area occupied has decreased from 15,000 km^2 in the 1980s to about 4,000 km^2 by 2010 (a 74% decline).
- For Div. 4VW Winter Skate, estimated natural mortality (M) for adults (75+ cm) was low (10.5% to 18.1% annually) during 1970 to 1990 and increased to 36% since 1998. This population had a negative intrinsic rate of increase since 2005, i.e., the stock is not replacing itself.

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

- There are no directed fisheries for Winter Skate in the ESSN DU. Winter Skate of this DU are incidentally captured in many fixed and mobile gear fisheries, including for groundfish, Thorny Skate (primarily in Subdivision 3Ps), shrimp, scallop, and surf clam. However, fishing mortality presently does not appear to be a limiting factor to Winter Skate survival and recovery.
- Winter Skate can only be retained in groundfish fisheries, but are usually discarded at sea. Based on low at-sea observer coverage (0% to 7% annually), annual discard estimates for these fisheries ranged from 0 to 63 t in Divs. 3LNOP, and 29 to 93 t in Divs. 4VW during 2005 to 2013.
- Based on estimates of landings, discards, and post-discard survival rates, maximum estimated exploitation rates during the 1970 to 2015 period in Divs. 4VW were 4% for small juveniles, 11% for large juveniles, and 17% for adults. Exploitation rates in 2011 to 2015 were 1.3% for small juveniles, 0.6% for large juveniles, and 0.41% for adults.

- Habitat is not a limiting factor to Winter Skate survival and recovery in the ESSN DU. There are no known anthropogenic threats that have reduced habitat quantity or quality for this population.
- Risk of extirpation has increased substantially for the ESSN DU population since the previous Winter Skate assessment by COSEWIC in 2005. At the DU level, estimated biomass declined by 98% over 1970 to 2015. For the Divs. 4VW component of this DU, adult abundance declined by 99% in this period. Despite closure of the Divs. 4VW skate-directed fishery and reductions in bycatch of skates in other fisheries, adult abundance in Divs. 4VW declined by 76% during 2005 to 2015. It is expected to continue declining even if there are no fishery catches. The estimated high natural mortality continues to be the most important limiting factor that places this population at risk of extinction.
- Predation by Grey Seal is a plausible cause of elevated natural mortality for Winter Skate in Divs. 4VW. Other predators, such as large sharks, may constitute an additional cause of the elevated mortality; although the abundance of large sharks appears to have declined to low levels in the Northwest Atlantic.

Recovery Targets

- Winter Skate life history characteristics of slow growth, late sexual maturity, and extended embryonic development result in low rates of potential population increase, decreased resilience and a limited possibility to recover from substantial declines, such as those induced by fishing or other causes.
- Candidate recovery targets for survival, size structure, distribution, and abundance are proposed. The survival target is defined by an intrinsic rate of population increase (r), or by an equivalency based on natural mortality (*M*). In terms of adult *M*, the population would increase and its risk of extinction would become negligible if current *M* (36% annually) was reduced by 50% (18% annually).
- The proposed size structure, distribution, and abundance targets cannot be realized until the current high natural mortality rate of adult Winter Skate has been substantially reduced.

Projections

- Modelling results indicated that the ESSN DU of Winter Skate is not viable under current conditions, due primarily to increases in adult natural mortality to unsustainably high levels. If the productivity conditions observed in 2005 to 2015 persist, this population is expected to decline to extinction, even with no fisheries catches.
- Assuming current productivity conditions, the Divs. 4VW component of this DU is expected to continue declining rapidly, with a 58% probability of decreasing below 50 t (a proxy for extinction) by 2040, even with no fishery-related losses.

Scenarios for Mitigation of Threats and Alternatives to Activities

- The lack of recovery and on-going decline of the Winter Skate ESSN DU is due to high natural mortality of adults. If this high natural mortality persists, any additional measures to further reduce the currently low fishing mortality will be ineffective in promoting recovery and reducing the high risk of extirpation.
- Potential measures to further reduce fisheries related losses of ESSN DU Winter Skate in scallop, groundfish, and shrimp fisheries are provided.

Allowable Harm Assessment

- Even with no fishery related losses (from retention and discarding), there is a greater than 50% probability that extirpation of the ESSN DU of Winter Skate would occur within 25 years if the productivity conditions of the 2005 to 2015 time period persist. At the level of the estimated exploitation rates during 2011 to 2015, there would be no noticeable impact on the projected population trajectory; although there would be a small increase in the probability of extirpation (58% to 65%) by 2040.
- Results were similar for the Divs. 4VW component of the DU based on a stage-structured model. If current conditions persist, the probability that adult biomass would decline below 50 t, a proxy for extinction, by 2040 is estimated to be 58% with no fishery catch, and 62% at 2011 to 2015 fishery exploitation rates.

INTRODUCTION

Winter Skate (*Leucoraja ocellata* Mitchill 1815) is a commercially exploited species in Canadian Atlantic waters. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) first evaluated the status of Winter Skate in Canadian Atlantic waters in May 2005 (COSEWIC 2005). In the 2005 COSEWIC assessment, four Designatable Units (DU) were identified, with the Eastern Scotian Shelf population assessed as Threatened. A Recovery Potential Assessment (RPA) for the Eastern Scotian Shelf DU (DFO 2005) concluded that the decline in abundances of Winter Skate adults and juveniles appeared to be caused primarily by an increase in natural mortality. Uncertainty in modelled population projections was great, and encompassed both extirpation and increased abundance, but the most probable trend was that no recovery was expected without a decrease in adult natural mortality (DFO 2005).

In its 2015 re-evaluation, COSEWIC concluded that Winter Skate in Canadian Atlantic 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 (COSEWIC 2015). The ESSN DU range consists of Northwest Atlantic Fisheries Organization (NAFO) Divisions 3LNOP and Divisions 4VW, with the majority of Winter Skate located in Divisions 4VW. The ESSN DU was assessed as Endangered by COSEWIC. Abundance of mature Winter Skate was estimated to have declined 98% since the early 1970s, and reached an historical low by 2015. The size of the population’s range varied over this time period: increasing until the mid1980s; then decreasing since. COSEWIC considered that overfishing in the 1980s and 1990s, including by directed skate fisheries, may have contributed to declining abundance during that period. Since then, the main threats have been unsustainably high non-fishing mortality possibly due to predation by Grey Seal or other predators, as well as fishing mortality due to skate bycatch in fisheries targeting other species (COSEWIC 2015).

Biology and Distribution

Winter Skate are endemic to the Northwest Atlantic, with a reported range extending from the Gulf of St. Lawrence and eastern Newfoundland coast southward to Cape Hatteras (Scott and Scott 1988). On the Scotian Shelf, this species is sympatric with Little Skate (*Leucoraja erinacea*). Both species are very similar in external appearance, and most often identified by size at first maturity: Little Skate matures at much smaller lengths than Winter Skate. This method cannot be applied to juveniles of both species and, in the absence of distinguishing external characteristics on individuals <36 cm in length, identifications of these skates to species remain highly suspect. It should be noted that no specimens from Newfoundland and Labrador (NL) waters have been confirmed as Little Skate since 1990; further supporting the understanding that previous identifications of Little Skate for this region were erroneous, and that this species does not inhabit waters of Newfoundland and Labrador.

Winter Skate in the ESSN DU have similar life history characteristics to Winter Skate elsewhere, maturing at a later age and larger size than Winter Skate in the GSL DU (DFO 2016). Based on aging analysis using bomb radiocarbon dating (McPhie and Campana 2009*b*), age of 50% maturity for this species in the ESSN DU is estimated to be 11 years for males and 13 years for females; corresponding to a total length (TL) of approximately 75 cm. In this study, maximum length was estimated to be higher for males (91 cm) than for females (80 cm).

Winter Skate are oviparous with internal fertilization: depositing one fertilized egg in a rectangular hard-shelled capsule (“Mermaid’s purse”) on the ocean floor. Reproductive rate (i.e., fecundity) is low, with adult females producing 41-56 egg cases per year (McPhie and Campana 2009*a*). The egg case has adhesive mucus and paired “horns” at each end, which help it attach to or become entangled with materials on the bottom (e.g., pebbles, seaweed, corals). Structure and function of the skate egg capsule are mostly similar to those of a bird or reptile egg shell. Predation by gastropods (e.g., whelks, which bore holes through the leathery egg capsule) is thought to be the primary source of natural mortality (estimated as 14% to 42% with a 24% average) during this embryo developmental stage. Gestation time for ESSN Winter Skates within egg purses is assumed to be 18-22 months. Length at hatching from egg cases for this species is approximately 10-15 cm TL (Scott and Scott 1988). Reported predators after hatching include sharks, other skate species, and Grey Seals.

Winter Skate feed primarily on marine worms and amphipods, although their diet also includes bottom-dwelling crabs, sea urchins, clams, and fish (Scott and Scott 1998). Winter Skate diet changes with increasing size: crustaceans decrease in importance as skate length (and mouth gape) increases, while fish become increasingly important prey for larger (81+ cm) Winter Skates and can constitute >50% of the diet.

Winter Skate life history characteristics are typical of most elasmobranchs (skates, sharks), including slow growth and late age of maturity which result in low rates of population increase. Winter Skate has the lowest predicted population growth rate among four common skate species on the Scotian Shelf (McPhie and Campana 2009*a*).

ASSESSMENT

Abundance and Life History Parameters

Information in this section is presented by management unit. Percent change in abundance over selected time periods was estimated as $100*(\exp(b*\Delta t)-1)$, where b is the regression slope (negative value indicates decline, positive value represents an increase) and Δt is the time period (number of years) over which the percent change is calculated. One generation time for Winter Skate is estimated to be 17 years (age at 50% maturity + 1 / *M*, with *M* set at 0.2).

Research survey indices

NAFO Divisions 3LNOP

Indices of Winter Skate abundance and biomass in Div. 3LNOP were obtained from stratified random bottom trawl research surveys conducted annually by DFO-NL Region during spring (1971 to present; Fig. 2). Due to different trawls being deployed during the spring survey (Yankee 41.5 during 1971 to 1983; Engel 145 during 1984 to 1995; Campelen 1800 since 1996) and a lack of species-specific conversion factors between each trawl type, the resultant abundance and biomass estimates are not comparable among the three different trawls of the

NL spring survey time series. In addition, the spring survey did not cover the entire area in some years, due to research vessel's mechanical difficulties. Most of Subdivison 3Ps was not sampled in 2006 and Subdivision 3Pn was not surveyed in 2008 and 2014. Furthermore, length data were not consistently collected for Winter Skate during the Divisions 3LNOP spring survey thereby precluding any length-based analyses.

No Winter Skate were caught in the Divisions 3LNOP spring survey during 1971 to 1983 with the Yankee trawl (Fig. 3). Survey catches increased with use of the Engel trawl, and peaked during the 1996 to 2002 period with the Campelen trawl. Since 2010, spring survey abundance estimates have been at or near their lowest values in this time series (Fig. 3). Biomass indices of Winter Skate (all sizes combined) declined by 90% during 1996 to 2014 (Fig. 3; Table 1).

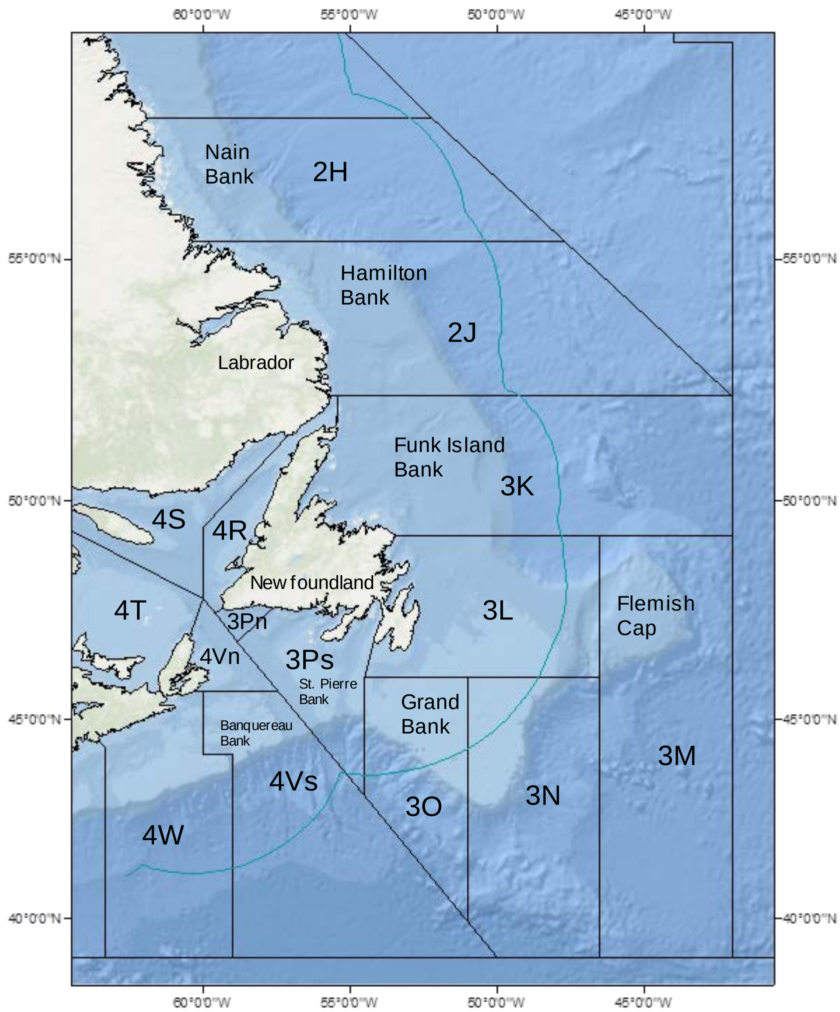

Figure 2. Map of the continental shelf off Eastern Canada, geographic features and NAFO Divisions and Subdivisions mentioned in the text. Depth range: < 100 m (light grey) to > 1000 m (dark grey). Canada's Exclusive Economic Zone is delineated by thin dotted lines and NAFO Divisions by thick dotted lines.

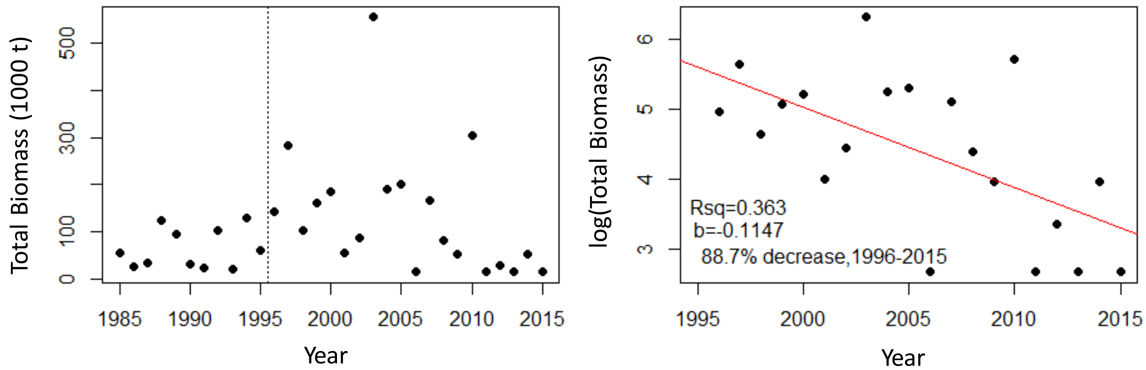

Figure 3. Estimated total biomass (1000 t) of Winter Skate from DFO-NL spring research surveys in Divisions 3LNOP, 1984 to 2015 (left panel) and the natural log of the total biomass index with the corresponding abundance trend regression line for 1996 to 2015 (right panel; red diagonal line). The survey trawl changed from Engel to Campelen in 1996 (left panel; black vertical line). No conversion factors exist for changes in survey gear or vessel. The spring survey was incomplete in 2006.

NAFO Divisions 4VW

Indices of abundance and biomass for Divisions 4VW Winter Skate are monitored by the DFO-Maritimes Region summer research survey, conducted annually on the Scotian Shelf (Divisions 4VWX and portion of Division 5Z) since 1970 using a stratified random design based on depth and geographic area (Fig. 4). This survey used four Canadian research vessels over the time series and, based on analyses of comparative fishing experiments, no conversion factors were required to adjust for changes in catchability between the different vessels.

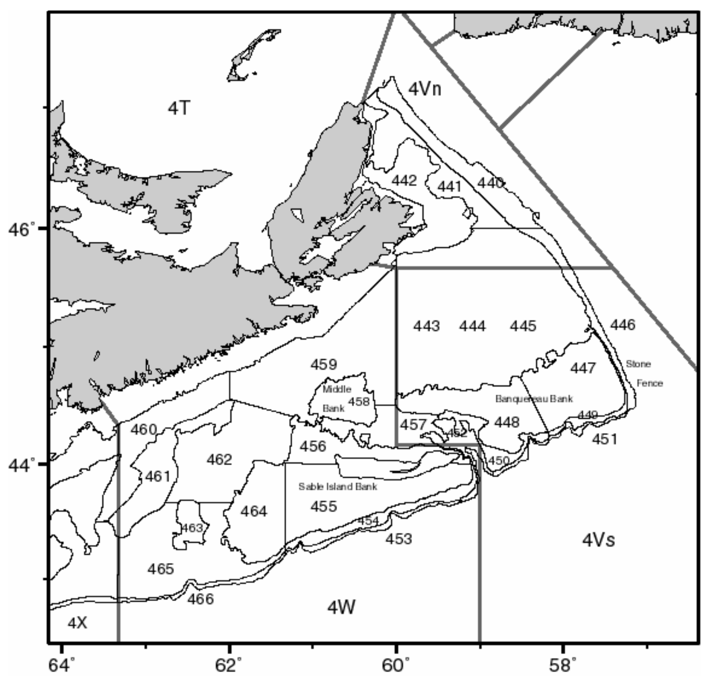

Figure 4. Stratification design of the DFO Maritimes summer bottom trawl survey in Divisions 4VW, and location of banks referred to in the text (from Swain et al. 2006).

Indices are in units of stratified mean numbers and weights per tow multiplied by the number of trawlable units in the survey area. Data were aggregated into three size classes: 36 to 59 cm Total Length (TL) representing small juveniles, 60 to 74 cm TL as an intermediate group of large juveniles vulnerable to the skate fishery, and ≥ 75 cm TL representing mature fish. Analyses were restricted to fish ≥ 36 cm, as small Winter Skate are difficult to distinguish from a co-occurring species, the Little Skate (*Leucoraja erinacea)*.

The biomass index for all sizes of Winter Skate in Divisions 4VW has declined since 1970, with a 99% decline from 1970 to 2015 and a 95% decline since 1992 (Fig. 5; Table 1).

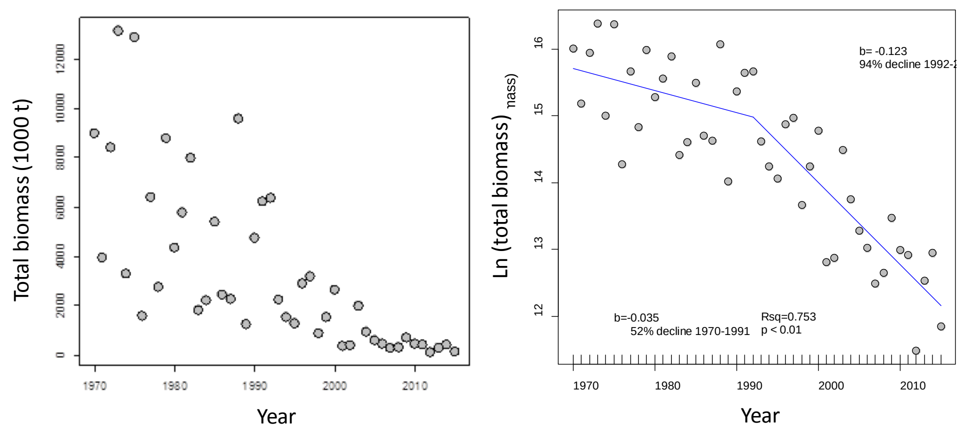

Figure 5. Estimated annual total biomass (1,000 tonnes) of Winter Skate >= 36 cm Total Length from DFO-Maritimes summer groundfish survey in NAFO Divisions 4VW, 1970 to 2015 (left panel) and rate of change of the natural log of the total biomass (right panel).

Table 1. Estimated percent change (negative is a decline, positive is an increase) in the trawlable biomass abundance indices for Winter Skate from research surveys conducted in Divisions 3LNOP and 4VW and for the estimated biomass for the DU based on a Schaefer production model.

Management unit	Survey	Size group	Time period	Instantaneous rate of change over period	Total change over period (years)
3LNOP	Spring survey Campelen	Biomass all sizes	1996 to 2015	-0.116	-89% (19)
4VW	July survey Western IIA	Biomass all sizes	segmented point 1992 to 2015	-0.123	-94% (23)
		Biomass all sizes	1996 to 2015	-0.130	-92% (19)
		Abundance 36 to 59 cm	1996 to 2015	-0.086	-80% (19)
			segmented point 1980 to 2015	-0.079	-94% (35)
		Abundance 60 to 74 cm	1996 to 2015	-0.163	-95% (19)
			segmented point 1980 to 2015	-0.092	-96% (35)
		Abundance >= 75 cm	1996 to 2015	-0.130	-92% (19)
			segmented point 1991 to 2015	-0.127	-95% (24)
ESSN DU	Index from Schaefer production model	Biomass all sizes	1970 to 2015	-0.783	-99% (45)
			1996 to 2015	-0.142	-93% (19)

The abundance index for small juvenile Winter Skate (36 to 59 cm TL) increased from 1970 to 1979, was relatively stable in the 1980s, and then declined to low values after 1980. This index declined by 95% from 1980 to 2015 (Fig. 6). For large juveniles, 60 to 74 cm TL, the abundance index initially increased from 1970 to 1980, but declined by 96% from 1980 to 2015. For adult skate, >= 75 cm TL, there was a 63% decline from 1970 to 1990, followed by a 96% decline from 1990 to 2015. During 1996 to 2015, decline rates for small juveniles, large juveniles, and adults were 81%, 96%, and 92%, respectively.

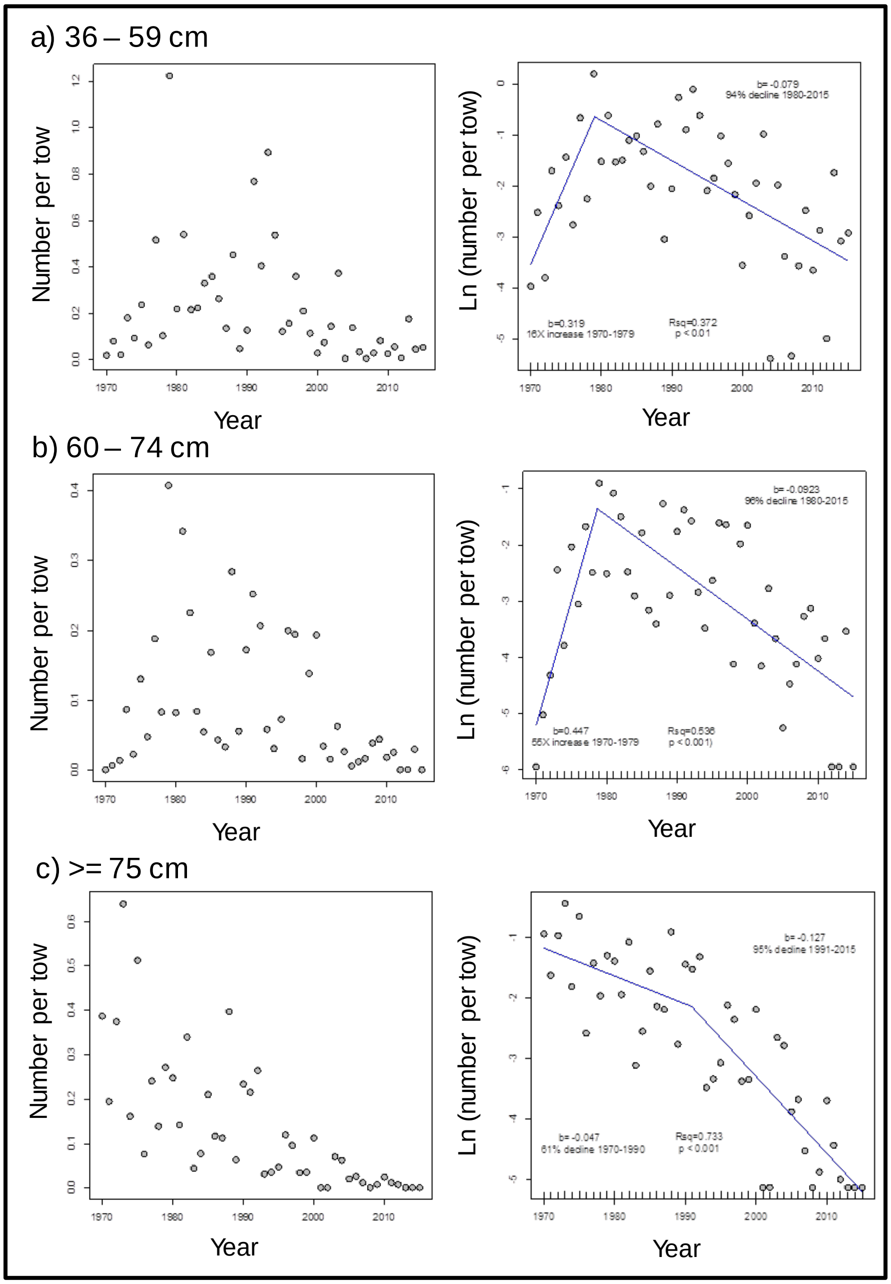

Figure 6. Estimated abundance (mean number per tow) of Winter Skate by size group in Divisions 4VW, 1970 to 2015. Size groups are small juveniles (a: 36 to 59 cm TL; upper row), large juveniles (b: 60 to 74 cm TL; middle row), and adults (c: >= 75 cm TL; bottom row). Panels in the left column show the time series of abundance and the panels in right column show the segmented regression of natural log of the abundance index versus time, and the resulting estimates of rates of change.

Population model estimates

Two types of population models were examined:

- a surplus production model for the entire ESSN DU, and
- a stage-structured model for the 4VW component of the DU, considering three size groups of Winter Skate from the Div. 4VW survey.

Surplus production model for the ESSN DU

Given the limited length composition data available for the Divs. 3LNOP area, the abundance and trends of the ESSN DU were modeled using a surplus production model. Data inputs were trawlable biomass in the July survey of NAFO Divs. 4VW (restricted to fish with TL ≥ 36 cm) and the spring survey of Div. 3LNOP (all sizes, predominantly of TL ≥ 36 cm based on limited length measurements). A consistent time series accounting approximately for the differences in trawl survey gear was constructed.

The estimated biomass index for all size groups for the ESSN DU showed a 98% decline from peak values of 48.6 kt in 1970 to 1.2 kt in 2015 (Fig. 7).

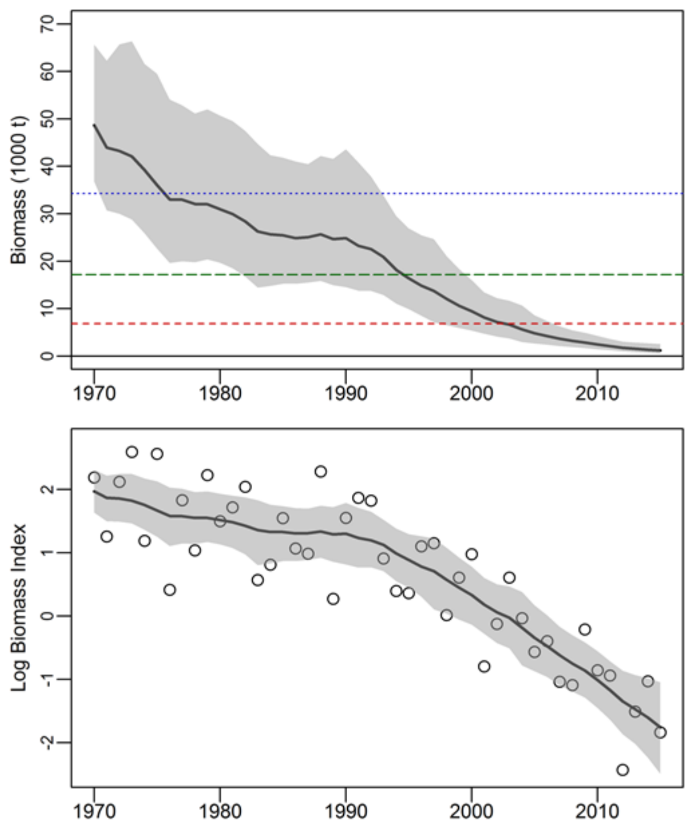

Figure 7. Estimated biomass of Winter Skate (1,000 t; upper panel) based on the Schaefer surplus production model and the trend in the natural log of the biomass index (lower panel) for the ESSN DU, 1970 to 2015. Lines indicate the posterior median and shading the 95% credible limits. Median estimates for carrying capacity (K), the biomass at maximum sustainable yield (B_{MSY}) and the Limit Reference Point (LRP or Blim, 40% of B_{MSY}) are indicated in the upper panel by the blue upper dotted line, the green long dashed middle line, and the red short dashed lower line, respectively. In the lower panel, circles show the observed indices and the line and shading show the median and 95% credible limits for the predicted values from the model.

Stage-based model for the Divisions 4VW component of the DU

Based on the stage-structured model for Divisions 4VW, both juvenile stages were estimated to have increased in abundance from 1970 to 1980, and then declined to low levels in the 2000s (Fig. 8). Estimated adult abundance declined sharply in 1970 to 1978, and then remained roughly stable until 1990. It then began to decline further, reaching an extremely low level by 2015. Adult abundance declined by 99% over the 1970 to 2015 period (Fig. 8).

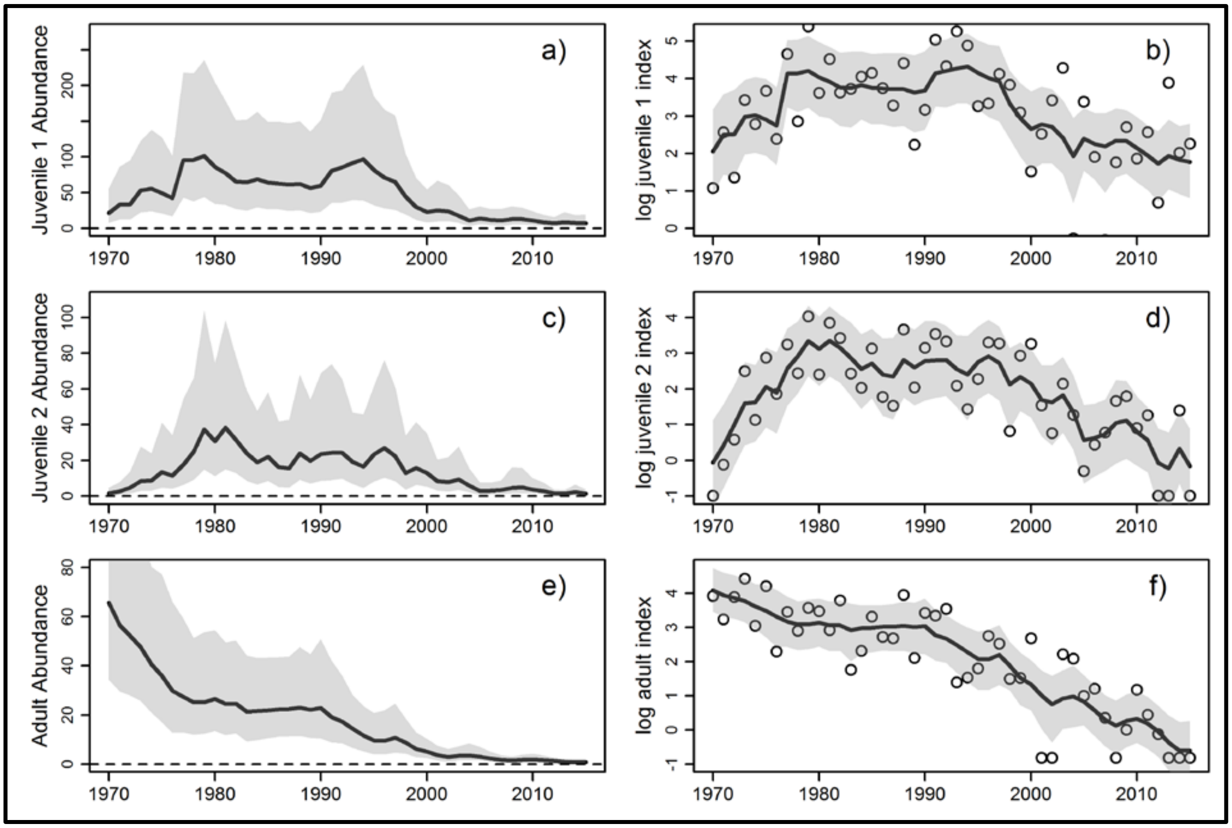

Figure 8. Estimated abundance (left column, panels a, c, and e) and observed (circles) and predicted (line and shading) log survey indices (right column, panels b, d, and f) for the small juvenile (36 to 59 cm TL; upper row), large juvenile (60 to 74 cm TL; middle row), and adult (≥ 75 cm TL; bottom row) stages based on the stage-based model with natural mortality (M) varying in time blocks of 7 years, and a final 11 year block. Lines show the posterior medians and shading the 95% credible limits.

Species distribution

Winter Skate is most commonly found at depths less than 111 m, but has been reported as deep as 371 m (Scott and Scott 1988) and as shallow as 1 m (Bigelow and Schroeder 1953). Winter Skate in Divs. 3LNOP are primarily observed in research surveys along the southern edge of the shelf, with highest catches in Subdiv. 3Ps (Fig. 9).

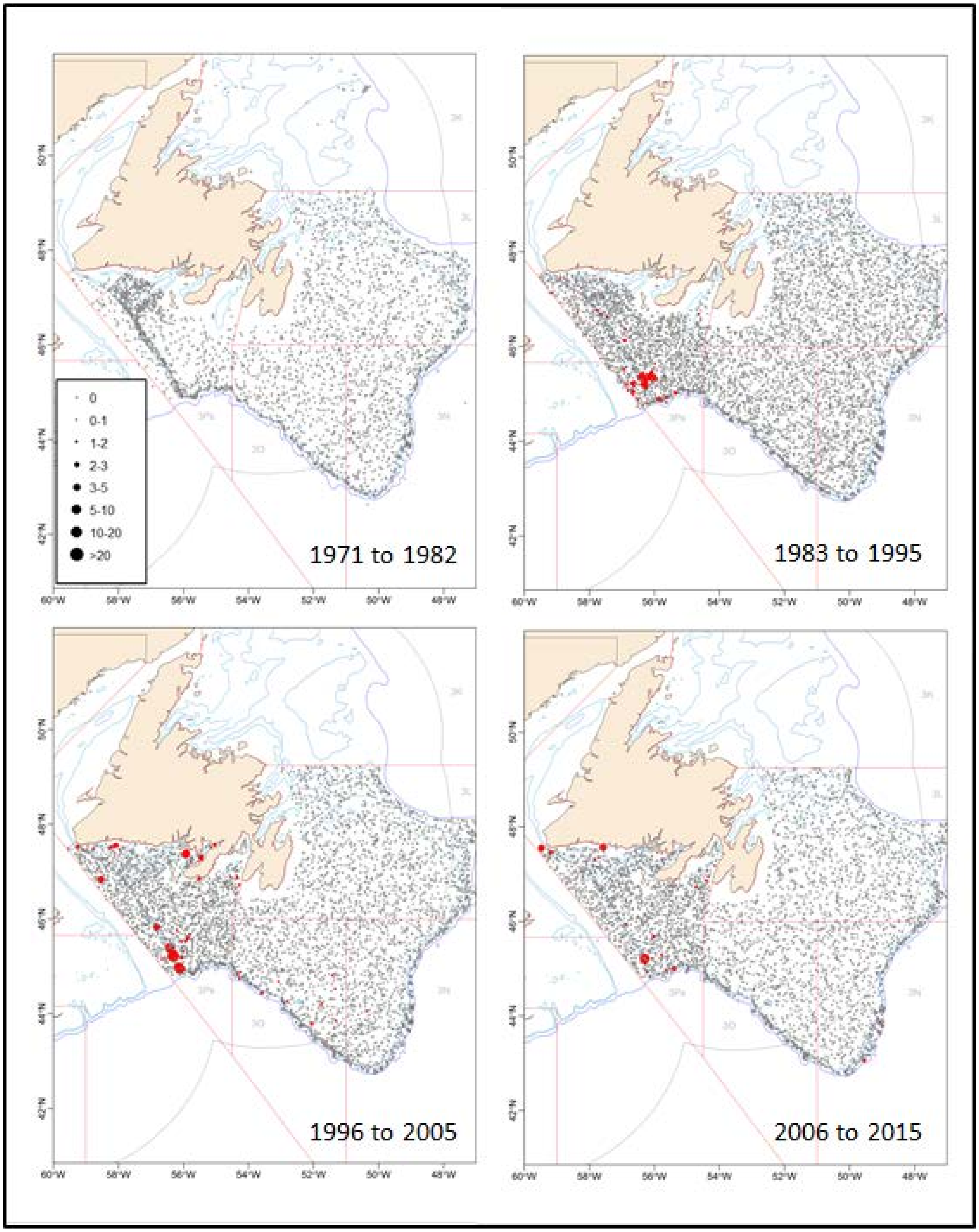

Figure 9. Distribution of Winter Skate survey catches (all sizes; numbers per tow) from DFO-NL Divisions 3LNOP spring research surveys, 1971 to 2015. The upper left panel is for the period of surveys using the Yankee trawl (1971 to 1982). The upper right panel is for the period of surveys using the Engel trawl (1983 to 1995). The panels in the bottom row are for the period of surveys using the Campelen trawl (1996 to 2015). The Subdivision 3Ps survey was incomplete in 2006, and Subdivision 3Pn was not surveyed in 2008 and 2014.

Winter Skate on the Eastern Scotian Shelf (Divisions 4VW) were historically broadly distributed on the offshore banks, with concentrations on Middle Bank, Sable Island Bank and Banquereau Bank (Figs. 10a, 10b, 10c). Small juveniles were mostly found in the vicinity of Sable Island Bank, with smaller concentrations on Banquereau and Middle banks (Figs. 10a). Distribution of small juveniles within the surveyed area shifted away from Sable Island towards deeper water after 1990. Distribution changes were similar for large juveniles and adults, except that the shift to deeper water was stronger for larger individuals (Fig. 10b, 10c).

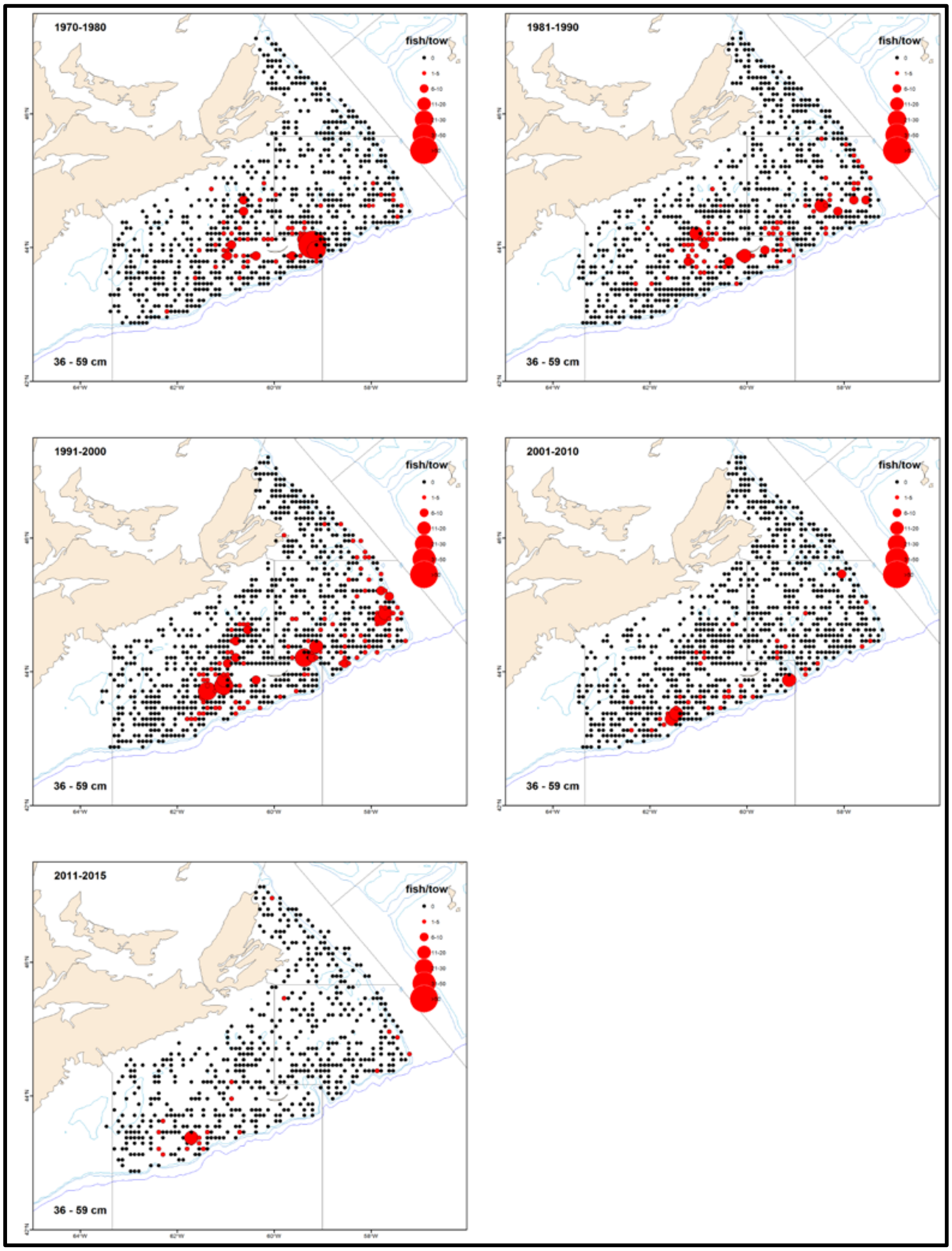

Figure 10a. Decadal geographic distribution for the small juvenile (36 to 59 cm TL) size group of Winter Skate in NAFO Divisions 4VW, based on DFO-Maritimes research survey catches (aggregated by 5 minute squares), 1970 to 2015.

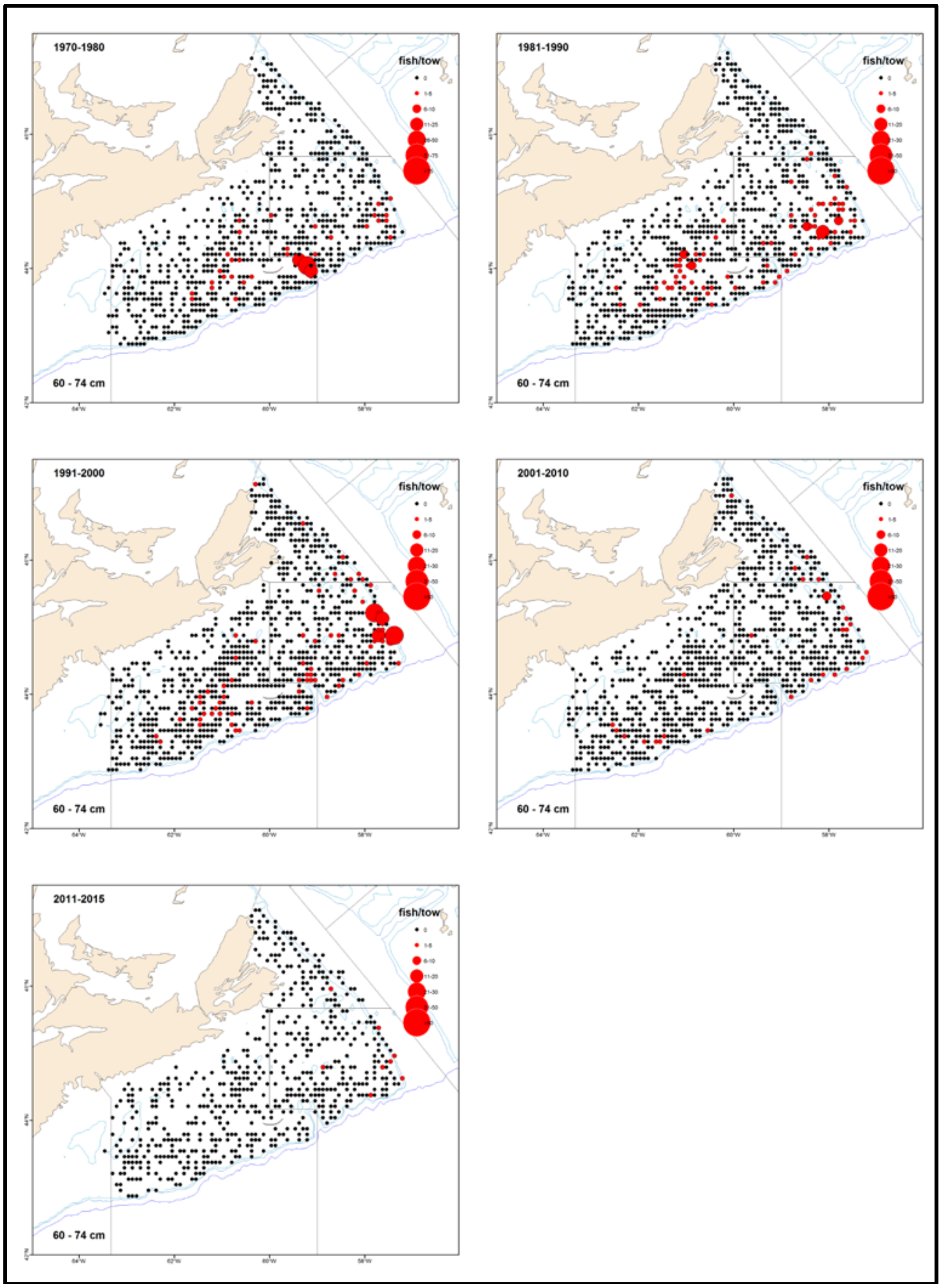

Figure 10b. Decadal geographic distribution for the large juvenile (60 to 74 cm TL) size group of Winter Skate in NAFO Divisions 4VW, based on DFO-Maritimes research survey catches (aggregated by 5 minute squares), 1970 to 2015.

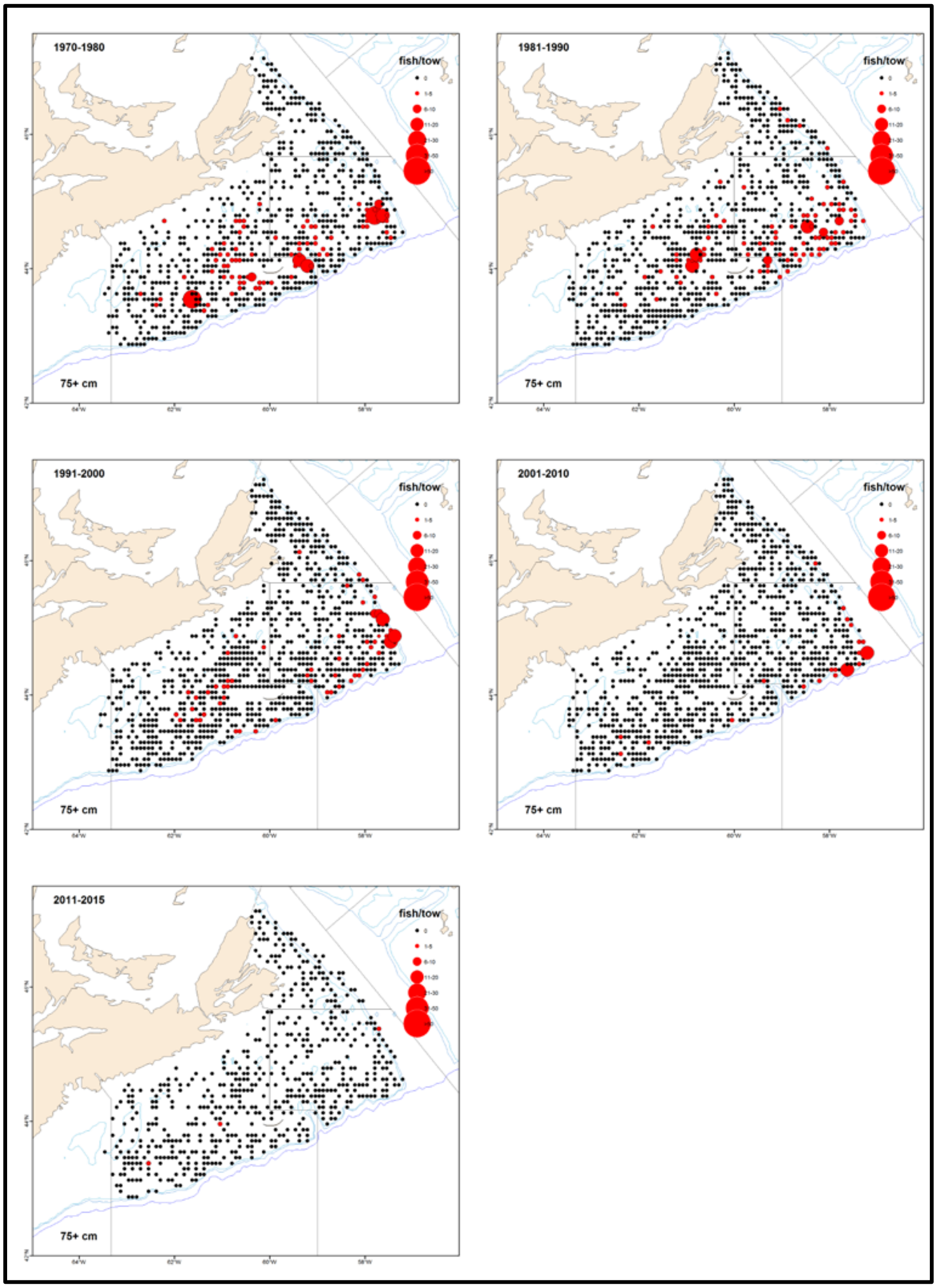

Figure 10c. Decadal geographic distribution for the adult (≥ 75 cm TL) size group of Winter Skate in NAFO Divisions 4VW, based on DFO-Maritimes research survey catches (aggregated by 5 minute squares), 1970 to 2015.

The DFO-NL Divisions 3LNOP spring research survey caught Winter Skate in the Laurentian Channel between Subdivision 3Ps and Division 4V; although at lower abundance. The DFO-Maritimes Divisions 4VW summer survey does not sample deeper waters in the Laurentian Channel. However, a DFO-Maritimes spring survey in 1986 to 2010 included deeper waters close to Subdivision 3Ps, and caught Winter Skate in this area (Fig. 11). Collectively, these data indicate that the distribution of Winter Skate is continuous across the Laurentian Channel.

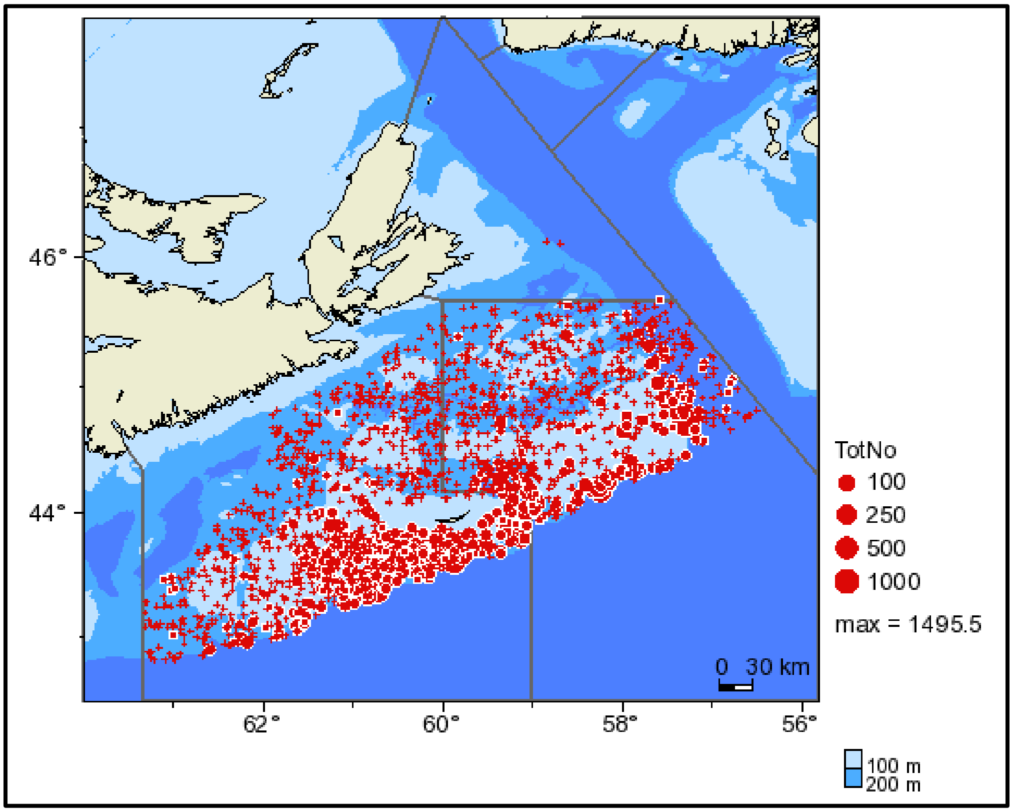

Figure 11. Geographic distribution of all size groups of Winter Skate in NAFO Divisions 4VW based on DFO-Maritimes spring research survey catches, 1986 to 2010.

Geographic range

For Divisions 3LNOP, the index of occupancy was calculated based on the Campelen spring survey catches of 1996 to 2015. The Design-Weighted Area Occupied (DWAO) index declined over that period (Fig. 12). Winter Skate during the period 2006 to 2015 were captured in the same areas as in the beginning of the time series almost exclusively at the southern shelf edge in Subdivisions 3Ps and 3Pn, and at the edge of Division 4R (Fig. 9).

The range of Winter Skate in Divisions 4VW contracted beginning in the mid 1990s (Figs. 10a, 10b, 10c). Adult Winter Skate were fairly broadly distributed in shelf waters of the Eastern Scotian Shelf at depths less than approx. 110 m in the 1970s and 1980s, but moved away from the Sable Island area and towards the edges of the Eastern Scotian Shelf beginning in the 1990s (Fig. 10c). For all sizes of Winter Skate caught in the research survey, the habitat occupied (DWAO) averaged 15,000 km^2 in the 1980s and has declined to about 4,000 km^2, a 74% decline since the mid-1990s (Fig. 12).

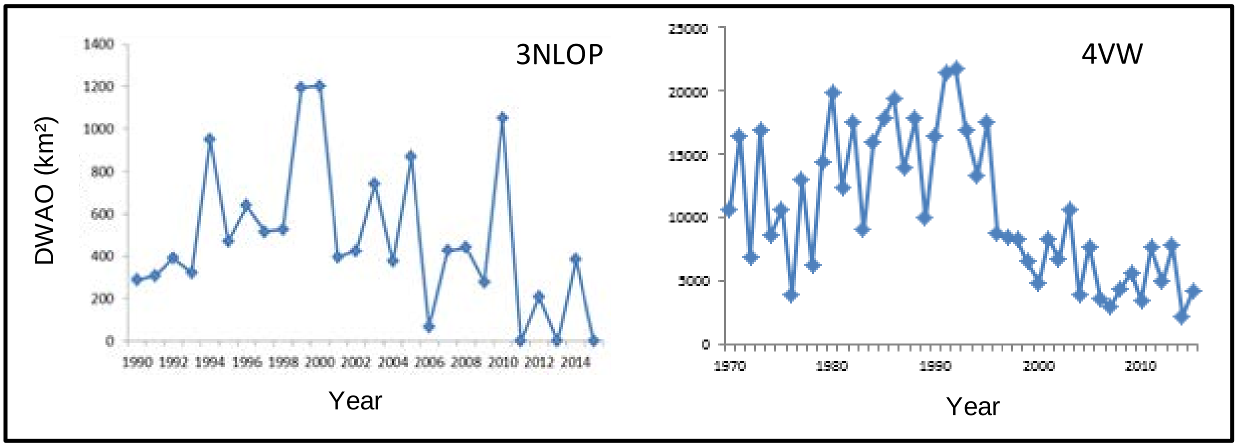

Figure 12. Indices of geographic range for Winter Skate (all sizes) from Divisions 3LNOP (left panel) and Divisions 4VW (right panel). Design Weighted Area Occupied (DWAO) is the area (km²) where catches exceeded 0, with the area associated with each tow based on the survey design. The diamond symbols are annual estimates.

In NAFO Divisions 4VW, the DWAO index for small juveniles, large juveniles, and adults decreased by 84%, 92% and 93% (respectively) from the mid1980s (Fig. 13).

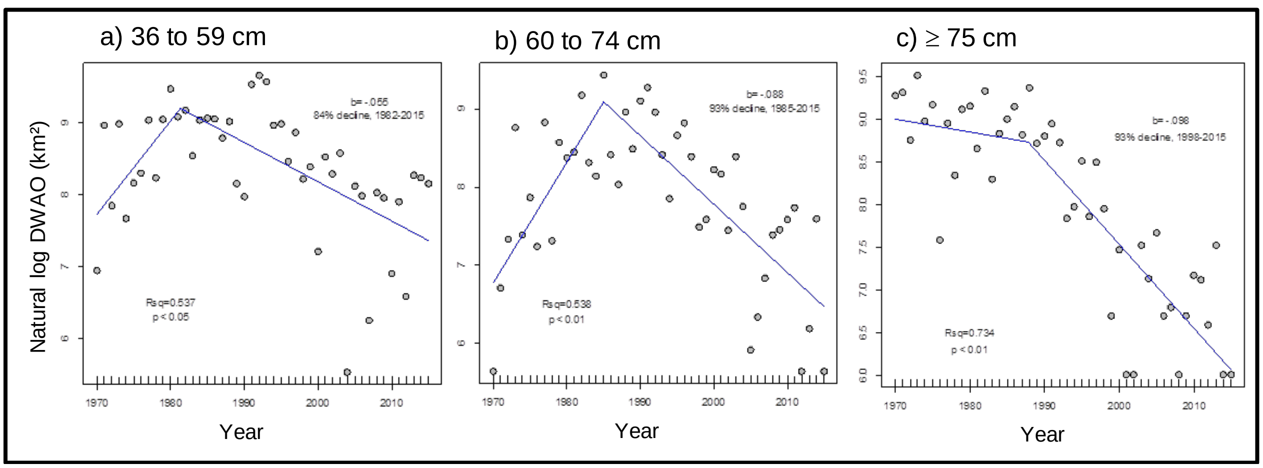

Figure 13. Indices of geographic range (natural log of DWAO in km²) for Winter Skate by size group (a: small juveniles 36 to 59 cm TL, left panel; b: large juveniles 60 to 74 cm, middle panel; and c: adults ≥ 75 cm, right panel) from NAFO Divisions 4VW. Design-Weighted Area Occupied (DWAO) is the area (km²) where catches exceeded 0, with the area associated with each tow based on the survey design. Open circles represent annual estimates, and solid lines indicate a segmented regression fit to the data.

Current or recent life-history parameters

Age, length, and maturity

Ageing information using thin sections of vertebrae was collected from 157 Winter Skate sampled from Divisions 4VW. The asymptotic length was estimated to be 88.4 cm, smaller than the largest fish aged (92.5 cm) and the largest fish observed in the survey in the 1970s (121 cm), when a high proportion of fish were greater than 89 cm in length (Figs. 14 and 15). Nonetheless, the model provided a reasonable fit to the data from recent years (Fig. 14).

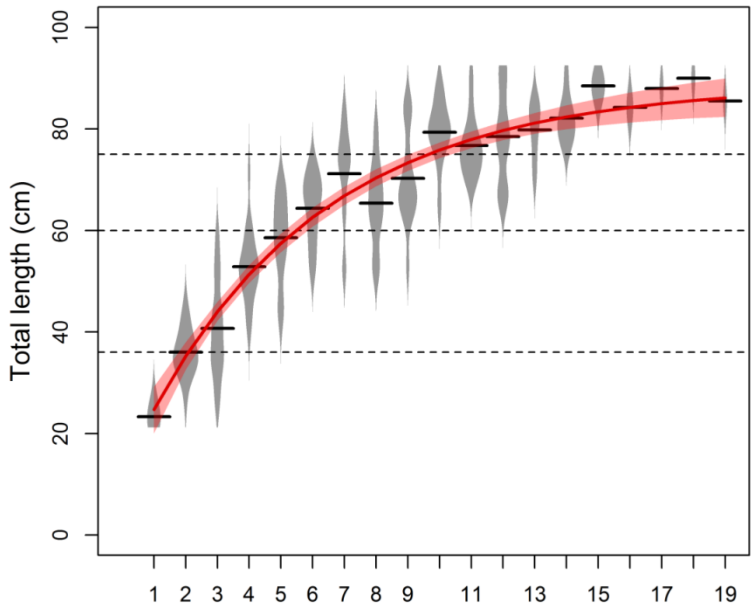

Figure 14. Total length (cm) at age (years from hatching) of Winter Skate from Divisions 4VW as reported in McPhie and Campana (2009a). Grey shading shows the distribution of lengths within age, with the means indicated by horizontal lines. The red line and shading shows the predicted lengths at age, and their 95% confidence intervals based on a von Bertalanffy model with L_∞ = 88.41 ± 5.91 cm (± 2SD), k = 0.1815 ± 0.0470 and t_0 = -0.7926 ± 0.704. Dashed lines show the lengths that delineate the small juvenile (36 to 59 cm TL), large juvenile (60 to 74 cm), and adult (≥ 75 cm) size groups.

Over the period 1970 to 2015, there has been an important contraction in size distribution of Winter Skate (Fig. 15). In the 1970s and early 1980s, there were abundant Winter Skate > 89 cm TL in research survey catches, accounting for 20% to 95% of all skates caught and measured. Since 1995, these larger fish comprised a very small percentage (0% to 22%) of the total Winter Skate catches (Fig. 15).

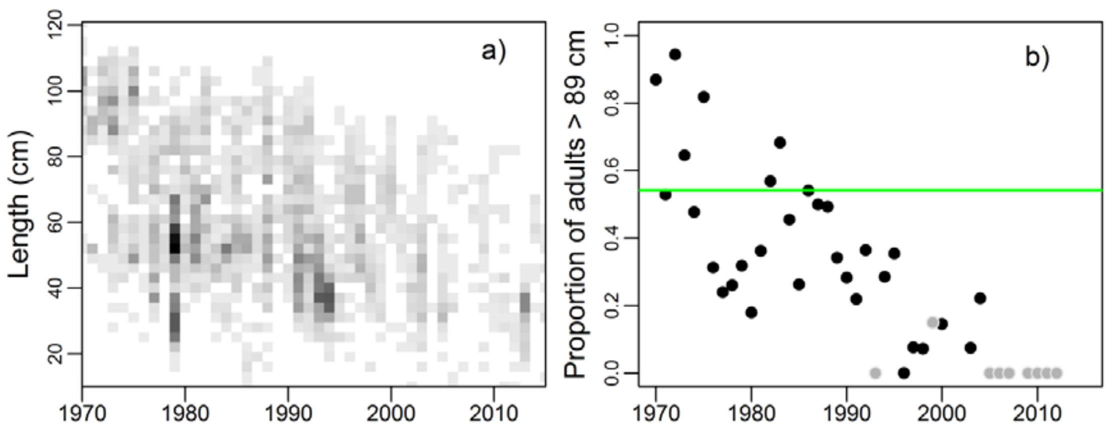

Figure 15. Size composition of Winter Skate in NAFO Divisions 4VW, 1970 to 2014 showing the length distribution in 3-cm intervals (left panel, a) with darker shading indicating higher relative abundance and proportion of adults ≥ 90 cm TL (right panel, b) with grey circles indicating years when the number of length bins with observations was less than 5 fish. The green horizontal line in the right panel represents the average proportion during the 1970s.

Age of 50% maturity for Winter Skate in the ESSN DU was estimated to be 11 years for males and 13 years for females, corresponding to a length of about 75 cm TL. Generation time for this population of Winter Skate is estimated to be 17 years (age at 50% maturity + 1 / *M;* assuming an *M* of 0.2 and the age at 50% maturity of 12 years).

Weight and condition at age

A Winter Skate measuring 60 cm TL has a predicted mean weight of 1.59 kg whereas an adult skate measuring 75 cm has a predicted mean weight of 3.32 kg (Fig. 16). 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.

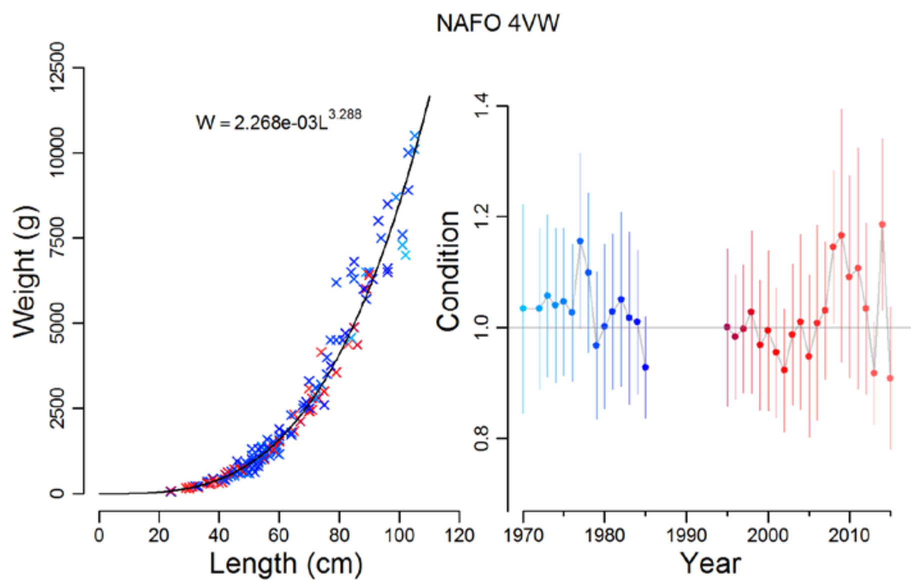

Figure 16. Length (cm) to weight (g) relationship (left panel; symbols are observations) and condition (right panel; expressed as observed weight divided by predicted weight from the length to weight relationship) for Winter Skate from NAFO Divisions 4VW, 1970 to 2014. Colour shading in the right panel represents the sampling year of individual observations in the left panel.

Mortality rates

Estimates of natural mortality (*M*) were obtained from the stage-structured model for Winter Skate from Divisions 4VW (Fig. 17). For small juveniles, *M* appeared to be high during 1970 to 1976 (median estimate of 79.3% annually) and at a lower level since then, with the lowest value in 2005 to 2015 (28.5%). For large juveniles, *M* was also high during 1970 to 1976 (58.7%), declined to a lower level (36.4%) during 1977 to 1983, then increased to 54.8% during 2005 to 2015. Adult *M* was at a low level (10.5% to 18.1%) during 1970 to 1990 and increased to a high level since 1998 (36%). High values of *M* for the juveniles in the 1970s may be partly due to high and unaccounted fishery catches prior to 1977 when fisheries in the area were unregulated. Consequently the level of discarding of juvenile skates may have been underestimated contributing to the high mortality estimate for that period (see Sources of Uncertainty).

The pattern of increasing natural mortality of large individuals appears to be widespread throughout the Eastern Scotian Shelf and the southern Gulf of St. Lawrence (sGSL) ecosystems, for various skate species (Swain et al. 2013), and more generally for groundfish species (Benoît and Swain 2008; Sinclair et al. 2015; Swain and Benoît 2015).

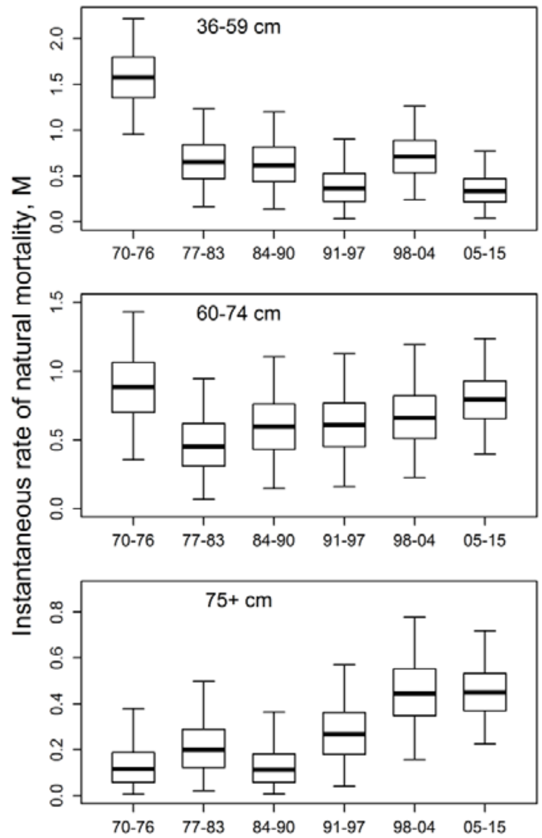

Figure 17. Posterior distributions for the estimated instantaneous rate of natural mortality (M) of Winter Skate in NAFO Divisions 4VW by size group and time block, 1970 to 2015. The thick black horizontal line represents the median, boxes denote the interquartile range (25^{th}-75^{th} percentiles of the distribution), and vertical lines indicate 95% credible intervals.

Recruitment and recruitment rates

In the stage structured model, recruitment rate was assumed to be a constant value and was estimated to be 6.8 age-2 recruits per female (95% credible limit: 3.8 to 12.2). In a sensitivity analysis, recruitment rate was allowed to vary annually, and was estimated to fluctuate without trend around an average value of 6.7 age-2 recruits per female.

Habitat and Residence Requirements

Habitat properties

On the Eastern Scotian Shelf, Winter Skate are concentrated on Sable Island Bank and northward to Middle Bank, and on Banquereau Bank. The DFO-Maritimes July survey caught a majority (76%) of Winter Skate in depths <100 m, with a few as shallow as 24 m. Although this species was captured at stations as deep as 657 m during the month of March, very few have been captured below 400 m. During an industry 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, it is likely that Winter Skate are found inshore in Divisions 4VW as well (Swain et al. 2006a). Along the coast of Newfoundland in summer, encounters with single young-of-the-year (YOY) skate in <1 m depths are sporadically reported by beach-combers and nature enthusiasts, with photographs of live YOY being verified as Winter Skate.

Little is known of seasonal movements of Winter Skate on the Eastern Scotian Shelf. A comparison of skate abundance and distribution from ESS seasonal surveys suggests that this species does not move inshore in winter, as it tends to occupy deeper waters with a more concentrated distribution along the southern side of Sable Island Bank, and along the Stone Fence (Figs. 4 and 10; Swain et al. 2006). Kulka et al. (2009) noted that Winter Skate annually migrate from warm, deeper waters in winter to shallower waters on the Scotian Shelf in spring and summer.

Winter Skate is a bottom-dwelling species that can bury itself in the substrate (Packer et al. 2003). On the Scotian Shelf, this species appears to prefer sand or gravel bottom, which is widely distributed in this area. Presence of suitable substrate does not seem to be a barrier to spatial distribution of Winter Skate.

Habitat features, functions and attributes of various life stages of Winter Skate on the Eastern Scotian Shelf are summarized in Appendix 1.

Spatial extent of the habitat areas

Adult Winter Skate of the ESSN DU were fairly broadly distributed in shelf waters less than ~110 m depth in the 1970s and 1980s. Based on historic distributions, physical environments suitable to Winter Skate are widespread throughout the shelf area in Divisions 3LNOP and 4VW. Physical characteristics of these habitats (e.g., water temperature, salinity) are still available to Winter Skate, and there has been no apparent change in spatial extent of this suitable habitat.

An opportunistic short-term study (2005 to 2012) to characterize spatial distribution of skate egg cases by species identified a concentration of Winter Skate purses in an area north of Sable Island (Fig. 18; J. Simon, unpublished data, pers. comm.). Features of this nursery ground that make it attractive for egg-laying females, and provide habitat for incubating egg cases over 1.5 to 2 years, remain unknown, as does the timing of Winter Skate egg case deposition.

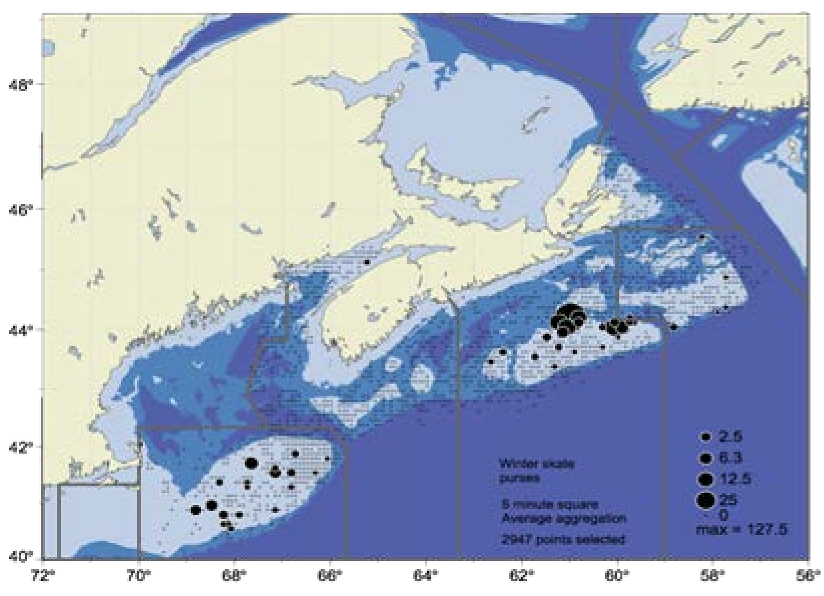

Figure 18. Locations of Winter Skate egg cases from samples collected opportunistically in NAFO Divisions 4VWX5Z, 2005 to 2012. Circles represent locations where egg cases were caught and the size of each circle indicates the number collected. Concentrations of Winter Skate egg cases are located north of Sable Island (Division 4W) and on Georges Bank (Division 5Z).

Presence and extent of spatial configuration constraints

Connectivity across the Laurentian Channel is indicated by survey data from spring research surveys conducted by DFO-Maritimes in Divisions 4VW (1986 to 2010) and by DFO-NL in Divisions 3LNOP (1996 to 2014) (Fig. 11).

Winter Skate distribution moved away from the Sable Island area and towards the edges of the ESS beginning in the 1990s. Similar shifts in distribution were also noted for a number of marine fish species (Harvey and Hammill 2011), and biological interactions (e.g., predation), rather than physical environmental factors (e.g., water temperature), are possibly involved (Swain et al. 2015). The population of Grey Seal at Sable Island, a known predator of skates, increased from 1,300 animals in 1960 to over 394,000 animals in 2014 (Hammill et al. 2014). The proposed mechanism for spatial contraction of Winter Skate distribution in the GSL DU (DFO 2016; Swain et al. 2016) is a shift out of areas with elevated levels of risk of predation by Grey Seal, a phenomenon which may be occurring on the ESS as well.

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 does not have life history characteristics or behaviors that would be characterized as having features of a residence. In accordance with the DFO January 2015 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 this species.

Threats and Limiting Factors to Survival and Recovery

Threats

The only quantified anthropogenic threat to recovery of this species over its entire ESSN DU is ongoing fishing related mortality resulting from bycatch (retained/landed and/or discarded) in commercial fisheries. However, fishing mortality presently appears to be a limited threat to Winter Skate survival and recovery.

Fishing

Winter Skate are incidentally captured in many fixed and mobile gear fisheries, including those for groundfish, Thorny Skate (primarily in NAFO Subdiv. 3Ps), shrimp, scallop, and surf clam in the ESSN DU. Winter Skate bycatch can only be retained in groundfish fisheries, but it is usually discarded at sea.

Losses of Winter Skate from commercial fisheries, including landed amounts as well as estimates of post-discard mortality, were estimated from:

- Canadian at-sea fisheries observer (ASO) reports of catches (landed plus discards) by species collected in a standardized format on a set-by-set basis on board commercial fishing vessels at sea, and
- DFO Zonal Interchange File Format (ZIFF) landings recorded by Canadian fishers in logbooks and on fish plant purchase slips.

Since ASOs constitute the only source of data on catch and discards by species, discard estimates remain very uncertain for most fisheries for a number of reasons:

- Very low to non-existent at-sea fisheries observer coverage (0 to 7%) in most Canadian Atlantic fisheries,
- A proportion of observer reports, in some areas, documenting bycatch as “skates-unspecified”, and
- Difficulties in correctly identifying Winter Skate from other skate species using external characteristics especially for skates < 36 cm in length for which there are no distinguishing external characteristics or in areas containing Little Skate or Thorny Skate.

Although survival rates of discarded skates have the potential to be high for longlines, the survival value of 0.75 used in this assessment was borrowed from empirical estimates of short-term survival of skates from studies in the southern Gulf of St. Lawrence (Benoît et al. 2012; Benoît 2013; Swain and Benoît 2016).

NAFO Divisions 3LNOP

There is no directed fishery for Winter Skate in NAFO Divisions 3LNOP. However, this species occurs as bycatch (retained plus discarded) in fisheries directing for Thorny Skate, primarily in Subdiv. 3Ps, using longlines, gillnets, and otter trawls. Winter Skate bycatch also occurs in fisheries targeting Atlantic Cod, Monkfish, Greenland Halibut (Turbot), shrimp species, Redfish, American Plaice, and Yellowtail Flounder, using gillnets, longlines, and otter trawls. Winter Skate bycatch estimates presented here were dependent on the percentage of ASO coverage of each fishery in each year, as well as whether the ZIFF database contained reported landings of this species for each year of ASO coverage. Given these limitations, small amounts of Winter Skate bycatch were estimated most frequently for shrimp fisheries (0.01 to 2.5 t annually), while highly variable annual estimates ranging from 0.01 to 49 t for groundfish-directed fisheries and 1 to 62 t for the Thorny Skate fisheries were derived from the observer database (Fig. 19, Table 2). The large variation in estimated bycatch is partly attributable to variations in annual fishery specific observer coverage.

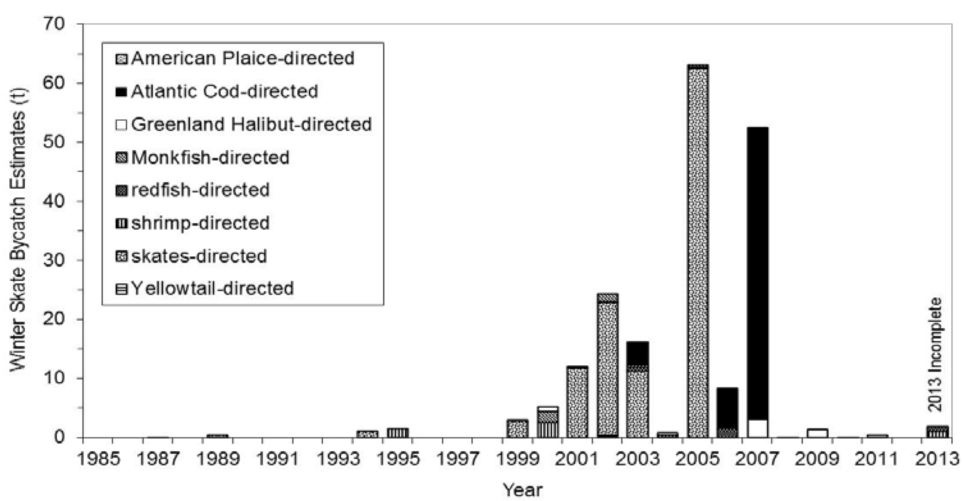

Figure 19. Estimated total annual bycatch (tonnes; landed and discarded) of Winter Skate by directed species (all gears combined) in Divisions 3LNOP, 1985 to 2013. Data are from Canadian at-sea fisheries observers and ZIFF in the same years.

NAFO Divisions 4VW

Catches and landings of Winter Skate by foreign fleets in NAFO Divisions 4VW were very high during 1970 to 2002, especially for unregulated fisheries prior to 1977 (Fig. 20). The Silver Hake fishery conducted by foreign vessels removed substantial quantities of Winter Skate. However, as the Canadian mobile gear fleet began to harvest Silver Hake, foreign participation was reduced and then was eliminated in 2002. There are currently no foreign vessels fishing in NAFO Divisions 4VW.

In 1994, a skate-directed fishery began in NAFO Divisions 4VW. This fishery primarily caught Winter Skate, with landings as high as 2,000 t (500 t average annually), but was discontinued in 2005 (Fig. 20).

Table 2. Estimated bycatch (tonnes; landed and discarded) of Winter Skate in various Div. 3LNOP fisheries by gear for the periods 1985 to 2008 and for the most recent five years of data (2009 to 2013). Data are from Canadian at-sea fisheries observers and ZIFF in the same years. The large variation in estimated bycatch is partly attributable to variations in annual fishery specific observer coverage.

Fishing gear	Directed species	1985 to 2008		2009 to 2013	
		Average	Range	Average	Range
Gillnets	Skate	0.9	0 – 22.4	0	0
	Atlantic Cod	2.3	0 – 49.3	0	0
	Monkfish	0.2	0 – 1.9	0	0
	Turbot	< 0.1	0 – 0.8	0	0
Longlines	Skate	2.5	0 – 57.4	0	0
	Atlantic Cod	0.2	0 – 2.2	0	0
Otter trawl	Skate	1.2	0 – 11.9	0	0
	Atlantic Cod	0.1	0 – 2.6	0	0
	Turbot	0.1	0 – 3.0	0.2	0 –1.0
	Plaice	< 0.1	0 – 0.4	0	0
	Yellowtail	< 0.1	0 – 0.5	0	0
	Redfish	0.1	0 – 1.5	0.2	0 – 0.8
	Shrimp	0.2	0 – 2.6	0.4	0 – 1.1

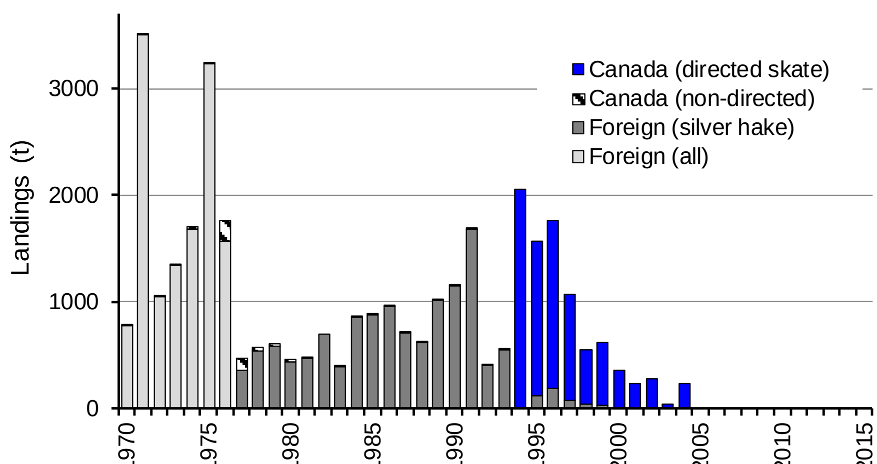

Figure 20. Winter Skate landings (tonnes) from NAFO Divisions 4VW for 1970 to 2015.

During 2005 to 2015, annual bycatch (mostly discards) estimates from groundfish fisheries in NAFO Divs. 4VW ranged from 29 to 93 t (Fig. 21; Table 3).

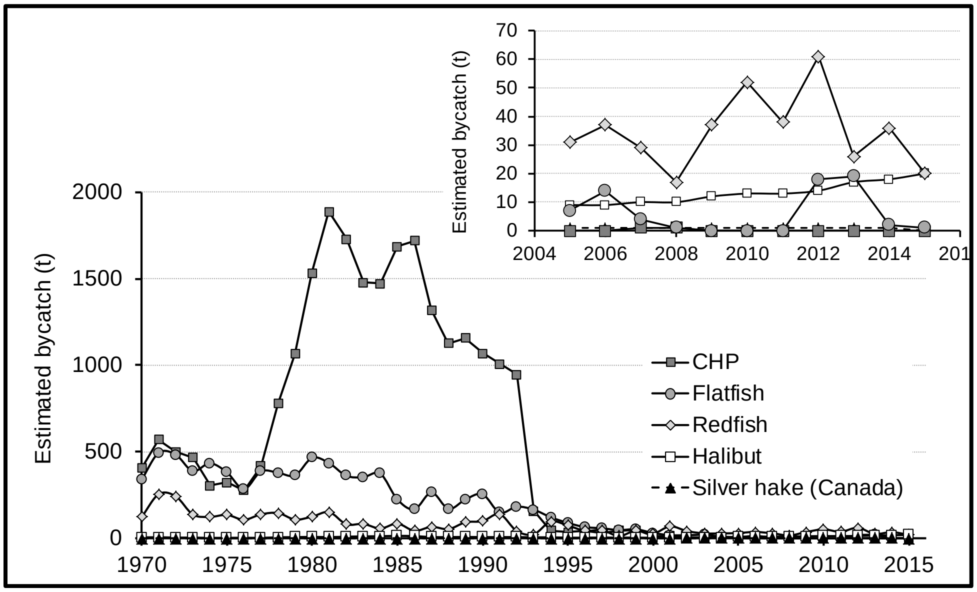

Figure 21. Estimated bycatch (tonnes; all discarded) of Winter Skate from groundfish fisheries in NAFO Divisions 4VW, 1970 to 2015. CHP represents the Cod/Haddock/Pollock combined fishery. Inset panel shows bycatch for 2005 to 2015 on a finer scale (0 to 70 t).

Table 3. Estimated landings (t) and estimated discards (t) of Winter Skate by directed species from commercial fisheries in NAFO Divs. 4VW, 2005 to 2015. CHP represents the Cod/Haddock/Pollock combined fishery.

Directed species	Landings (t)	Discards (t) mean (range)
Silver Hake	0	0.9 (0 - 1)
CHP	0	0.2 (0 - 1)
Halibut	0	13.2 (0 - 20)
Flatfish	0	6 (0 - 19)
Redfish	0	34.9 (0 - 61)
Scallop	0	2.6 (1.1 - 7.2)
Surf Clam	0	3.3 (0.2 - 4.9)

Based on estimates of landings, discards, and post-discard survival rates, maximum estimated exploitation rates over the period 1970 to 2015 were 4% for small juveniles, 11% for large juveniles, and 17% for adults (Fig. 22). These exploitation rates contributed to declines prior to the mid-2000s. During 2010 to 2015, exploitation rates for small juveniles were 0.3% to 2% and 0.4% to 0.8% for large juveniles. Exploitation rates for adults peaked in the mid-1990s, then decreased to <1% since 2005 (Fig. 22). Relatively high rates for large juveniles and adults during 1994 to 2004 reflect the skate-directed fishery in that period.

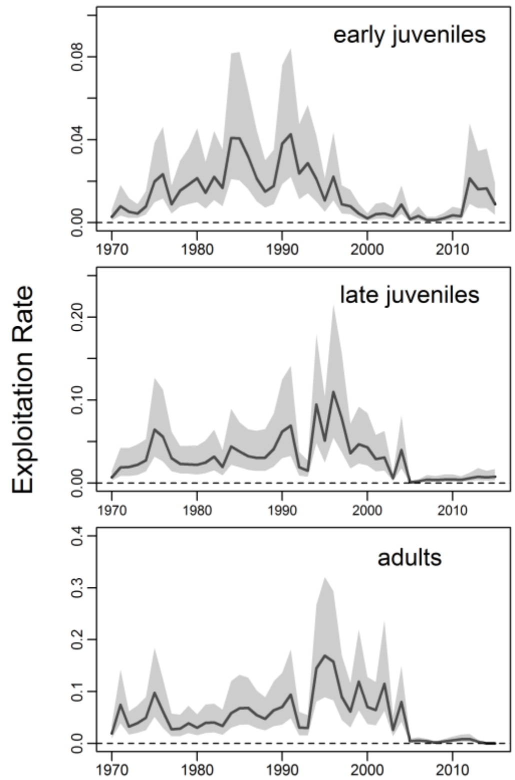

Figure 22. Estimated exploitation rates for three length groups of Winter Skate in NAFO Divisions 4VW (small juveniles 36 to 59 cm TL in upper panel; large juveniles 60 to 74 cm in middle panel, and adults ≥ 75 cm in lower panel) based on the stage-based model with varying natural mortality. Solid black lines represent posterior medians, and grey shading the 95% credible intervals.

Activities most likely to damage or destroy the habitat properties

No data currently exist regarding impacts of other anthropogenic activities (e.g., seismic surveys, oil and gas drilling, marine pollution) on Winter Skate habitat.

Natural factors that may limit survival and recovery

Model results indicated a decline in the intrinsic productivity of Winter Skate in this DU. The intrinsic rate of population increase was estimated to be negative since the late 1990s, suggesting that this population is no longer viable. The ESSN population declined by about 98% during 1970 to 2015. The winter skate biomass in Divs. 3LNOP averaged 5% of the total biomass in the DU (after adjusting for differences in catchability of sampling gear.) Thus the biomass trend in the DU is dominated by the trend in Divs. 4VW. Biomass in the early 1970s was above the estimated carrying capacity. Thus, the model attributes some of this decline to density-dependent effects on productivity due to high biomass in the early 1970s.

The surplus production model fit to data for the ESSN DU indicated a decline in the productivity of Winter Skate during 1970 to 2015, with a production deficit since 1998. The stage-structured models indicated that the cause of this decline in productivity in 4VW (representing 95% of the biomass in the DU) was an increase in adult natural mortality. In contrast to adults, natural mortality of small juveniles decreased over this time period. Large juveniles showed an intermediate pattern with an initial decrease in natural mortality followed by a gradual increase. This pattern of increasing natural mortality of large fish and decreasing mortality of small individuals appears to be widespread throughout the ESS (Div. 4VW) and sGSL (Div. 4T) ecosystems, among various skate species (Swain et al. 2013), and more generally for other groundfish species (Benoît and Swain 2008; Sinclair et al. 2015; Swain and Benoît 2015).

Changes in the population dynamics of Div. 4VW Winter Skate appear to reflect increased productivity at early life stages (i.e., either increased recruitment rates or decreased natural mortality), and decreased productivity (i.e., increased natural mortality) of adults.

Adult abundance declined during the 1970s, even though natural mortality was estimated to be low (i.e., normal) in that period. This appears to reflect reduced recruitment of juveniles, whose abundance was at very low levels in the 1970s. This low juvenile abundance is attributed to an estimated high natural mortality during 1970 to 1976. It is also possible that the level of discarding of juvenile skates at sea was underestimated for this time period; thereby contributing to the high level of estimated mortality.

Results from both the surplus production model of the entire DU and the stage-structured model of Div. 4VW indicated that the Winter Skate population does not appear to be viable, due to increased natural mortality of adults to unsustainably high levels. If current productivity conditions persist, this population is expected to decline to extirpation; even with no fishery catches.

Predation appears to be the most likely cause of the elevated natural mortality of adult Winter Skate in this DU. For example, the losses attributed to elevated natural mortality do not appear to be caused by unaccounted fishing mortality or emigration to other areas (Swain et al. 2013). Predators of adult Winter Skate include Grey Seal and large sharks. Most large sharks (e.g., Porbeagle) are estimated to have declined on the ESS (DFO 2015) and thus predation by sharks is unlikely to represent an important component of increased *M* of adult Winter Skate. In contrast, Grey Seal abundance on the ESS is estimated to have increased from 1,300 animals in 1960 to 394,000 in 2014 (Hammill et al. 2014). Prior to 1990, when skates were more abundant in the GSL DU, they were found in about 30% of Grey Seal stomachs examined in the sGSL and were considered to be a regular diet item of Grey Seal. In the sGSL, where Grey Seal abundance is substantially lower, all of the elevated adult *M* of Winter Skate could be accounted for by predation by Grey Seal if Winter Skate contributed only 0.2% of the average diet (Benoît et al. 2011). Based on fatty acid analyses, Winter Skate were estimated to represent a small proportion of the diet of Grey Seal sampled on Sable Island (D. Bowen DFO pers. comm.). Given the high Grey Seal abundance and low Winter Skate abundance on the ESS, these results suggest that predation by Grey Seal is a likely contributing factor to the high adult *M* of Winter Skate on the ESS. This is further supported by recent shifts in the distribution of Winter Skate out of areas where the risk of predation by Grey Seal is high.

Recovery Targets

Candidate abundance and distribution target(s) for recovery

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

Survival target

The survival target is defined by an intrinsic rate of population increase (r) from a surplus production model, or by an equivalent target based on *M* from a stage-based state space model. Based on Winter Skate life history characteristics (including a growth model, length-weight relationship, recruitment rate, maturity at age, natural mortality), the average value of r that would allow this population to grow and reduce its extinction risk is 0.050. At that r value, probability of extinction (biomass <50 t) by 2045 is 0.2% compared to a 58% probability of extinction under current conditions which are characterized by a negative intrinsic rate of increase (-0.14; Table 4).

In terms of adult *M*, the population would stabilize at a low level and its risk of extinction become low (<10%) if current *M* (0.44, corresponding to an annual mortality of 36%) was reduced by 25% to a value of 0.33 (28% annual mortality). If *M* were reduced by 50% to 0.22 or 20% annually, population biomass would be expected to increase rapidly.

Size structure target

High natural mortality has resulted in a contraction of the adult size structure. In the 1970s, there were abundant catches of adult (≥ 75 cm TL) Winter Skate which exceeded 89 cm TL in research survey catches and these large skates represented 24% to 94% of the catches (Fig. 14; Table 4). Since 2005, no Winter Skate ≥ 90 cm TL has been captured. Recovery of this population would require a return to the Winter Skate size structure observed in survey catches during the higher abundance period of the 1970s. This size structure target cannot be realized until adult natural mortality is substantially reduced. The proposed size structure target is a proportion of adult Winter Skate ≥ 90 cm TL that is greater than or equal to the average level in the 1970s (54%).

Distribution target

Adult Winter Skate during the 1970s to 1990s were widely distributed in shallow waters of the shelf areas of NAFO Divisions 4VW during the summer (Fig. 10). A summer distribution of this species, corresponding to its distribution in the 1980s to the early 1990s, is proposed as a distribution target for recovery. The DWAO index (i.e., habitat in which Winter Skate was captured) for that time period averaged 15,000 km^2 (Table 4). This distribution target cannot be realized until adult natural mortality is substantially reduced, abundance increased, and factors that contributed to the significant range contraction of this species are mitigated.

Abundance Target

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

A candidate recovery target corresponding to 40% of B_{MSY} (i.e., biomass producing the maximum sustainable yield, or MSY) is proposed as the abundance target (Table 4). This target is consistent with DFO's 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 a 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} for the ESSN DU (Fig. 23). The estimated LRP was 6,860 t of total biomass of Winter Skate ≥ 36 cm TL. The probability that total biomass was below this level increased from 54% in 2003 to 92% in 2007, and greater than 99% since 2011. Total biomass in 2011 was estimated to be 31% of the LRP, declining to 17% of the LRP in 2015.

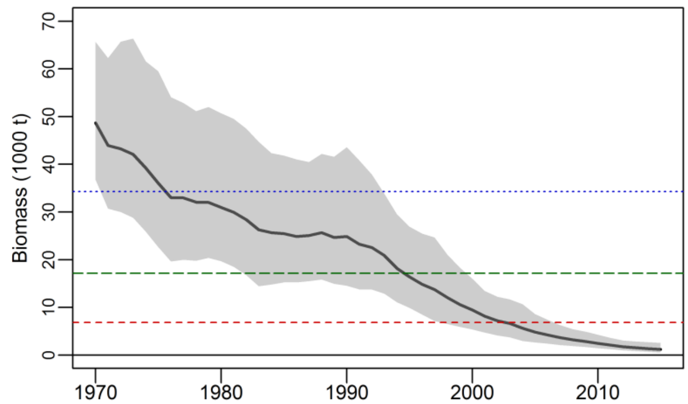

Figure 23. Estimated biomass of Winter Skate based on the surplus production model for the ESSN DU Solid black line indicates the posterior median and grey shading the 95% credible intervals. Median estimates for carrying capacity (K), the biomass at maximum sustainable yield (B_{MSY}), and the Limit Reference Point (LRP, 40% of B_{MSY}) are represented by the blue dotted line, the green long-dashed line, and the red short-dashed line (respectively).

Table 4. Summary of recovery targets for Winter Skate adult biomass, abundance, and distribution for the ESSN DU and Div. 4VW.

Recovery target characteristic	Unit	Reference	ESSN	Div. 3LNOP	Div. 4VW
Survival	Intrinsic rate of increase	1970 to 1976	0.05	not applicable	not applicable
	Natural mortality (M)	50% of current M	not applicable	not applicable	0.22 (20% annual)
Size structure	Proportion adult Winter Skate >= 90 cm TL	1970 to 1979	not applicable	not applicable	54%
Distribution	DWAO value	1980 to 1995	not applicable	not applicable	15,000 km^2
Abundance	40%BMSY	16.5% of biomass in 1970	6,860 t (>= 36 cm TL)	not applicable	5,170 t (adult biomass)

A surplus production model was also fit to the NAFO Divisions 4VW component of the DU. The median estimate of the LRP was 6,210 t of total biomass of skates ≥ 36 cm TL, corresponding to 16.5% of the estimated total biomass in 1970. At the scale of the Divisions 4VW stage-structured model, this corresponds to a LRP of 5,520 t of total biomass (16.5% of 33,426 t; total biomass in 1970) or 5,170 t of adult biomass (16.5% of 31,330 t; adult biomass in 1970). The median estimate of total biomass declined from 33,427 t in 1970 to 1,261 t in 2015, a 96% decline (Fig. 24). Accounting for uncertainty in estimates of the LRP and total biomass in 2015, the probability that total biomass was below its LRP in 2015 is 99.8%. The median estimate of adult biomass declined from 31,333 t in 1970 to 350 t in 2015, a 99% decline (Fig. 24). Accounting for uncertainty in estimates of the LRP and total biomass in 2015, the probability that total biomass was below its LRP in 2015 is 100%.

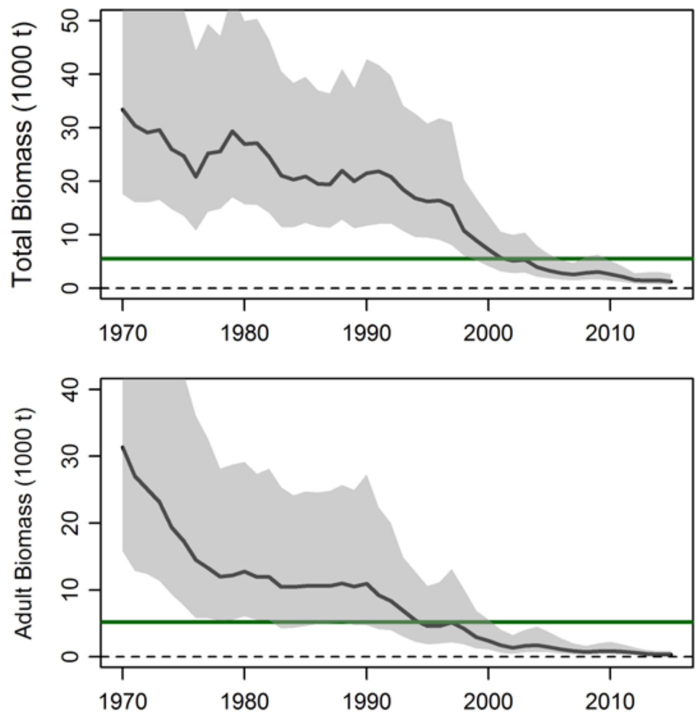

Figure 24. Estimated total (upper panel) and adult (lower panel) biomass of NAFO Divisions 4VW Winter Skate from the stage-based model with varying natural mortality by periods. Solid black lines indicate posterior medians, and grey shading the 95% credible intervals. The solid green horizontal line represents the value of the abundance recovery target in relation to adult and total biomass, equivalent to 0.165 of the biomass in 1970.

Expected population trajectories

ESSN DU

The Winter Skate population was projected forward 25 years under the assumption that productivity conditions in 2005 to 2015 would persist over this period. As expected with a negative intrinsic rate of increase ($r < 0$), total biomass was projected to continue declining even with no fisheries catches (Fig. 25). The probability that biomass would remain below the LRP was 99% to 100% throughout the projection. The probability that biomass would decline below very low levels (100 t to 10 t) began to increase above 0 by 2020. By 2040, this probability rose to 29% for 10 t, 58% for 50 t, and 71% for 100 t (Fig. 25). These very low levels of abundance (<50 t) are considered proxies for extinction.

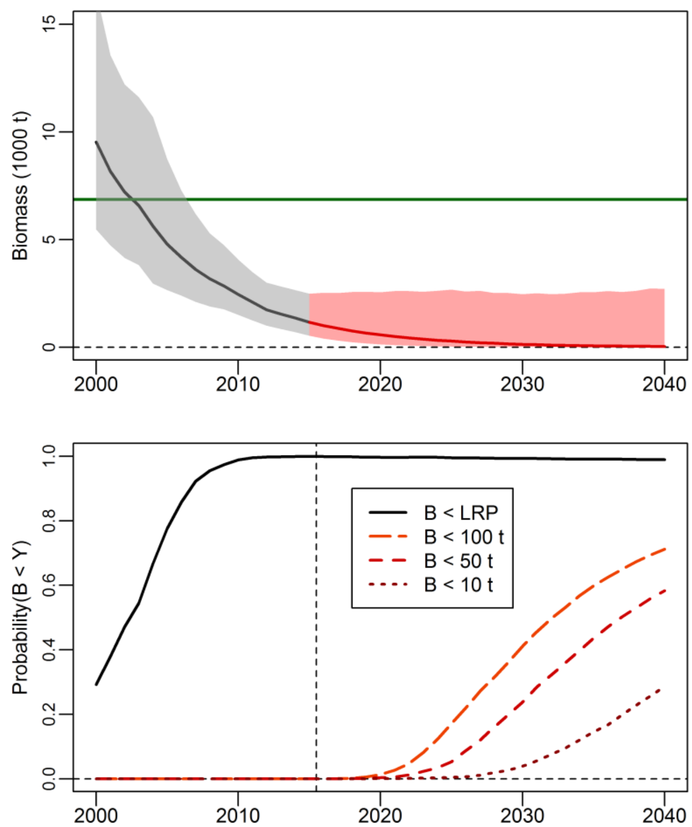

Figure 25. Biomass of Winter Skate for the ESSN DU projected forward 25 years (upper panel) and the probability that biomass will be below specified levels between 2000 and 2040 (lower panel) assuming that 2005 to 2015 productivity conditions persist and there are no fishery catches in the ESSN DU. The line in the upper panel represents the posterior median, shading the 95% credible intervals, and the green horizontal line is the LRP.

NAFO Divisions 4VW

The NAFO Divisions 4VW Winter Skate population was projected forward 25 years to 2040; assuming that 2005 to 2015 levels of natural mortality persist over the projection period and no fisheries catches occur. Median estimates of total biomass and adult biomass continued to decline over this projection although uncertainty in these estimates increased (Fig. 26). The probability that biomass was below the abundance recovery target increased from 29% in 2000 to 99.7% in 2015 for total biomass and from 91% to 100% for adult biomass (Fig. 26). Over the projection, this probability slowly declined to 97% (total biomass) or 99% (adult biomass) due to increasing uncertainty. Probabilities that biomass will decline below very low levels (10 t to 100 t) increase to non-negligible levels by the end of this projection (Fig. 26). For total biomass, the probability of decline below 50 t by 2040 with no fisheries catches was 32% whereas for adult biomass, the probability was 58% (Fig. 26). Under current productivity conditions, this population is expected to continue declining; even with no fisheries catches, and there is a substantial probability (58%) of declines to a level that is a proxy for extinction (< 50 t).

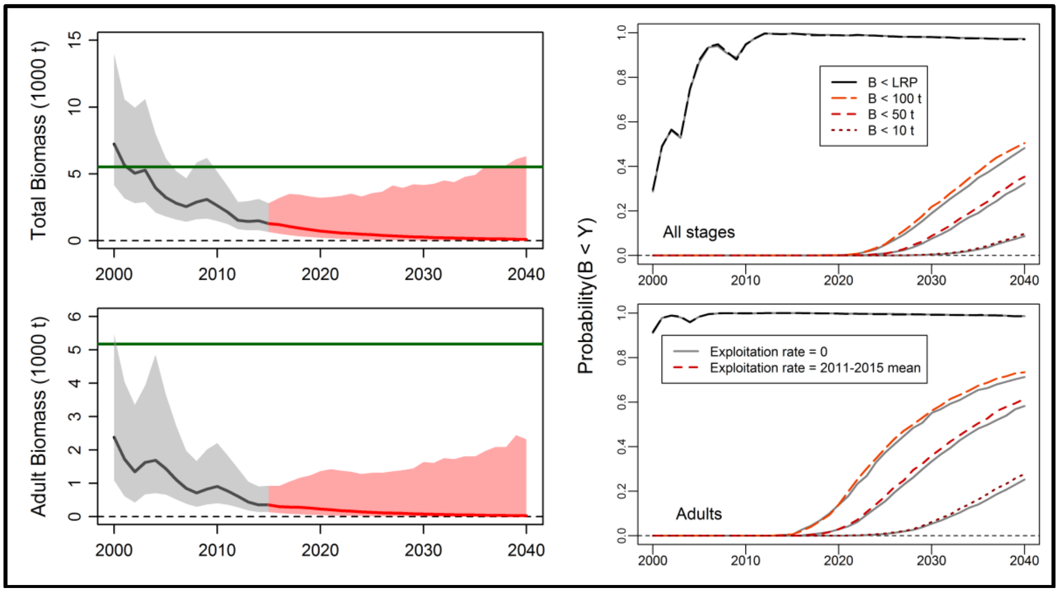

Figure 26. Projected biomass (total biomass upper row, adult biomass lower row) of NAFO Divisions 4VW Winter Skate to 2040 (left panels) and probabilities that biomass will be below various levels (B < Y; right panels) assuming that 2005 to 2015 productivity conditions persist and with no fishery catches or at exploitation rates of the 2011 to 2015 levels. In the left panels, solid lines indicate median estimates, and shading the 95% credible intervals. Grey/black represents observed years, and red the projected years. Solid green horizontal lines are the median estimate of the abundance recovery targets (LRP).

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

Habitat availability is not considered to be a factor limiting recovery of the Winter Skate population in the ESSN DU, presently and when recovery occurs.

Probability of achieving potential recovery target(s) with different mortality and productivity parameters

For the NAFO Divisions 4VW management unit, projections were conducted at reduced levels of adult *M* to examine the reductions in adult *M* required for population viability and recovery (Fig. 27). Based on these projections, total and adult biomass would stabilize if *M* was reduced to 0.75 of the 2005 to 2015 level. Under this condition, the probability that total biomass remained below the LRP in 2040 decreased from 97% to 83% and the probability that adult biomass would decline below 50 t decreased from 58% to 10% (Fig. 27). With 50% reduction in adult *M*, biomass is expected to increase rapidly. The probability that total biomass would remain below the LRP in 2040 decreased to 28% and the probability that adult biomass would decline below 50 t remained negligible (<0.1%; except 0.12% in 2040) over this projection period.

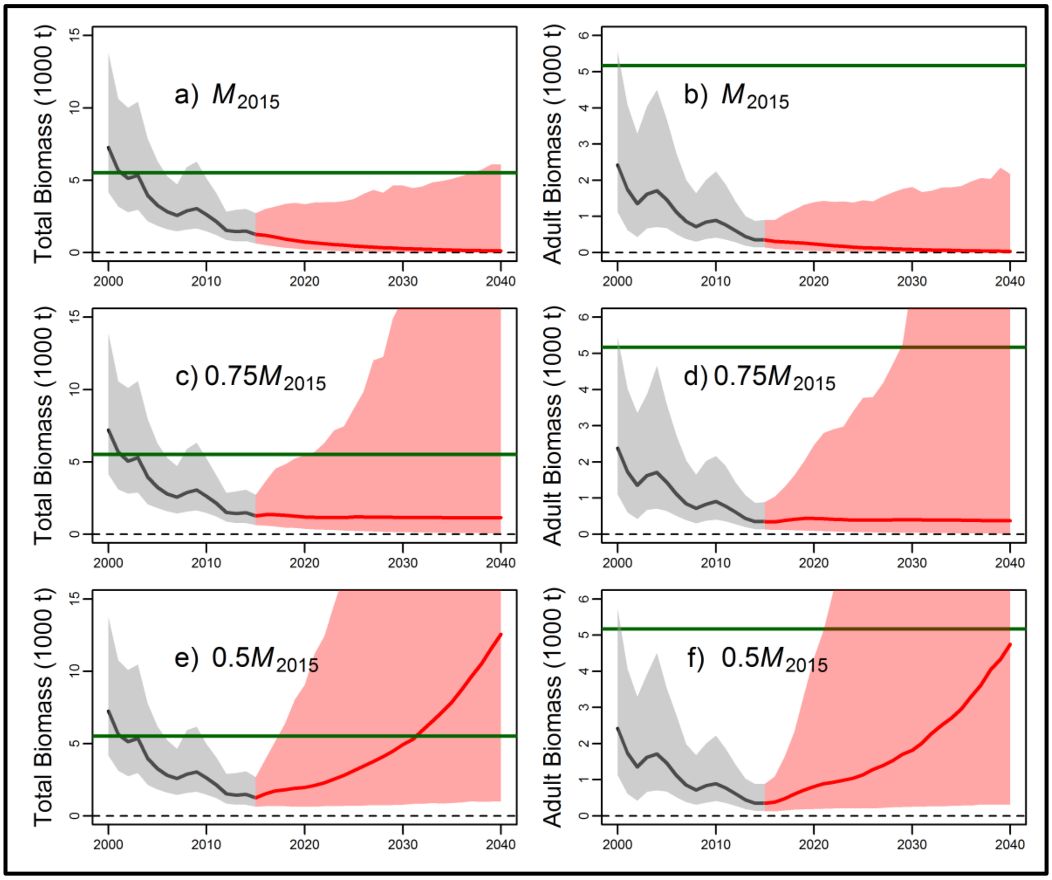

Figure 27. Projections of total (left column) and adult (right column) biomass of NAFO Divisions 4VW Winter Skate at three levels of adult natural mortality (M) during the 25-year projection. M_{2015} is estimated M during the period 2005 to 2015. Solid lines indicate median estimates and shading the 95% credible intervals. In all panels, grey/black represents observed years and red the projected years. The solid green horizontal line is the median estimate of the LRP. All components of productivity other than adult M were assumed to remain at their 2005 to 2015 levels throughout the projection period and fishery catches were assumed to be nil.

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

Fishing is the only known source of anthropogenic mortality for Winter Skate in the ESSN DU. Although there are no directed fisheries for Winter Skate in this DU, they are captured and landed in the directed Thorny Skate fishery, primarily in NAFO Subdivision 3Ps, and bycatch mortality occurs in other fisheries. There are no known gear modifications to reduce catches of Winter Skate in any fishery except for groundfish excluders (e.g., Nordmore grate) installed in shrimp-directed trawls.

Potential additional measures to decrease mortality of this species in scallop, groundfish, and shrimp fisheries, and their expected effectiveness include:

- Prohibition of retention of Winter Skate in the skate-directed fishery in NAFO Divisions 3LNOP because discard survival rates are estimated to be high.

- Prohibition of retention of any skate species in other directed fisheries within the ESSN DU because discard survival rates are estimated to be high.
- License Condition stating that priority be given to sorting and rapidly discarding Winter Skate and other skate catches with the least possible harm, as there is potential for a high post-release survival rate for discarded adult skates in longline and bottom trawl fisheries.
- Reduced fishing efforts for commercial species in areas and times with the highest potential of encountering Winter Skate to reduce bycatch.
- Prohibition of retention of Winter Skate in recreational or Food, Social and Ceremonial fisheries. However, FSC catches are unreported and, if as low as assumed, will have an insignificant effect on this population.

Given that no discards are reported from fishing activities, at-sea observers constitute the only source of catch data by species for estimating discards at sea. Average annual observer coverage of relevant fisheries in the ESSN DU remains very low (≤ 7%). Improved monitoring of fisheries that catch Winter Skate in the ESSN DU by increasing at-sea fisheries observer coverage would provide crucial information on fishing activities that will impact Winter Skate survival.

Inventory of activities that could increase the productivity or survivorship parameters

As previously discussed, the lack of recovery and on-going decline of the Winter Skate ESSN DU is due to high natural mortality of adult skates. If this high natural mortality persists, any additional measures to further reduce currently low fishing mortality will be ineffective in promoting recovery and reducing the high risk of extinction for this species. Activities to reduce the abundance of Grey Seals foraging on the Scotian Shelf may lead to increased survivorship of Winter Skate.

Feasibility of restoring the habitat to higher values

Habitat is not a limiting factor to the Winter Skate population in the ESSN DU. Current distribution of Winter Skate in NAFO Divisions 4VW is greatly reduced from historically important areas around Sable Island and Banquereau Bank. Causes of this shift in distribution are uncertain but may be associated with high risk of predation by Grey Seal. As in the GSL DU (DFO 2016), it is unlikely that Winter Skate will reoccupy these areas until causal factors of this distributional shift are mitigated.

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 in the current rate of adult natural mortality by approximately 50% (i.e., to $M = 0.225$) would be required to result in a negligible risk (<1%) of extinction for Winter Skate. Based on available evidence, predation by Grey Seal appears to be an important factor driving this high adult natural mortality.

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

Projections were conducted at reduced levels of natural mortality (M), and are described above.

Parameter values for population models for additional scenarios analyses

Models for estimating Winter Skate population trajectories were described, reviewed, and accepted as appropriate for assessing management scenarios associated with its recovery (see the previous section “Expected population trajectories”).

Allowable Harm Assessment

Winter Skate mortality due to Thorny Skate-directed and other bycatch fisheries continues in the ESSN DU. Estimated losses are the sum of the reported landings and the estimated post-discard mortalities. The post-discard mortality rate value of 0.25 used in this assessment was borrowed from empirical estimates of short-term survival of skates from studies in the southern Gulf of St. Lawrence (Benoît et al. 2010; Benoît 2013; Swain and Benoît 2016).

ESSN DU

Estimated losses of Winter Skate in the ESSN DU over 2005 to 2013 varied annually between 7.3 and 89.9 t, with an average of 24.5 t (Table 5). Most catches and losses occurred in NAFO Divisions 4VW. Over the past five years, estimated losses of Winter Skate in commercial fisheries averaged 16.5 t (12.6 to 23.5 t range), with almost all losses occurring in NAFO Divisions 4VW.

Table 5. Mean and range of estimated landings (t), estimated discards (t), and estimated losses (t; landings plus post-discard mortalities) of Winter Skate from all commercial fisheries in NAFO Divisions 3LNOP and 4VW, and the ESSN DU, 2005 to 2013 and 2009 to 2013. The large variation in estimated bycatch is partly attributable to variations in annual fishery-specific at-sea observer coverage.

Area	Years	Landings (t) mean (range)	Estimated discards (t) mean (range)	Total losses (t) mean (range)
Div. 3LNOP	2005 to 2013	0 (0 - 0)	16 (0 - 63)	16 (0 - 63)
	2009 to 2013	0 (0 - 0)	1 (0.3 - 2)	1 (0.3 – 2)
Div. 4VW	2005 to 2013	0.2 (0.0 – 0.7)	56 (29 - 93)	14 (7 - 23)
	2009 to 2013	0.3 (0.0 - 0.7)	64 (49 - 93)	16 (12 - 23)
ESSN DU	2005 to 2013	0.2 (0.0 – 0.7)	70 (21 -110)	25 (7 – 90)
	2009 to 2013	0.3 (0.0 - 0.7)	65 (50 - 93)	17 (13 - 24)

NAFO Divisions 3LNOP

Estimated losses from fisheries in NAFO Divisions 3LNOP during 2005 to 2013 represent 0 t to 16.9 t of Winter Skate (Table 6). In 2009 to 2013, estimated losses ranged from 0 to 0.50 t annually, with most losses estimated from redfish, turbot, and shrimp fisheries.

Scientific survey losses (number of fish, all sizes combined) in NAFO Divisions 3LNOP totalled 0 to 20 Winter Skate annually during 2005 to 2013 and over the past five years (Table 6).

Table 6. Estimated landings (t; 2005 to 2013), estimated discards (t; 2005 to 2013), and estimated losses (t; post-discard mortalities, for two time periods) of Winter Skate from commercial, recreational, and aboriginal fisheries, and scientific surveys in NAFO Divisions 3LNOP. Losses are the sum of landings and mortalities from discarding (as 25% of catch). For scientific surveys, values are numbers of Winter Skate rather than weight. Commercial data are from Canadian at-sea fisheries observers and ZIFF in the same years. The large variation in estimated bycatch is partly attributable to variations in annual fishery-specific observer coverage. For scientific surveys, values are numbers of Winter Skate, rather than weight.

Fishery type	Directed species	Landings (t; 2005 to 2013) mean	Estimated Discards (t; 2005 to 2013) mean (range)	Discard Losses (t) mean (range)	
				2005 to 2013	2009 to 2013
Gillnets	Skate	0	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
	Atlantic Cod	0	6 (0 - 49)	1.5 (0 - 12)	0 (0 - 0)
	Monkfish	0	0.1 (0 - 0.5)	0 (0 - 0.1)	0 (0 - 0)
	Turbot	0	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Longlines	Skate	0	6.4 (0 - 54)	1.6 (0 - 14)	0 (0 - 0)
	Atlantic Cod	0	0.2 (0 - 2)	0.1 (0 - 0.5)	0 (0 - 0)
Otter trawls	Skate	0	0.5 (0 - 5)	0.1 (0 - 1)	0 (0 - 0)
	Atlantic Cod	0	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
	Turbot	0	0.5 (0 - 3)	0.1 (0 - 1)	0.1 (0 - 0.2)
	Plaice	0	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
	Yellowtail	0	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
	Redfish	0	0.3 (0 - 1)	0.1 (0 - 0.4)	0.0 (0 - 0.2)
	Shrimp	0	0.3 (0 - 1)	0.1 (0 - 0.3)	0.1 (0 - 0.3)
Recreational	Groundfish	0	unknown	unknown	unknown
Aboriginal	Groundfish	0	0	0	0
Scientific surveys (expressed as number of fish)	Multi-species (Campelen)	0	8.0 (0 - 26)	6.0 (0 - 20)	5.4 (0 - 20)
	Other surveys	0	0	0	0

NAFO Divisions 4VW

Estimated losses (landings and assumed 25% mortality rate from discarding for all commercial gears) from fisheries in NAFO Divisions 4VW during 2005 to 2015 represented 0 t to 23.5 t of Winter Skate (Table 7). In 2009 to 2015, estimated losses ranged from 0 t to 23.5 t annually, with most losses estimated to occur from redfish and halibut fisheries.

Scientific survey losses (number of fish, all sizes combined) in NAFO Divisions 4VW were 2 to 27 skates annually during 2005 to 2013 (Table 7). For the past five years, survey catches ranged from 1.5 to 2.2 skates annually.

For early Winter Skate juveniles, exploitation in the past five years was about 0.3% to 2%, whereas for larger juveniles, exploitation rates were recently 0.4% to 0.8%. Exploitation rates of adults peaked in the mid1990s, and dropped suddenly to below 1% since 2005 (Fig. 22).

An exploitation rate increase from 0 to the 2011 to 2015 average of 1% did not have a noticeable impact on population trajectory of the ESSN DU (Fig. 28). However, probabilities of decline to very low biomass levels by 2040 did rise slightly, from 29% to 34% for 10 t of biomass, 58% to 65% for 50 t of biomass, and 71% to 76% for 100 t of biomass.

Results are similar for the NAFO Divisions 4VW component of the DU. There is again a negligible difference in projected trajectories assuming current productivity conditions and exploitation rates of either 0% or the 2011 to 2015 average values of 1.3% for small juveniles, 0.6% for large juveniles, and 0.4% for adults. Based on an adult biomass of < 50 t as a proxy for extinction, the probability of extinction by 2040 is slightly higher at the higher exploitation rate (62% versus 58%; Fig. 29).

Table 7. Estimated landings (t; 2005 to 2015), estimated discards (t; 2005 to 2015), and estimated losses (t; landings plus post-discard mortalities) for two time periods of Winter Skate from commercial, recreational, and aboriginal fisheries, and scientific surveys in NAFO Divisions 4VW. For scientific surveys, values are numbers of Winter Skate, rather than weight.

Fishery type	Directed species	Landings (t) 2005 to 2015 mean	Discards (t) 2005 to 2015 mean (range)	Losses (t) 2005 to 2015 mean (range)	Losses (t) 2009 to 2015 mean (range)
Commercial	Silver Hake	0	0.9 (0 - 1)	0.2 (0 - 0.3)	0.2 (0 - 0.3)
	CHP	0	0.2 (0 - 1)	0 (0 - 0.3)	0 (0 - 0)
	Halibut	0	13.2 (0 - 20)	3 (0 - 5)	4 (0 - 5)
	Flatfish	0	6 (0 - 19)	2 (0 - 5)	2 (0 - 5)
	Redfish	0	34.9 (0 - 61)	9 (0 - 15)	9 (0 - 15)
	Scallop	0	3 (1 - 7)	3 (2 - 5)	2 (1 - 3)
	Surf Clam	0	3 (0.2 - 5)	3 (0.2 - 4)	2 (0.2 - 4)
Recreational	Groundfish	0	unknown	unknown	unknown
Aboriginal	Groundfish	0	unknown	unknown	unknown
Scientific surveys (expressed as number of fish)	Multi-species (Western IIA)	0	16 (2 - 36)	12 (2 – 27)	11 (2 – 22)
	Other surveys	0	0.3(0 - 3)	0.1 (0 - 2)	0.1 (0 - 0.4)

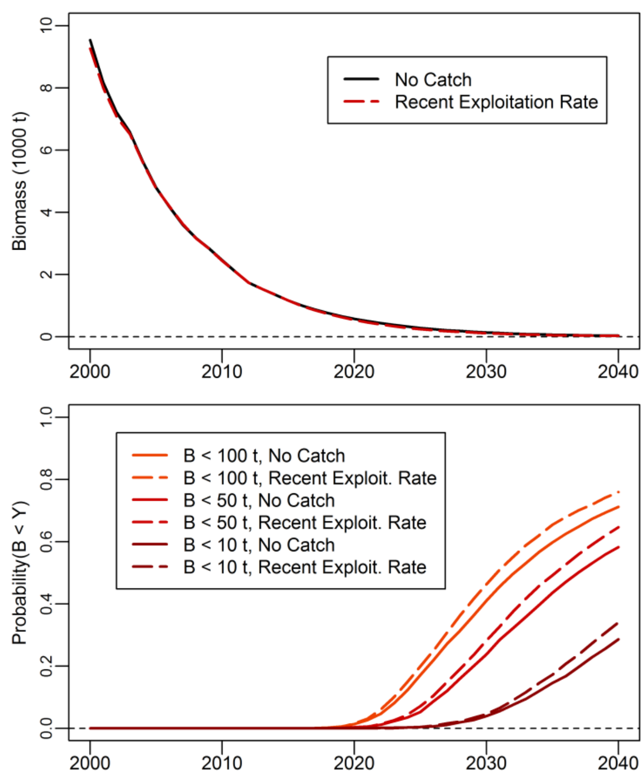

Figure 28. Projected total biomass of ESSN DU of Winter Skate (upper panel) and probabilities that biomass will be below various levels (<10 t, < 50 t, < 100 t) in 25-year projections at two exploitation rates (lower panel). Projections were done assuming the productivity would remain at the 2005 to 2015 level over the projection period. Exploitation rates over the projection period are set at 0 (no fishing) or 1% (the 2011 to 2015 average value).

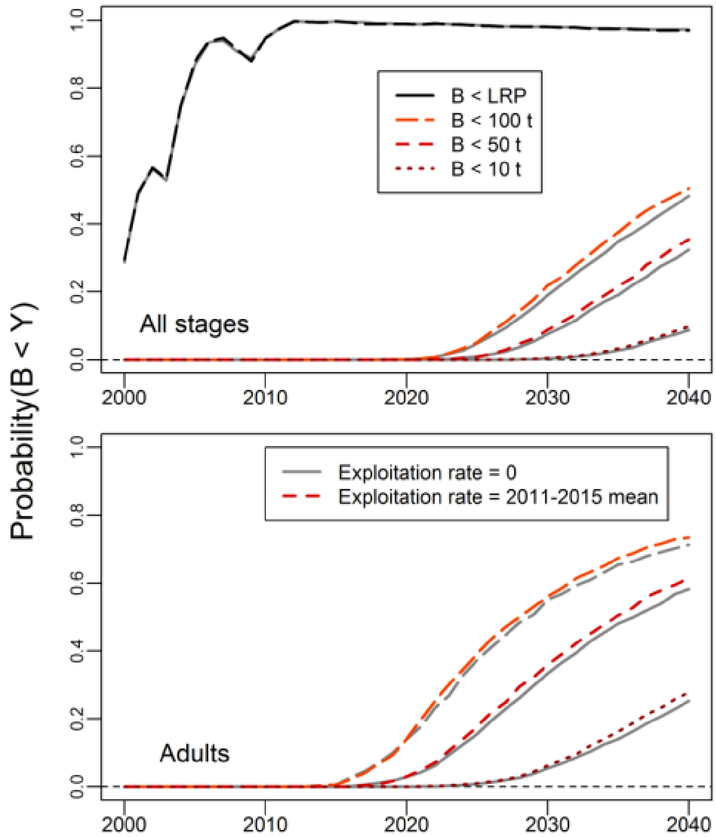

Figure 29. Probabilities that the biomass (all stages in upper panel; adults in lower panel) of Winter Skate in NAFO Divisions 4VW will be below various levels (<10 t, < 50 t, < 100 t) in 25-year projections at two levels of exploitation rate. Projections were done assuming the productivity would remain at the 2005 to 2015 level over the projection period. Exploitation rates over the projection period are set at 0 (no fishing) or 1% (the 2011 to 2015 average value).

Sources of Uncertainty

The decline in the abundance indices in NAFO Div. 4VW are interpreted as representative of a decline in population abundance rather than a change in the proportion of the population available to the survey. The decline in the abundance indices of Winter Skate on the eastern Scotian Shelf has been accompanied by a shift in distribution of Winter Skate to deeper waters within the surveyed area. Winter Skate may occur in waters shallower than those surveyed but there is no evidence that the proportion of catches in the inshore portions of the survey has increased; rather the distribution has shifted to deeper water within the survey area. Based on limited sampling in some years of deep waters off the Scotian Shelf in which no Winter Skate were captured, Winter Skate do not appear to be extending their summer distribution into waters deeper than those covered by the survey. They are however found in deep waters of the Laurentian Channel and off the shelf edge in winter.

Surplus production models are limited to very simple dynamics. Given the estimated history of fishery removals, the only way that these models could account for the decline in the biomass index in the 1970s was to attribute this decline to low productivity due to density-dependent effects. If the decline instead reflected unaccounted catch, then the model estimates of BMSY, and thus the LRP, would be biased low.

The stage-structured models used have more flexible dynamics than surplus production models. Nonetheless, their dynamics are partially unrealistic compared to age-structured models. The development of a length-based age-structured model could provide improved understanding of the dynamics and status of Winter Skate in this DU.

Uncertainties in the projections are reflected in the probability profiles. It is also important to keep in mind that these projections depend on the assumptions regarding future productivity and therefore the probabilities are conditional on the assumptions. These are not the probabilities that a particular event will happen in the future; they are probabilities that the event will happen given the projection assumptions.

Discarding at sea of skate bycatch remains unreported or poorly reported in Canadian and other fisheries. Canadian at-sea observers constitute the sole source of catch data by species, including discards at sea, however there is very low to non-existent at-sea fisheries observer coverage in most Canadian Atlantic fisheries. Consequently, the losses of Winter Skate attributed to fishing activities are likely higher than what are estimated in this assessment using the available catch information.

Commercial skate landings are not identified to species when reported in Canadian and other fisheries. In part, this is due to difficulties in identifying Winter Skate using external characteristics, especially for fish < 36 cm length (i.e., with no distinguishing external characteristics), or in areas with co-occurring Little Skate or Thorny Skate.

There are no empirical data on short-term survival rates of ESSN Winter Skate after discarding at sea and values are borrowed from data on Thorny Skate collected in NAFO Div. 4T. A sensitivity analysis was conducted assuming that discard survival was 40% instead of 75%. The difference in estimated M was negligible, e.g., 0.44 instead of 0.45.

Given that skates are cartilaginous and do not possess otoliths or other bony structures that are often retained in predator stomachs and intestines, research using large sample sizes is necessary to identify partially digested skate remains in potential predator stomachs including Grey Seal. Alternative methods, such as fatty acid analysis, have reported finding signatures consistent with Winter Skate, confirming findings from other areas that Winter Skate are constituents of seal diets. However, a quantification of the effects of seal predation on Winter Skate abundance in the ESSN DU is currently difficult and highly uncertain.

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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APPENDIX

Appendix 1. Known habitat features, functions and attributes for Winter Skates on the Eastern Scotian Shelf.

Life-Stage	Function	Features	Attributes
Egg purse and hatched young	rearing (embryo development, hatch, initial growth)	Sandy waters off Sable Island	Water depth: <110m Salinity: 32-34 ppt Temperature: 5^{o}-9^{o}C Substrate: sand and some gravel Predators: gastropods, seals, sharks, other skates Prey: no data
Juvenile (36-59 cm)	Feeding and Growth	Sandy waters off Sable Island out to shelf waters of the Eastern Scotian Shelf	Water depth: <110m Salinity: 32-34 ppt Temperature: 5^{o}-9^{o}C Substrate: sand and some gravel (Sable Island area) and Scotian Shelf drift (glacial till). Predators: sharks, seals, and other skates Prey: crustaceans (including Gammaridae, Caprellidae, decapods like Cancridae), arthropods, Sand Lance (*Ammodytes* sp.), various fish species
Sub-Adult (60-74 cm)	Feeding Growth Reproductive maturation	shelf waters of the Eastern Scotian Shelf	Water depth: <110m (most common at 35m-90m) Salinity: 32-34 ppt Temperature: 5^{o}-9^{o}C Substrate: sand and some gravel (Sable Island area) and Scotian Shelf drift (glacial till) Predators: sharks, seals, other skates Prey: crustaceans (including decapods like crab and shrimp, Oregoniidae, Cancridae), polychaete worms, Sand Lance (*Ammodytes* sp.) and other fish species (including Gadidae and Pleuronectidae)
Mature Adult (75+ cm)	Feeding Growth Spawning	shelf waters of the Eastern Scotian Shelf and Sandy waters off Sable Island (spawning)	

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