Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat
Gulf Region | Science Advisory Report 2021/033

IMPACT OF AN EXPANDING REDFISH (*SEBASTES* SPP.) FISHERY ON SOUTHERN GULF OF ST. LAWRENCE WHITE HAKE (*UROPHYCIS TENUIS*)

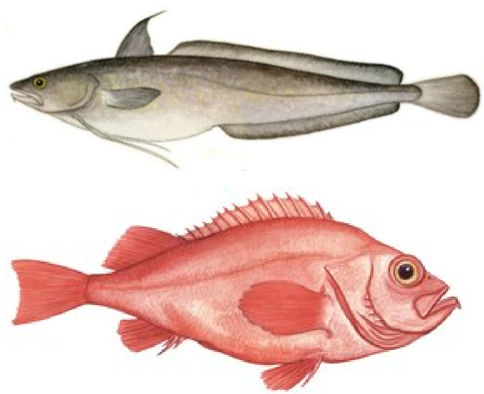

Image: White Hake (above), Redfish (below).
Credit: Fisheries and Oceans Canada

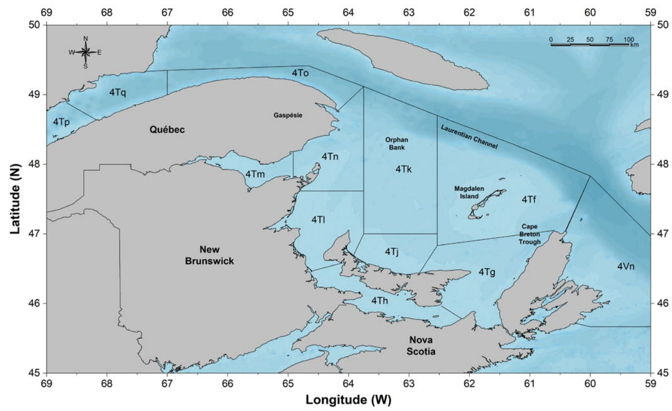

Figure 1. Map of the Gulf of St. Lawrence showing NAFO divisions.

Context:

The southern Gulf of St. Lawrence (sGSL) White Hake Designatable Unit (DU) has been assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This DU consists primarily of White Hake occurring in the Northwest Atlantic Fishery Organization (NAFO) Division 4T. The Recovery Potential Assessment for this stock found that extremely high natural mortality was preventing the recovery of this stock, while fishing mortality with a bycatch limit of 30 t has a negligible effect on the population trajectory. However, if fishing effort is increased as proposed with the expansion of the Redfish fishery, the impacts of bycatch fisheries on this population may no longer be considered negligible. This report aimed to examine existing information from surveys and fisheries to evaluate whether increased catch levels of Redfish would result in increased bycatch of White Hake.

*This Science Advisory Report is from the February 17, 2021 regional advisory meeting on the Impact of an expanding Redfish (*Sebastes *spp.) fishery on southern Gulf of St. Lawrence White Hake (*Urophycis tenuis*). Participants at the meeting included DFO Science (Gulf, Québec, National Capital regions), DFO Fisheries Management (Gulf, Québec regions), provincial governments, and the fishing industry.*

SUMMARY

- The southern Gulf of St. Lawrence (sGSL) White Hake Designatable Unit (DU) has been assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).
- sGSL White Hake and Redfish have largely overlapping distributions, as White Hake have shifted their distribution almost exclusively to the deep waters of the Laurentian Channel which is the same distribution as Redfish.
- An expanding Redfish fishery could have an impact on the sGSL White Hake population due to strong overlap in their spatial distribution.
- Spawning stock biomass (SSB) of the sGSL White Hake population declined rapidly in the late 1980s and the 1990s. A moratorium on directed fishing was established in 1995. No signs of recovery have occurred since then despite negligible fishing mortality. Estimated SSB was 7,400 t in 2019, 13% of the average level in the early to mid 1980s.
- The failed recovery of this population is due to extremely high natural mortality. Estimated natural mortality of adult White Hake has been 80-85% annually for the past 20 years. Predation by Grey Seal appears to be a major cause of this high mortality.
- Recruitment has fluctuated without trend since 1978 despite the decline in SSB. This reflects an increase in recruitment rate, the number of age-2 recruits produced per unit weight of SSB. The average rate was ten times greater for recruitment in 2000-2019 compared to 1980-1994. The estimated recruitment rate in 2019 is the highest on record though the uncertainty in this estimate is high.
- At the current high level of natural mortality the sGSL White Hake population persists only because of the unusually high recruitment success since the year 2000. If recruitment rate were to decrease a decline leading to local extinction would be expected at the current level of natural mortality.
- The spawning stock of this population consisted of ages 4 to 10 years and older in the past. It now consists mostly of 4-year-old fish. A spawning stock consisting of a single reproductive cohort represents a high risk to this population.
- The sGSL White Hake population was projected forward 25 years assuming that productivity would remain at recent levels. SSB was estimated to decline by 38.7% with no catch and 39.3% with annual bycatch of 20 t, the recent level. With annual bycatch of 150 t to 350 t, SSB was estimated to decline by 43% to 48%. With bycatch of 500 t to 1,500 t, SSB declined by 53% to 70%.
- The probability that SSB would be less than 2,000 t at the end of the 25-year projection (a 73% decline) was estimated to be 22.8% with no catch and 23.3% at the recent bycatch level (20 t). With bycatch of 150 t to 350 t this probability was 26% to 30%. With bycatch of 500 t to 1,500 t, this probability increased to 33% to 49%. For a population that had an SSB near 60,000 t in the early 1980s, an SSB near 2,000 t represents a very high risk of local extinction.
- There is clear evidence that the Redfish fishery will overlap with the sGSL White Hake stock. Available data suggests this interaction risk varies with time of year, depth, and geographic location.

- sGSL White Hake bycatch in Redfish catches is lower at depths greater than 380 m and in area of 4T outside of the Cape Breton Trough. Deeper than 350 m, the proportion of White Hake is 34% sGSL DU and 66% Atlantic DU.
- Based on a small scale experimental and index Redfish fishery and multi-species bottom-trawl surveys, we calculated an average estimated bycatch rate of 10.5%. This estimate was not observed to be gear dependent.
- In considering the development of a future Redfish fishery, the bycatch rate may be lower for various reasons that could reduce bycatch of White Hake, including improvement in the fishing technology, fishing season (timing), location of the fishing grounds and species interaction.

INTRODUCTION

Two concurrent activities are occurring within Fisheries and Oceans Canada that are interlinked and have potentially divergent outcomes. The first, the Species at Risk Programs (SARA), needs to provide a listing recommendation for southern Gulf of St. Lawrence (sGSL) White Hake (*Urophycis tenuis*, Mitchill 1814) under the Species at Risk Act. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed the sGSL White Hake Designatable Unit (DU) as Endangered (COSEWIC 2013). In the development of management scenarios as part of the listing process, ongoing bycatch could be permitted under a SARA listing scenario as high natural mortality is preventing the recovery of this stock while current bycatch levels of 30 t in NAFO Div. 4T have negligible effects on the stock trajectory (DFO 2016). At the same time, the imminent arrival of Redfish (*Sebastes* sp.) cohorts from 2011 to 2013 at sizes greater than the minimum regulatory size is generating strong interest from a number of stakeholders. Resource Management is considering expanding the Redfish fishery to exploit this new biomass. The commercial Redfish fishery reopening in Unit 1, which overlaps with NAFO Div. 4T, may have significant impacts on bycatch of sGSL White Hake and may mean that fishing mortality is no longer considered negligible.

In this instance, we have a productive stock, Redfish, and a weak stock, White Hake that may both be caught in an expanding fishery. The spatial distribution, vertical position within the water column, and seasonality of both White Hake and Redfish will determine whether policies developed to rebuild the weak stock will be in contrast to efforts to maximize yield in the productive Redfish stock. This is referred to as the “weak stock problem” and is one of the most challenging aspects facing fisheries management (Caddy 1999, Hall et al. 2000). At present the regulations for sGSL White Hake are a 30 t annual bycatch limit and a maximum bycatch of up to 5% in the Redfish fishery and 10% in other fisheries in order to minimize preventable decline in this stock. It is possible that White Hake will be the choke stock constraining harvest of the Redfish stock.

The purpose of this report is to examine existing information to evaluate the potential impacts of increased bycatch of sGSL White Hake in the directed Redfish fishery.

Data sources

Overlap between White Hake and Redfish and bycatch of White Hake

The experimental and index fisheries targeting Redfish and conducted by the industry, were used as a fishery-dependent data source with 100% at-sea observer coverage. The data was extracted to only keep sets (n = 108) that were conducted in NAFO division 4T between 2015 and 2018, and was collected using either bottom-trawl (n = 51), pelagic-trawl (n = 20) or seine (n = 37). To comply with gear type specifications, the recorded fishing depth was used for the depth distribution analyses.

The information collected from both northern Gulf of St. Lawrence (nGSL) and sGSL research vessel (RV) surveys, conducted in August and September, respectively, were used as a fishery-independent data source. The data was extracted to keep sets from 2015 to 2019, and strata 401 to 408 were used for the nGSL, while strata 415 to 439 were used for the sGSL.

The bycatch (%) was estimated as the amount of White Hake (kg) over Redfish (kg) caught in each individual set. For the fishery-dependent dataset, in the event a set had no Redfish but White Hake the bycatch was set at 100%. Finally, for the fishery-independent dataset, in order to simulate a directed fishery on Redfish, only the sets that caught Redfish were kept in the analyses (n = 103 for the nGSL and n = 186 for the sGSL).

White Hake population modelling

Indices of abundance and biomass since 1971 were obtained from the sGSL RV survey and a mobile sentinel (MS) survey conducted each August since 2003. The RV and MS surveys are both bottom-trawl surveys using the same stratified-random design. Twenty-four strata (415-439) have been fished since 1971, with three inshore strata (401 to 403) added in 1984. The sentinel programs were conducted by commercial fishing vessels using standardized gear and protocols.

Species Information

White Hake (sGSL Designable Unit)

White Hake in the sGSL have a genetic composition that is distinct from that of White Hake in other areas of Atlantic Canada (Roy et al. 2012). The sGSL DU was assessed as Endangered by COSEWIC and the most recent assessment of this stock was the recovery potential assessment (RPA) in January 2015 (DFO 2016, Swain et al. 2016) with the most recent indicator update occurring in 2020 (DFO 2020a). For the purposes of this report it was assumed that the status of the sGSL DU could be assessed based on analysis of the NAFO Division 4T management unit, which is dominated by the sGSL DU and comprises the bulk of the area occupied by this DU. Over 90% of White Hake collected in the sGSL (NAFO Division 4T, Fig. 1) at depths less than 200 m are of the sGSL DU, with this proportion declining as depth increased, from about 80% in the 200 – 250 m range to 34% at depths greater than 350 m (Swain et al. 2012).

sGSL White Hake overwinter in the Laurentian Channel in NAFO Division 4T and Subdivision 4Vn (Cabot Strait), occurring at depths greater than 200 m (Chouinard and Hurlbut 2011). In summer, White Hake either remain in relatively deep water (> 100 m) or move into shallow water (mostly < 50 m) along the Gulf coasts of New Brunswick, Prince Edward Island, mainland Nova Scotia, and southwestern Cape Breton Island. The inshore migration generally begins in April-May and proceeds rapidly until June, when most of the traditional summer habitats have been occupied. The return migration to the overwintering grounds in the Laurentian Channel historically occurred in November and December (Darbyson and Benoît 2003), but now appears to occur in July. The proportion of White Hake occurring in inshore areas has declined over time, with White Hake virtually absent from these areas in recent years (Swain et al. 2016). This shift in the distribution of adult White Hake is related to risk of predation by Grey Seal, an important predator of White Hake (Hammill et al. 2014; Swain et al. 2015). As seal abundance increased, White Hake distribution shifted into deep waters where risk of predation by Grey Seal remained low.

White Hake was historically a commercially important groundfish in the sGSL, ranking third or fourth in terms of annual landings. Landings of White Hake in the 4T management area fluctuated between about 4,000 and 7,000 t between 1961 and 1978, and then rose sharply to a peak of 14,000 t in 1981 (Fig. 2). A precautionary TAC of 12,000 t was established in 1982 and reduced in subsequent years. Landings declined beginning in 1982 and averaged 5,000 t in the 1985-1992 period. The fishery for White Hake in NAFO Division 4T was closed in January 1995, and has remained under moratorium with a 30 t quota for bycatch in commercial fisheries, recreational fisheries, scientific surveys, and Aboriginal fisheries. The stock is now in the Critical Zone of the Precautionary Approach using the biomass recovery target as defined in the RPA (12,800 t, 40% of the spawning stock biomass (SSB) producing the maximum surplus production with no fishing mortality) as the limit reference point.

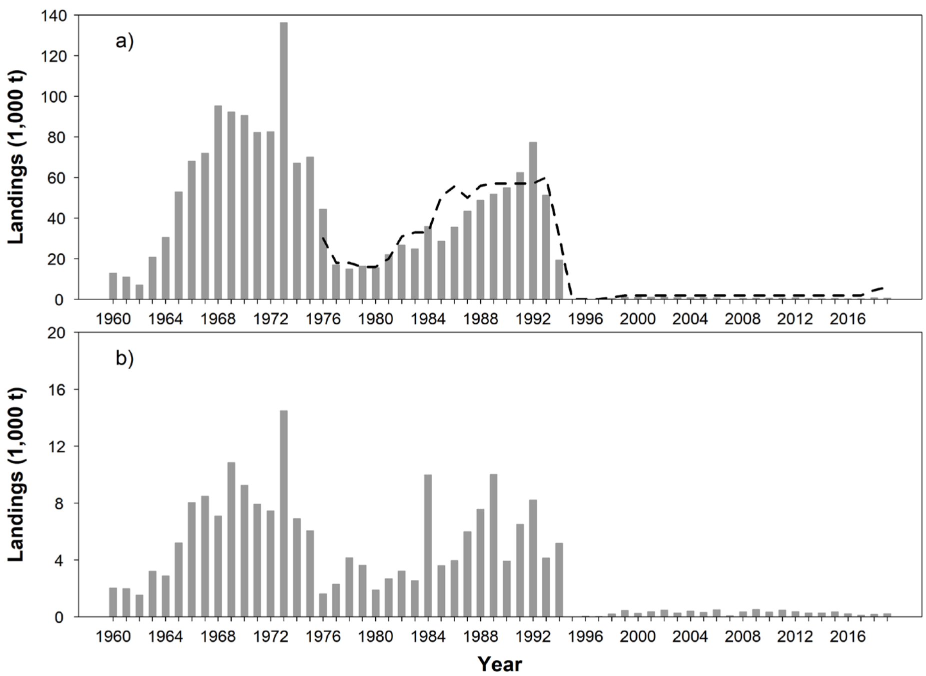

Figure 2. Landings and total allowable catch (TAC) for White Hake in NAFO Division 4T (a - upper panel). The bottom panel (b) shows the bycatch landings of White Hake following the moratorium in 1995.

Unit 1 Redfish

Two Redfish species are present in Unit 1 (NAFO 4RST and 3Pn + 4Vn) namely: Deepwater Redfish (*Sebastes mentella*, Travin, 1951) and Acadian Redfish (*S. fasciatus*, Storer 1854). Redfish inhabit cold waters at depths of 100 to 700 m. Deepwater Redfish are typically found in deeper waters than Acadian Redfish. In the sGSL, Redfish is almost exclusively found in the Laurentian Channel. The two species of Redfish can be distinguished based on anal fin ray count, genetics, and extrinsic gasbladder muscle passage patterns (Senay et al. 2019). For the purpose of this report, we will be grouping the species and referring to them as Redfish.

In 2011, 2012, and 2013, three strong cohorts dominated by Deepwater Redfish with the Gulf of St. Lawrence ecotype recruited to the stock (Benestan et al. 2020). Since, the Deepwater Redfish biomass has continued to increase in research surveys. If the anticipated growth of these cohorts continues, 51% of the individuals of the 2011 cohort should be larger than 25 cm by 2020.

Redfish was intensely exploited in the GSL from 1954-56, 1965-1976, and 1987-1992. A moratorium was declared in Unit 1 in 1995, but an index fishery started in 1998 (Fig. 3). In 2010, COSEWIC designated the Deepwater Redfish (*S. mentella*) as Endangered and Acadian Redfish (*S. fasciatus*) as threatened (DFO 2011). The most recent assessment of Unit 1 Redfish was in January 2020 (Senay et al. 2019; DFO 2020b; Senay et al. 2021). Based on the empirical reference points Deepwater Redfish in Unit 1 are in the Healthy Zone of the Precautionary Approach, while Acadian Redfish are in the Cautious Zone (DFO 2020b).

Given the expected opening of the Redfish commercial fishery in the near future, a Management Strategy Evaluation was conducted in 2018 (DFO 2018). The four Management Procedures that met the goal of maintaining Redfish spp. in the healthy zone included total allowable catches (TACs) of a minimum of 14,500 t in 2020 reaching upwards of 60,000 t by 2028 for both Units 1 and 2.

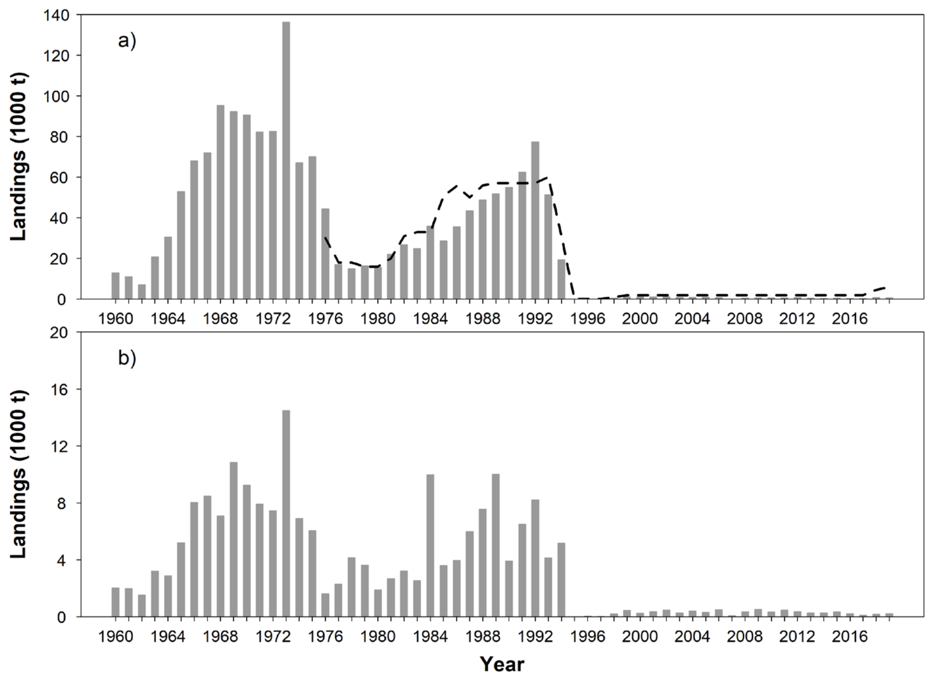

Figure 3. Landings and total allowable catch (TAC) for Redfish spp. in Unit 1 (a – upper panel) and landings in NAFO Division 4T (b – lower panel).

Species interaction

Based on the 2015 to 2019 data available from two research vessel (RV) surveys conducted in August (nGSL) and September (sGSL) the spatial distribution of both species revealed how they share the slopes along of the Laurentian Channel, the deepest part of the sGSL (Fig. 4). White Hake were distributed throughout the Laurentian Channel at relatively even densities. The only area where Redfish were mostly not captured alongside White Hake was within the Cape Breton Trough. The depth profile at which White Hake were caught follows a unimodal distribution centered around 250 m deep (Fig. 5). The interaction of both species was observed at depth intervals ranging from 140 to 410 m. From 0 to 250 m, White Hake catch proportion averaged 4.3% of the combined catch of both species, while deeper than 250 m, the co-occurrence drops to 0.9%.

Stomach content analysis of White Hake and Redfish has provided a glimpse into the trophic relationship between these species and why they are commonly caught together (Ouellette-

Plante et al. 2020). This study revealed that fishes contributed the most to White Hake (22 to 65 cm length) diet and that, when all prey types were combined, Redfish was their most important prey. The shrimp group and zooplankton ranked second and third, respectively. The stomach contents obtained from Redfish revealed that their diet is size dependent. Redfish smaller than 25 cm (7 to 24 cm) preyed mainly on zooplankton and those larger than 25 cm (25 to 48 cm) fed mostly on shrimp and to a lesser extent fish. Less than 5% of the analyzed Redfish stomachs contained fishes and no White Hake was observed in any of the stomachs.

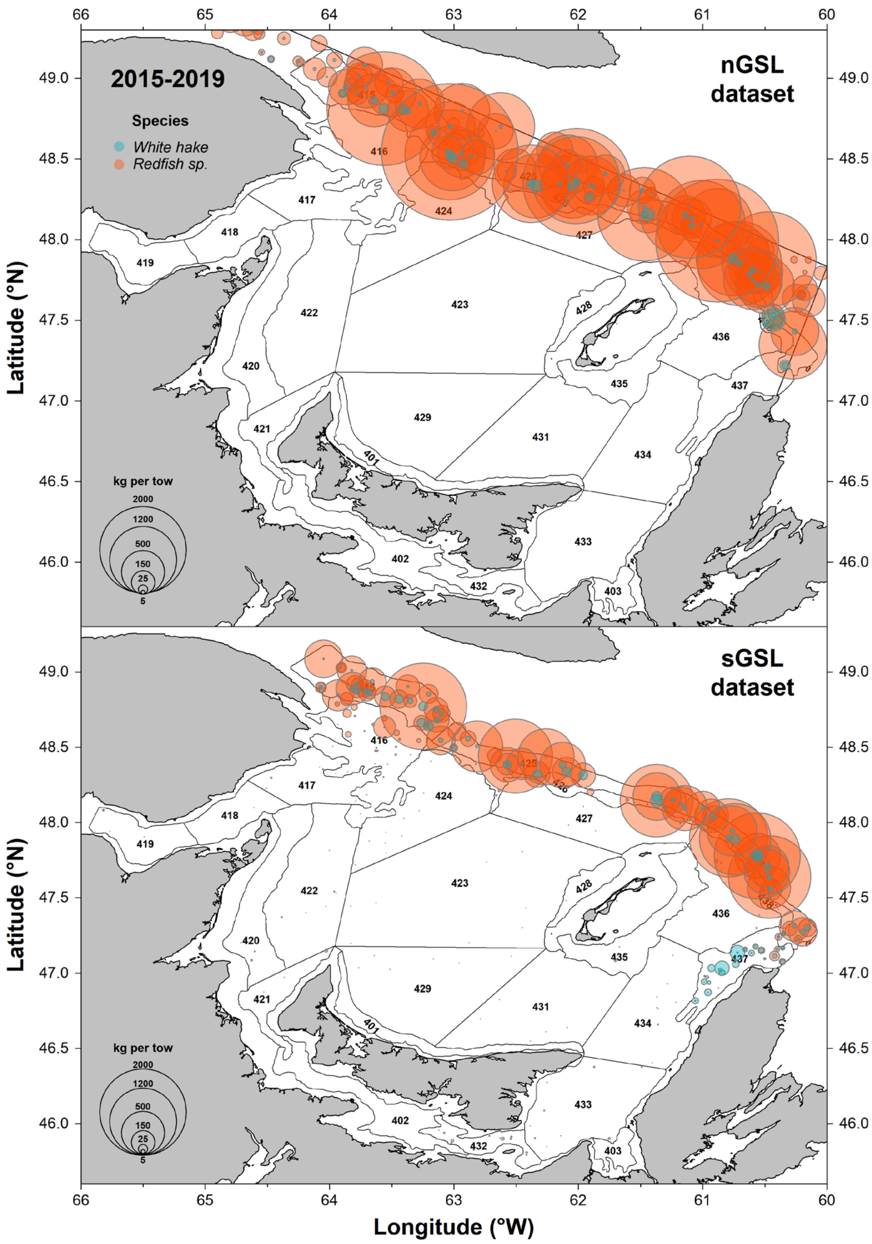

Figure 4. Spatial distribution and abundance (kg per tow) of White Hake and Redfish spp. from the nGSL (upper panel) and the sGSL (lower panel) bottom trawl research vessel survey for 2015 to 2019.

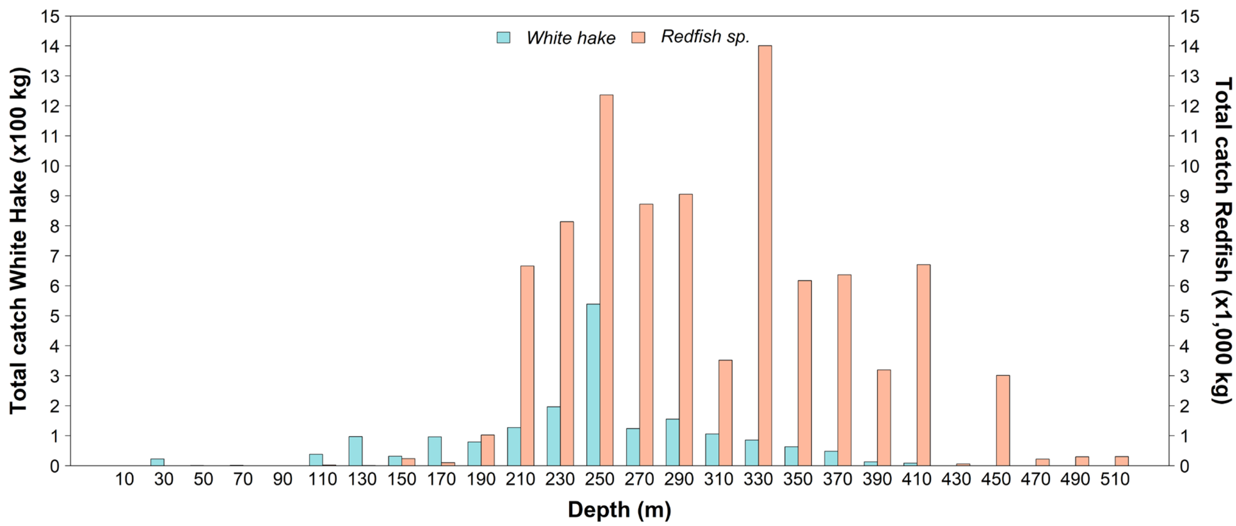

Figure 5. Total catch (kg) of White Hake and Redfish at the average depth of each sets from the bottom trawl research vessel surveys for 2015 to 2019.

ASSESSMENT

White Hake bycatch

Evaluation of the bycatch of White Hake from both fishery-dependent and fishery-independent data when evaluated on an individual set-basis was on average 10.5%, with a median ranging from 0 to 1.6% (Fig. 6). The high averages were driven by some sets where the bycatch was over 100% White Hake. The average bycatch would also have been greater in the sGSL RV survey if we had not constrained sets to the maximum bycatch observed in the other data sources (cut-off of 250% based on the maximum observed in the fishery-dependent and nGSL RV survey datasets).

Although for each data source the bycatch distribution is skewed toward the median (Fig. 6), the observed maximum and mean values of the fishery-dependent data source that specifically targeted Redfish revealed that in some instances the interaction with White Hake could be extremely high (> 130%; Fig. 6). The targeted Redfish fishery had very high bycatch of White Hake in June (mean of 42.6% and median of 11.4%), July (mean of 35.2% and median of 6.6%), and in December (mean of 47.6% and median of 7.11%) (Fig. 7). The other months had lower bycatch with medians of 1.7%, a maximum of 6.2% and a mean of 3.3% (Fig. 7).

As observed in the spatial distribution of both species, the area where White Hake are most likely to be caught if Redfish are the targeted species cover the entire Laurentian channel portion of the sGSL (Fig. 8). The area north of Gaspé, north of the Orphan Bank and north-east of the Magdalen Island have the highest probability of bycatch whereas the Cape Breton Trough has the lowest values. Moreover, the depth distribution of the standardized catch ratios of bycatch confirmed that at depths below 280 m, the bycatch values of the combined datasets were almost entirely under 10% with only few instances of values between 10 and 250% (Fig. 9). Deeper than 380 m, all catches had bycatch less that 10% and below 440 m the bycatch was at 0%. However, shallower than 280 m the range of bycatch are much higher with few cases of values bycatch values less than 10%.

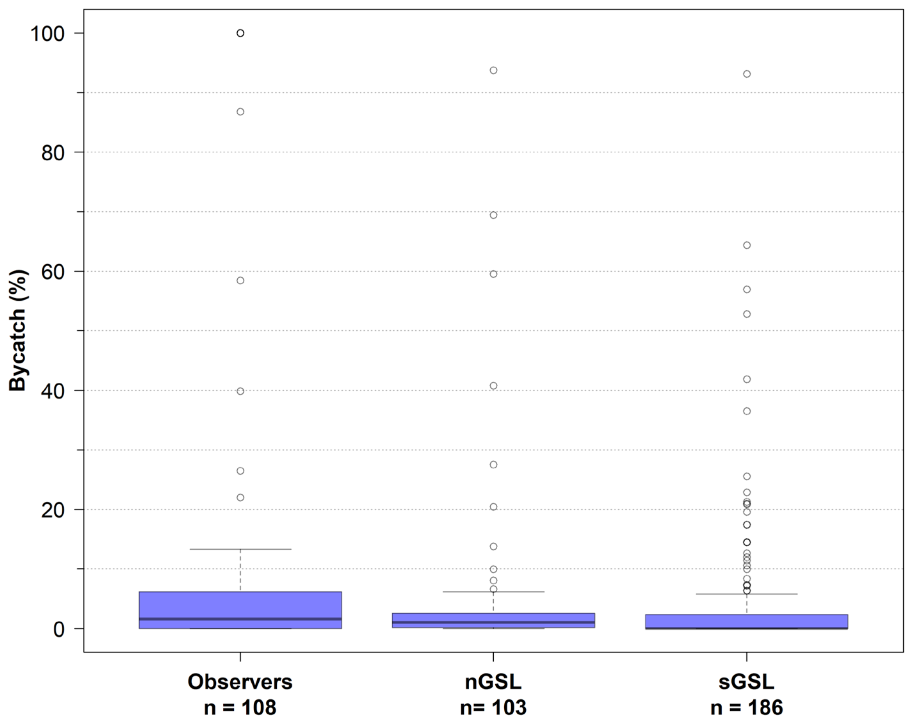

Figure 6. Box plots of bycatch (%) of White Hake from the fishery-dependent dataset (observer), and the fishery-independent datasets (nGSL and sGSL bottom trawl research vessel surveys). In the event a set had no Redfish but White Hake in the observer dataset, the bycatch was set at 100%. Only the sets with a catch of Redfish were kept in the nGSL and sGSL datasets, and the maximum bycatch was set to 250 %.

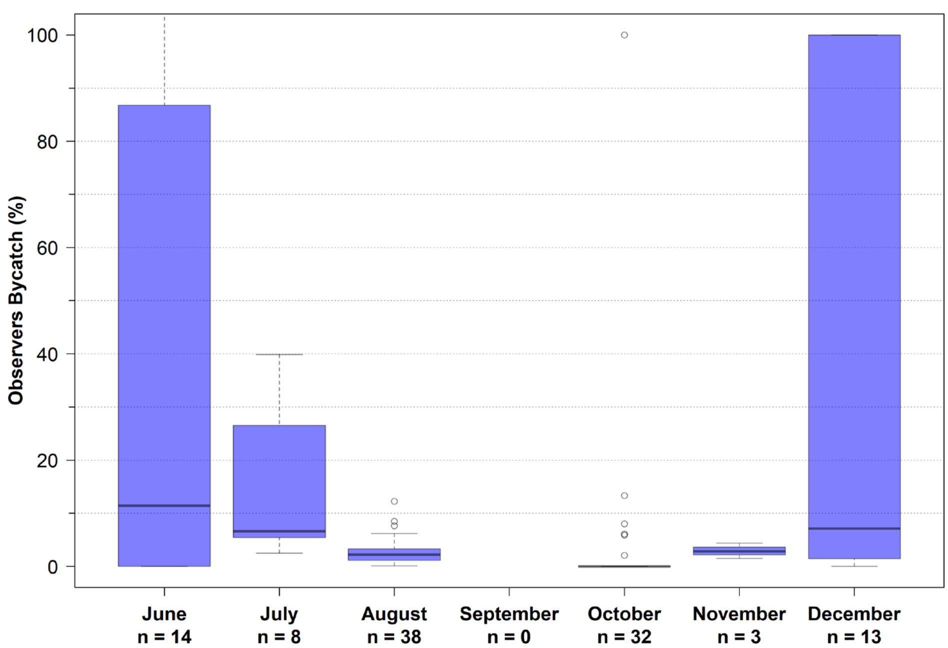

Figure 7. Monthly box plots of bycatch (%) of White Hake from the fishery-dependent observer dataset. In the event a set had no Redfish but White Hake, the bycatch was set at 100%.

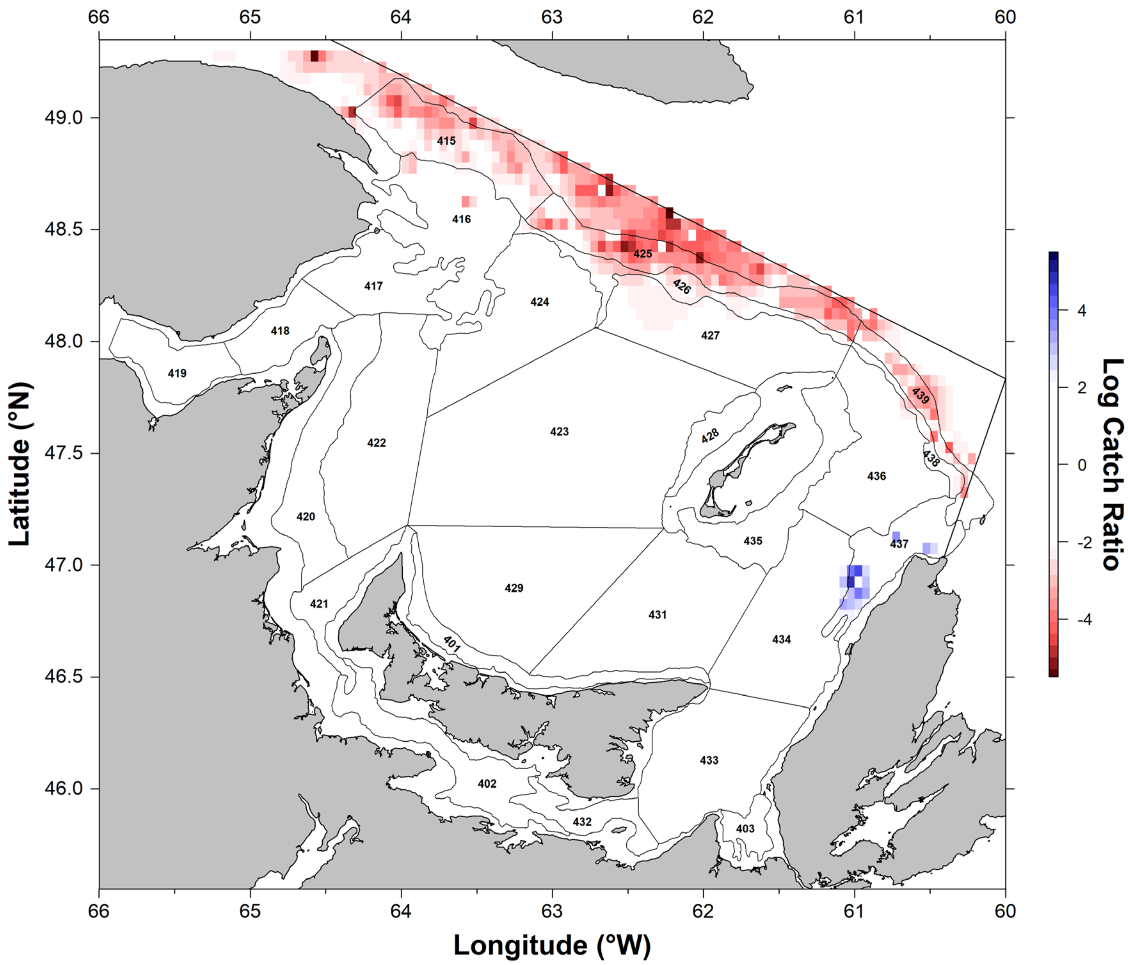

Figure 8. Inverse distance weighting of catch ratio of White Hake over Redfish from both the fishery-dependent (2015-2018) and fishery-independent (2015-2019) data sources. The catch ratio were standardized to constrain the values between 0 and 1 and the resulting results were plotted on a log-scale.

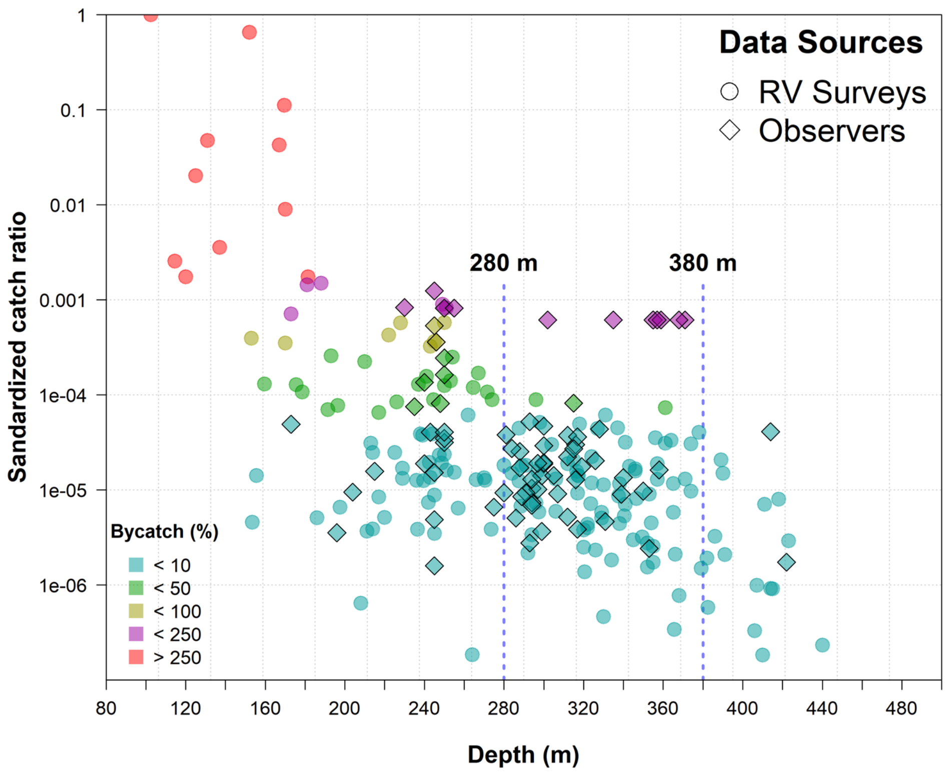

Figure 9. Standardized catch ratio of bycatch of White Hake over Redfish by depth (m) from both the fishery-dependent (2015-2018) and fishery-independent (2015-2019) data sources.

White Hake Abundance and Life History Parameters

Recent species abundance

An age-structured population model was fit to the White Hake data to estimate abundance and biomass for the years 1978 (the first year with reliable fishery catch-at-age data) to 2019 and for age 2 to ages 10+ (i.e., 10 years and older). Independent time series of the instantaneous rate of natural mortality (*M*) were estimated for three age groups: ages 2 and 3, ages 4 and 5 and ages 6+. The results from a Statistical Catch at Age (SCA) model fit to the age-aggregated RV and MS survey biomass indices and to the proportions at age in these surveys and in the fishery catch are presented here.

Research vessel indices (RV)

The length-based indices of White Hake adult (≥ 45 cm) abundance and biomass showed a sharp decline from 1985 to 1995, and have remained at very low levels since (Fig. 10). The estimated decline in the abundance of the adult length class from 1985 to 2014 (about 3 generations) was over 90%. For juveniles (< 45 cm) there was no observable trend in biomass or abundance between 1971 and 2019 (Fig. 10).

The age composition of the sGSL White Hake population has collapsed over time (Fig. 11). In the 1978-1989 period, White Hake were caught up to ages 10 years and older. However, no White Hake over 7 years of age has been observed in the survey since 1989. Since the 2002-2007 period, the spawning population has been restricted to essentially ages 4 and 5 years, with age 4 comprising about 75% of the spawners.

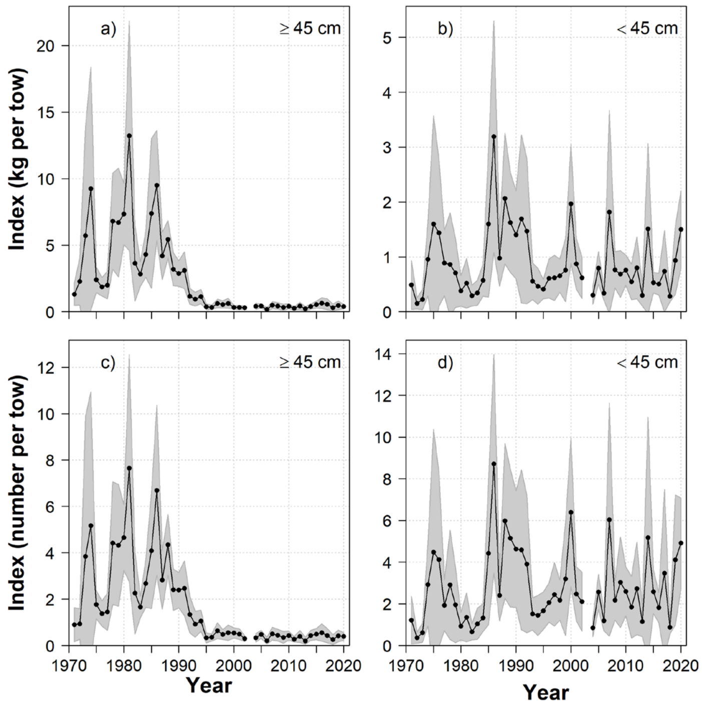

Figure 10. Mean annual catch indices (kg per tow, panels a) and b), number per tow, panels c) and d)) of White Hake ≥ 45 cm in length (a and c) and < 45 cm (c and d) in the sGSL bottom trawl research vessel survey. The gray shading denote approximate 95% confidence limits (± 2 standard errors).

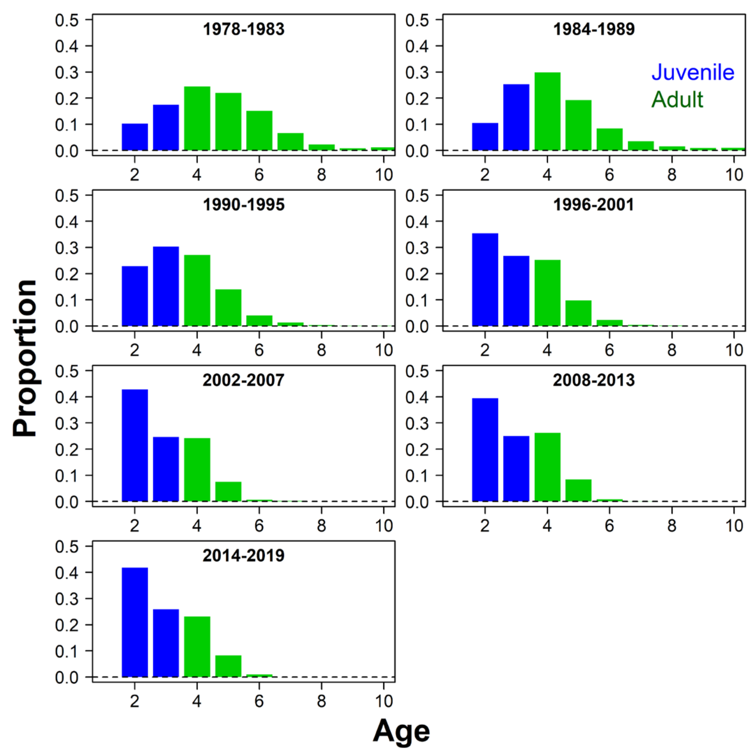

Figure 11. Proportion-at-age of White Hake in sGSL bottom trawl research vessel survey.

Mobile sentinel index (MS)

Age-aggregated White Hake abundance and biomass indices from the MS fluctuated without trend between 2003 and 2019 (Fig. 12). White Hake were at a low but relatively stable level during this period according to the sGSL RV survey. The age-aggregated abundance and biomass indices from the MS are consistent with the sGSL RV results.

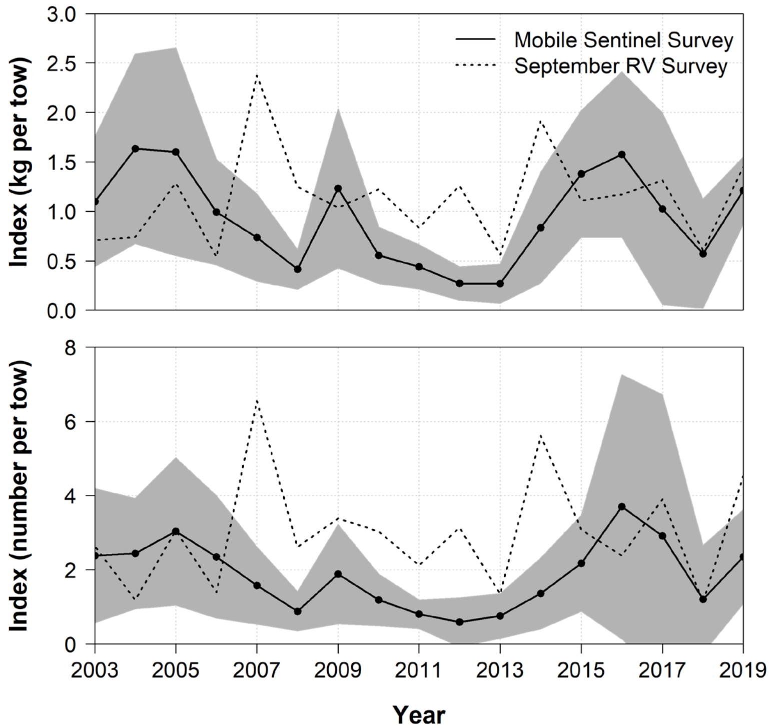

Figure 12. Annual mean catch indices of White Hake caught in the sGSL mobile Sentinel trawl survey (kg per tow, top panel; number per tow, bottom panel). The gray shading denotes approximate 95% confidence limits (± 2 standard errors). The dashed line represents the same information from the bottom trawl research vessel (RV) survey.

Population model estimates

Estimated juvenile abundance (ages 2-3 years) fluctuated without trend over the 42 year time series (1978-2019, Fig. 13). Juvenile abundance was estimated to be 123 million at the start of the time series in 1978 and 169 million at the end of the time series in 2019. Average juvenile abundance was 102 million in the 1980s, 83 million in the 1990s, 107 million in the 2000s and 110 million in the 2010s. In contrast, adult abundance was at a high level from the late 1970s to the late 1980s, peaking at 56 million fish in 1980 and 51 million in 1986. It then declined steadily to 15 million in 1995, and remained at a low level for the remainder of the time series. Average adult abundance since 2005 is estimated to be 11.6 million, about an 80% decline from the peak levels in the 1980s.

Estimated spawning stock biomass (SSB) was at a high level from 1979 to 1987, averaging 56,425 t and peaking at 63,400 t in 1981 (Fig. 14). Estimated SSB then declined sharply in the late 1980s and the 1990s, falling to 8,860 t by 2000, an 85% decline. SSB has remained at a very low level since then. Estimated SSB at the start of 2019 was 7,396 t, about 13% of the average level in 1979 to 1987.

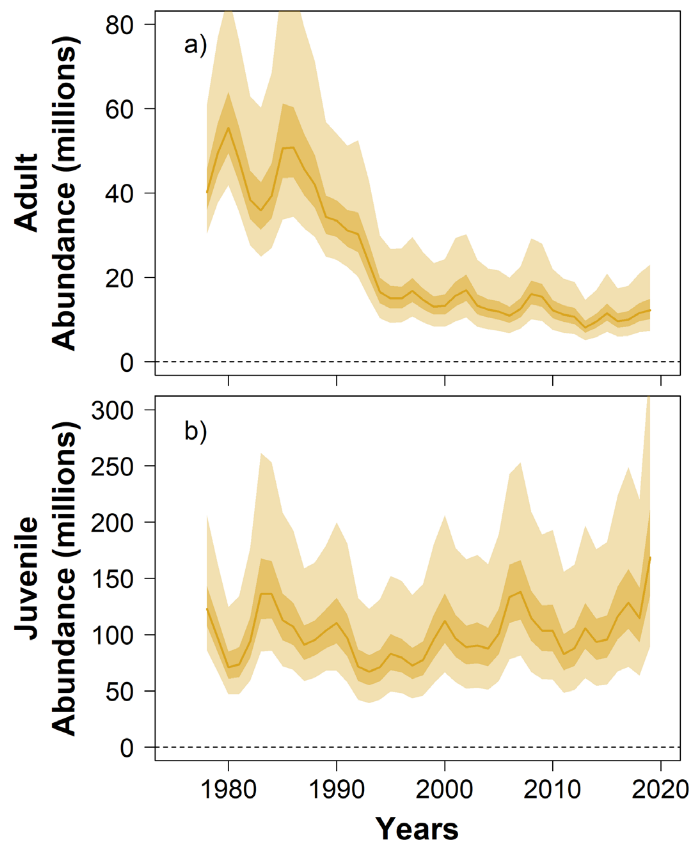

Figure 13. Estimated abundance of adult (a) and juvenile (b) White Hake in the SGSL. Lines are the median estimates of abundance, the heavy shading is the middle 50% of estimates and the light shading shows the 95% confidence limits.

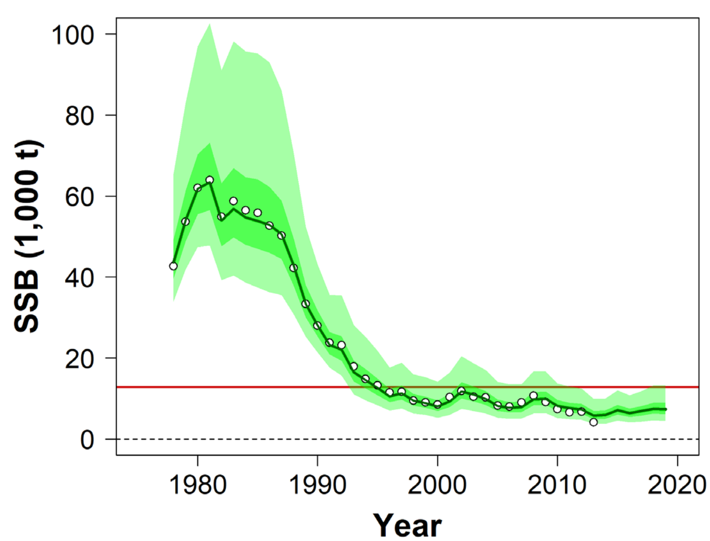

Figure 14. Estimated SSB of White Hake in the sGSL. The line is the median estimate of SSB, the heavy shading is the middle 50% of estimates and the light shading is the 95% confidence limits. The circles show the median estimates of SSB obtained by the 2015 RPA model. The red horizontal line is the LRP of 12,800 t.

Despite the severe decline in SSB, recruitment of age-2 fish has fluctuated without trend since 1978 (Fig. 15, top panel). Some of the strongest recruitment has been produced by the weakest SSB. The estimated recruitment in 2019 is the strongest on record, though the uncertainty in this estimate is very high. The estimated recruitment rate has increased substantially since the early 1990s (Fig. 15, bottom panel). The average estimated recruitment rate for the 1978-1992 cohorts was 1,400 age-2 fish per kt of SSB. The average rate for the 2008-2017 cohorts was 13,900 age-2 fish per kt of SSB, a ten-fold increase. The estimate for the most recent cohort (2017) is the highest on record (23,800 age-2 fish per kt of SSB), though again uncertainty in the estimate is very high.

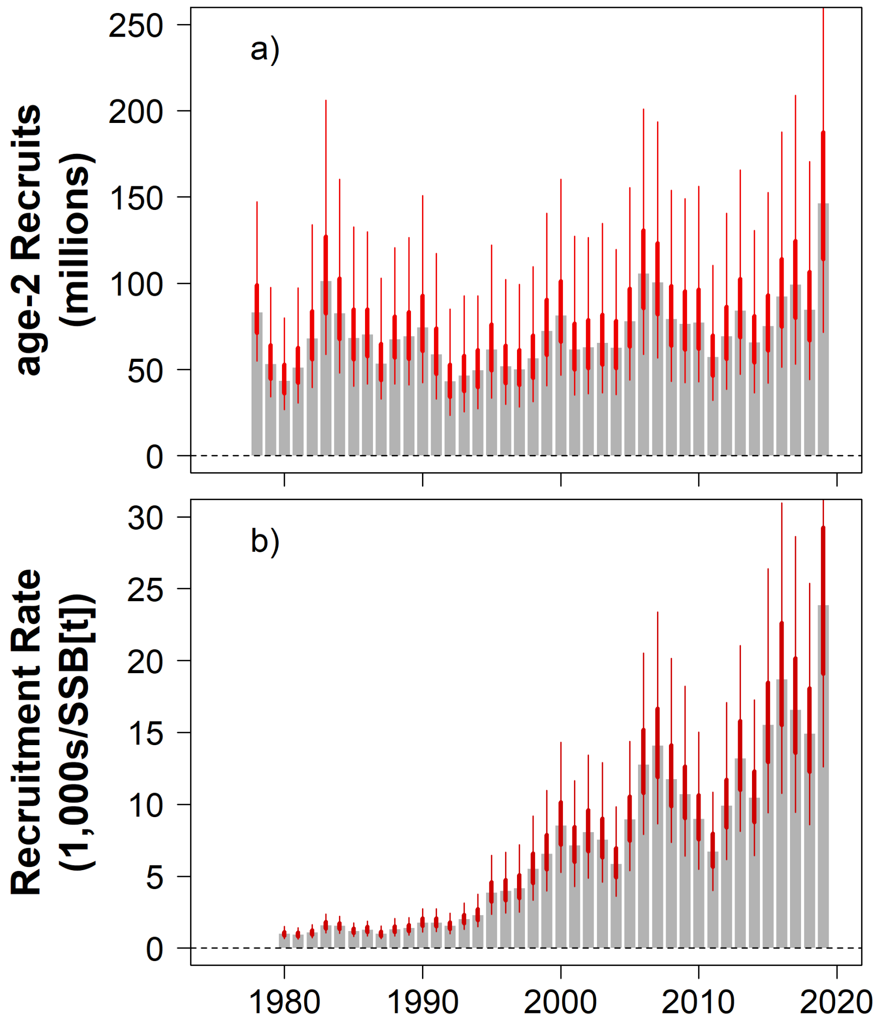

Figure 15. Age-2 recruit abundance (a) and recruitment rate (b) of White Hake in the sGSL. Grey bars show the median estimates, thick red lines show the middle 50% of estimates and thin red lines show the 95% confidence limits.

The instantaneous rate of fishing mortality *F* has been at a negligible level for the past 10-15 years (Fig. 16). However, while *F* of White Hake has been negligible since the mid-2000s, the population is now so low that very small landings can cause significant fishing mortality. For example, in 1978 to 1986 annual landings averaged about 8000 t, SSB averaged 54,660 t, and 6+ *F* averaged 0.25. However in 1998 to 2001, when SSB averaged 8,670 t, average annual landings of only 236 t resulted in the same average 6+ *F*.

In most years, the dominant source of mortality for sGSL White Hake has been natural mortality (Fig. 16). For juveniles (ages 2-3 years), estimated m increased from 0.58 in 1978 to 1.13 in 2013 (44% to 68% annual mortality). For older ages, increases in m were even more extreme, from 0.38 in 1978 to an average value of 1.97 since 2000 for ages 4-5 (from 32 to 86% annually), and from 0.32 to 1.67 (from 27 to 81% annually) for ages 6 years and older. For ages 2-3, *M* has been gradually increasing since the late 1980s and may be continuing to increase. For the older ages, *M* steadily increased from the start of the time series in 1978 to about 2000 and has since been roughly stable at a very high level.

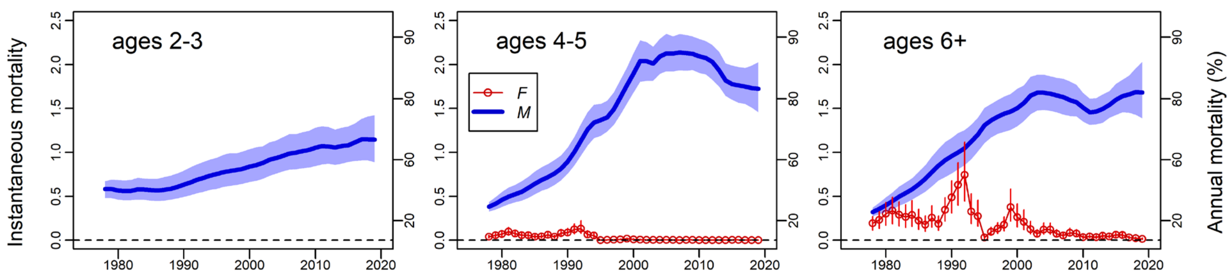

Figure 16. Estimated instantaneous rates of fishing and natural mortality (F and M, respectively) by age group (ages 2-3, ages 4-5, ages 6+). The values shown for F are abundance-weighted averages for each age length group (1978:2006). Blue lines and red circles show the median estimates. Shading and vertical lines show their 95% confidence intervals based on MCMC sampling. The right-hand axis shows the corresponding annual mortality. Average Fs for ages 2 and 3 are not shown since they were negligible (< 0.001 in all years, < 0.00005 since 2000).

The natural mortality of large adult individuals has increased to very high levels in many fish species in the sGSL (Swain and Benoît 2015). This elevated natural mortality has been attributed to predation by Grey Seal in these species (e.g., Swain and Benoît 2015, Neuenhoff et al. 2019, Swain et al. 2019) including White Hake (Hammill et al. 2014, Swain et al. 2016).

White Hake population trajectories in a directed Redfish fishery

The sGSL White Hake population was projected forward for 25 years to evaluate the expected impact of bycatch on the population status given bycatch levels of 0, 20, 150, 250, 350, 500, 750 and 1,500 t. Uncertainty around the SSB projections was high, presumably reflecting the high variability in recruitment rates incorporated in the projections. The projections also exhibited a dampening 4-year cycle in SSB, a consequence of the record-high recruitment estimated for 2019. Projected SSB declined at all five catch levels, including no catch (Fig. 17). Based on the median estimates of SSB, a 38.7% decline in SSB was projected to occur over the 25-year period with no fishery catch. The estimated decline was virtually the same (39.3%) with an annual bycatch of 20 t, the average level in recent years. With annual bycatch of 150 t to 350 t, SSB was estimated to decline by 43% to 48%. With bycatch of 500 t to 1,500 t, SSB declined by 53% to 70% (Table 1).

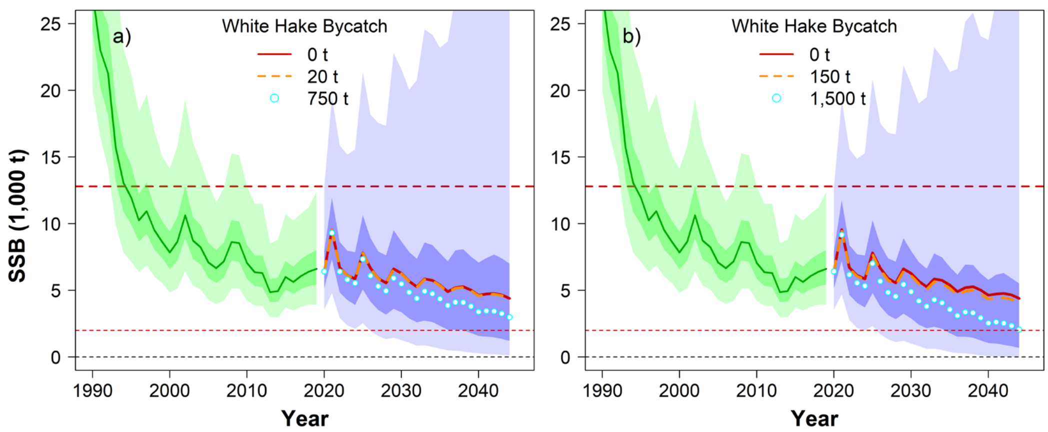

Figure 17. Estimated historical (green) and projected (other colours) SSB of sGSL White Hake at different levels of projected bycatch (0, 20, 150, 750 and 1,500 t). Lines and circles are the median estimate. Shading indicates the 50% (dark) and 95% (light) confidence intervals. These intervals are shown for the historical estimates and the projections at the highest bycatch levels in each panel. For the projections recruitment rates are sampled from the 2000-2019 period. The horizontal dashed lines represent the LRP of 12,800 t and the level of 2,000 t which represents the limit of a very high risk of local extinction.

Table 1. Risk analysis table for the effects of different levels of bycatch of White Hake on the status of the sGSL White Hake population. Risk estimates are based on 25-year population projections. Two sets of projections were conducted, one sampling from the recruitment rates observed in 2000 to 2019 and one sampling from the recruitment rates observed in 2000 to 2010. Recruitment rates greater than any previously observed occured in the 2011-2019 period. Three statistics are reported: 1) the percent decline in SSB over the 25-year projection, 2) the probability that SSB would be less than 4,000, 2,000 or 1,000 tonnes at the end of the 25-year projection, and 3) the median estimates of SSB in years 5, 10, 15, 20 and 25 of the projections. SSB is reported in kilotonnes (kt). Horizontal lines indicate projections that were not conducted.

Bycatch Level (t)	25-year decline in SSB (%)	Probability (%) SSB25 will be below			Median estimates of SSB (kt) at year				
		4,000 t	2,000 t	1,000 t	2024	2029	2034	2039	2044
Recruitment rates from 2000-2019									
0	38.7	46.2	21.8	7.9	5.9	6.6	5.7	5.0	4.4
20	39.3	46.8	22.4	8.2	5.8	6.6	5.7	5.0	4.3
150	43.0	49.4	25.7	10.2	5.8	6.4	5.5	4.8	4.1
250	45.7	51.3	28.0	12.2	5.7	6.3	5.4	4.6	3.9
350	48.4	53.1	30.2	13.8	5.7	6.3	5.2	4.4	3.7
500	52.0	55.1	33.4	17.7	5.7	6.2	5.2	4.2	3.4
750	57.2	59.0	37.9	20.7	5.6	5.9	4.8	3.8	3.0
1,500	69.9	67.3	49.4	32.4	5.3	5.4	4.1	2.9	2.1
Recruitment rates from 2000-2010									
0	82.3	-	-	-	4.7	4.3	2.8	1.9	1.3
20	82.7	-	-	-	4.7	4.2	2.8	1.8	1.2
150	84.9	-	-	-	4.7	4.1	2.7	1.7	1.1
250	-	-	-	-	-	-	-	-	-
350	-	-	-	-	-	-	-	-	-
500	-	-	-	-	-	-	-	-	-
750	91.5	-	-	-	4.4	3.7	2.2	1.1	0.6
1,500	95.7	-	-	-	4.3	3.4	1.7	0.7	0.2

Probabilities that projected SSB would decline below 4,000, 2,000 and 1,000 t was estimated at each catch level based on the MCMC sampling (Fig. 18). With no fishery catch, the probabilities that SSB would be below 1,000, 2,000 and 4,000 t were 8%, 22% and 46%, respectively. Probabilities were nearly identical with annual bycatch of 20 t (the recent average), and similar with 150 t of bycatch. These probabilities were substantially greater with bycatch of 750 or 1,500 annually. The probability that SSB would be less than 4000 t at the end of the 25-year projection was estimated to be 46.2% with no bycatch, increasing to 53.1% with 350 t of bycatch and 67.3% with 1,500 t of bycatch. The probabilities of a decline below 2,000 t of SSB were 21.8%, 30.2% and 49.4% at these levels of bycatch. For a population that had an SSB near 60,000 t in the early 1980s, an SSB near 2,000 t represents a very high risk of local extinction. The probabilities of a decline in SSB to below 1,000 t at these three bycatch levels was estimated to be 7.9%, 13.8% and 32.4 %, respectively.

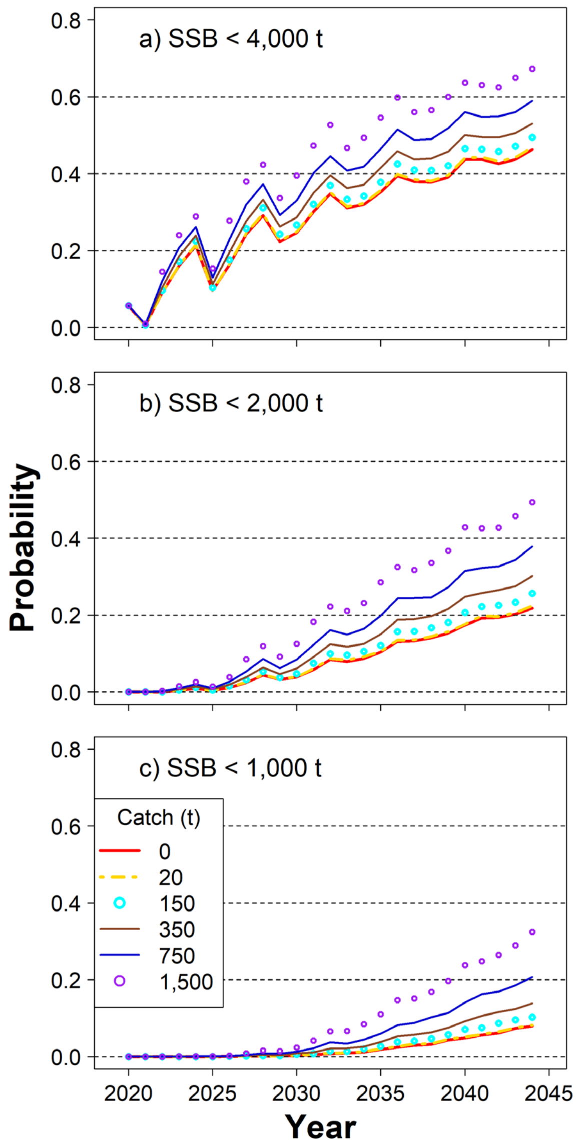

Figure 18. Probability that projected SSB is below 1,000, 2,000 or 4,000 t at different levels of White Hake bycatch (0, 20, 150, 350, 750, and 1,500 t).

When the depletion during the year before recruitment is considered, the adult abundance decline is extreme in the projection (Fig. 19). With bycatch at 750 t, adult abundance is 5.2 million at the start of the year and 0.7 million at the end of the year, 14% of the starting abundance. With bycatch of 1,500 t, the decline over the final projection year is from 3.7 million to 0.4 million. At these levels of bycatch, the adult stock would appear to be on the verge of disappearance each year until replenished by recruitment.

The White Hake population in the sGSL currently does not appear to be viable at recruitment rate levels that are less than extraordinary. Our projections incorporated the recruitment rates observed over the past 20 years (2000-2019). These rates were all very high, particularly those observed in the last five years (which were all the highest rates on record). Sampling from these recruitment rates, the estimated decline was 38.7% over the 25-year projection with no fishery catch. Restricting the sampling to the rates in 2000-2010, the estimated decline was 82.3%.

The fishing mortality rates estimated during the projections with bycatch levels of 150 t or less annually are very low (Fig. 20). With annual bycatch of 750 t fishing mortality increases to a high level (*F* near 1 or 63% annually) near the end of the projection. With annual catches of 1,500 t, *F* would increase to 3 or more (greater than 95% annually). At recent rates of natural mortality, *F* near 1 or more would clearly not be sustainable for the White Hake population at any recruitment rate that would be plausible. An *F* of 3 or more seems unlikely. A level this high would require extremely high fishing effort and/or catchability to the fishery. This would be expected to be especially unlikely for a bycatch species. On the other hand, large White Hake have tended to be caught in survey catches containing large quantities of Redfish in recent years (Fig. 4). White Hake preying on Redfish may concentrate in the vicinity of Redfish aggregations. This would result in high catchability to the Redfish fishery and high vulnerability to effort in this fishery.

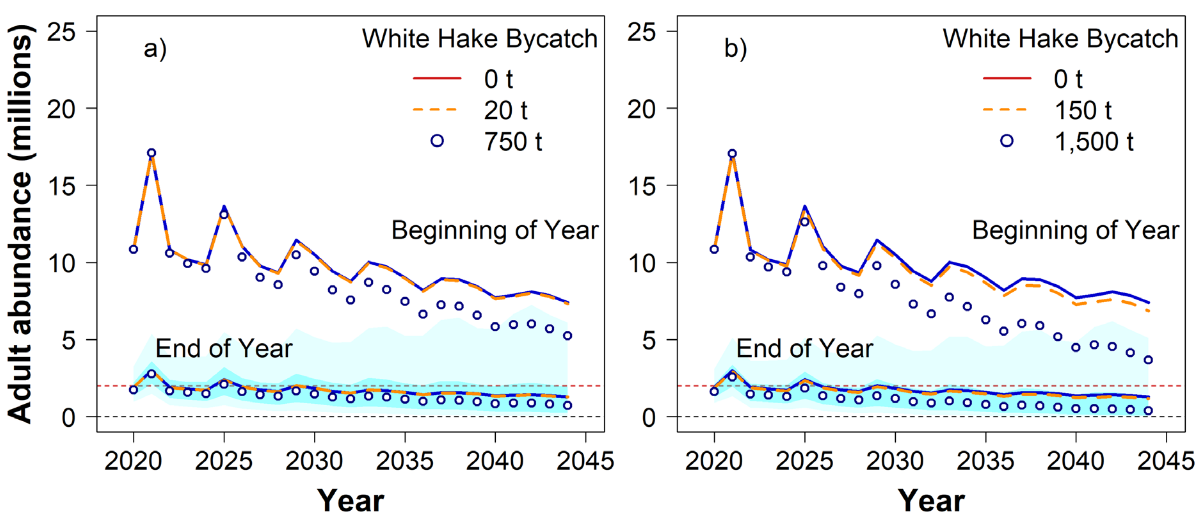

Figure 19. Projected adult abundance of sGSL White Hake at different levels of bycatch (a: 20 t and 750 t, b: 150 t and 1,500 t). Median estimates are shown for both the beginning of the year (upper lines and circles) and the end of the year before recruitment (bottom lines and circles). Shading shows the 50% (dark shading) and 90% (light shading) confidence intervals for the highest bycatch levels (circles) at the end of year.

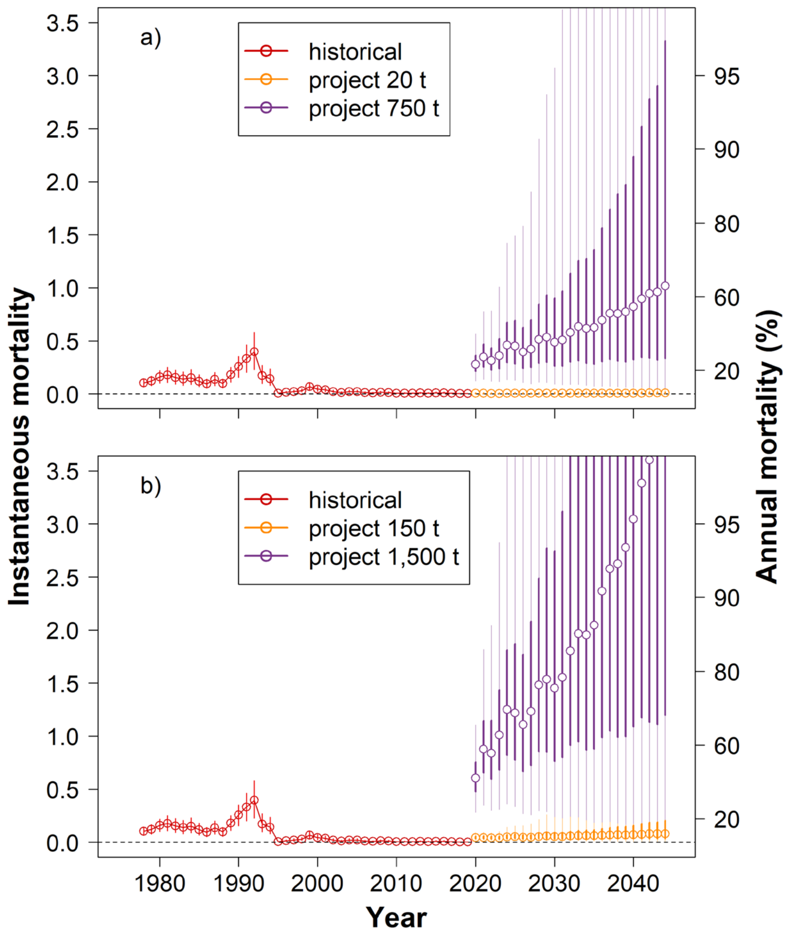

Figure 20. Projected fishing mortality rates during projections at different catch levels (a: 20 t and 750 t, b: 150 t and 1,500 t). Fishing mortality is shown for age 5 years. Circles show the median estimates. Heavy and light vertical lines show the 50% and 95% confidence intervals.

Sources of Uncertainty

This analysis is based on small scale fishery and multi-species surveys, however we had to assume that the average estimated bycatch rate of 10.5% would also apply to the expansion of the Redfish fishery. In reality, the bycatch rate may not be 10.5% for various reasons including the fishing technology, timing, and location that could reduce bycatch of White Hake. As Redfish continue to grow they may become too large for White Hake to consume which may have implications on the potential overlap of the species. Nonetheless, we used the average bycatch for our projections to be consistent with the precautionary approach. The 10.5% bycatch is also above the limit bycatch level for the Redfish fishery (up to 5%). As White Hake continue to decline their bycatch will also likely decline, but so will their ability to sustain bycatch. Because of the uncertainty in the eventual bycatch rates in an expanding Redfish fishery, projections of the White Hake population were based on White Hake bycatch levels and not linked to particular levels of Redfish catch. As the Redfish fishery develops it will be necessary to closely monitor White Hake bycatch in this fishery to ensure that it does not exceed acceptable levels.

Uncertainty around the SSB projections was high, presumably reflecting the high variability in recruitment rate incorporated in the projections. Recruitment rates of White Hake have progressively increased since the mid-1990s, repeatedly breaking records for the highest level observed. Causes of these high and increasing recruitment rates are not well understood, but they are now critical to the persistence of this population. Finally, White Hake catches ≥ 1,500 t would require very high fishing mortality (> 95%). It is questionable whether this is plausible.

CONCLUSIONS

The sGSL White Hake population (NAFO Div. 4T) has declined to very low biomass, and is continuing to decline despite very low landings (< 50 t annually since 2005). This failed recovery is due to extremely high natural mortality (81-85% annually for adult fish). Predation by grey seals appears to be an important cause of this high mortality. This stock persists despite this high natural mortality because recruitment rate has also increased to unusually high levels. If recruitment rates were to decline to the lower (but still high) rates observed in 2000 to 2010 the population would be expected to decline at twice its current rate if natural mortality remained high. Furthermore, the spawning stock, which consisted of ages 4 to 10 years and older in the past, now consists mostly (75%) of 4 year olds. Given only a single reproductive cohort, extremely high natural mortality of adults and the uncertain persistence of its current high recruitment success, the status of this population remains very precarious.

White Hake and Redfish have largely overlapping spatial and depth distributions, as White Hake have shifted their distribution almost exclusively to the deep waters of the Laurentian Channel which is the same distribution as Redfish. This is also further compounded by the diet interdependencies. Both White Hake and Redfish are evenly distributed along the slope of the Laurentian channel, with no specific areas within the channel where both species were not caught together. However, the Cape Breton Trough was one of the few areas where White Hake was captured at greater densities than Redfish. Given the spatial overlap between both species, it was expected that bycatch of White Hake in the Redfish fishery could be substantial. This overlap was found to be greater at depth shallower than 380 m, and in water deeper than 440 m, White Hake were not captured. Moreover, deeper than 350 m, the proportion of White Hake is 34% sGSL DU and 66% Atlantic DU.

Across the three data sources, the average bycatch rate of White Hake associated with catches of Redfish was 10.5%. However, our estimates of the impacts of different bycatch levels do not depend on this 10.5%. Consequently, our results provide guidance on tolerable bycatch limits. The Redfish experimental and index fisheries also revealed that this level of bycatch could be much higher depending on the month that fishing occurred. Bycatch was very high in June, July, and December. Moreover, the Laurentian Channel represents overwintering habitat for multiple species already at low abundances. Caution should be taken when considering opening a fishery on overwintering grounds.

Based on projections, White Hake catches of ≤ 150 t would result in very little increase in population decline. However, catches > 150 t would increase the rate of decline and lead to local extinction if persistent.

sGSL White Hake has also been identified as a major fish stock and as a stock that has declined below its limit reference point. Bill C-68 requires that a rebuilding plan be developed that is in line with the Precautionary Approach Framework which states that management actions must promote stock growth and removals by all human sources must be kept to the lowest possible level. At present, the maximum allowable bycatch of White Hake is 30 t in the 4T management zone. Bycatch of White Hake is limited to 5% of target species catch weight by fishing trip for Redfish and 10% for other species. In the last 5 years, an average of 20 t of White Hake has been captured as bycatch, of this 20 t approximately 50% has been from the experimental and index Redfish fisheries. As such, of the 30 t bycatch limit of White Hake only 20 t is available to be caught in an expanding Redfish fishery. With their overlapping distributions White Hake will be a choke species for the Redfish fishery at 30 t bycatch. The four

Management Procedures that met the goal of maintaining Redfish spp. in the healthy zone including an initial TAC of 14,500 t for both Units 1 and 2. It is unclear how the TAC will be distributed spatially and temporally in both Units 1 and 2 and consequently how much will overlap with NAFO Div. 4T. Prior to the moratorium on Redfish, the fishery largely took place in NAFO Division 4RS, however both the experimental and index fisheries have targeted the Laurentian Channel along the boundary of NAFO Division 4T and 4S.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Mark Laflamme	DFO Gulf, CSAS
Mélanie Roy	DFO Gulf, CSAS
Matthew Hardy	DFO Science Gulf, Chair
Doug Swain	DFO Science Gulf
Nicolas Rolland	DFO Science Gulf
Jenni McDermid	DFO Science Gulf
Daniel Ricard	DFO Science Gulf
Rémi Sonier	DFO Science Gulf
Francois Turcotte	DFO Science Gulf
Caroline Senay	DFO Science Quebec, IML
Daniel Lapierre	DFO FM Gulf
Leigh Edgar	DFO FM NCR
Lauren Bottke	DFO FM NCR
Kris Vascotto	Atlantic Groundfish Council (AGC)
Brian Boudreau	Pêcheur GNS
Mathieu Pellerin	DFO FM Québec
Stéphanie Labbé-Giguère	DFO FM Quebec
Diane Amirault-Langlais	DFO SARP Gulf
Lisa Robichaud	DFO SARP Gulf
Ryan Chleback	DFO Science NCR
Elizabeth Thompson	DFO Science Gulf
Claude Pelletier	Government of NB
Pierre Mallet	DFO FM Gulf
Jason Spingle	Fish, Food and Allied Workers (FFAW)
Adam Mugridge	Government of NS

SOURCES OF INFORMATION

This Science Advisory Report is from the February 17, 2021 regional advisory meeting meeting on the impacts of increases in fishing effort on White Hake (*Urophycis tenuis*), Southern Gulf of St. Lawrence Population. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Benestan, L., Rougemont, Q., Senay, C., Normandeau, E., Parent, E., Rideout, R., Bernatchez, L., Lambert, Y., Audet, C., and Parent, G.J. 2020. Population genomics and history of speciation reveal fishery management gaps in two related redfish species (Sebastes mentella and Sebastes fasciatus). Evol. Appl.

Caddy, J. 1999. Fisheries management in the twenty-first century: Will new paradigms apply? Rev. Fish. Biol. Fish. 9: 1–43.

Chouinard, G.A., and Hurlbut, T.R. 2011 An atlas of the January distribution of selected marine fish species in the Cabot Strait from 1994 to 1997. Can. Tech. Rep. Fish. Aquat. Sci. 2967: viii + 94 p.

COSEWIC. 2013. COSEWIC assessment and status report on the White Hake Urophycis tenuis in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 45 pp.

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

DFO. 2011. Recovery potential assessment of redfish (Sebastes fasciatus and S. mentella) in the northwest Atlantic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/044. (Erratum: June 2013).

DFO. 2016. Recovery Potential Assessment for White Hake (Urophycis tenuis): Population of the Southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/034.

DFO. 2018. Units 1+2 Redfish Management Strategy Evaluation. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/033.

DFO. 2020a. Updated indices of abundance to 2019 for Winter Flounder from NAFO Div. 4T, Witch Flounder from NAFO Divs. 4RST and White Hake from NAFO Div. 4T. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/008.

DFO. 2020b. Redfish (Sebastes mentella and S. fasciatus) Stocks Assessment in Units 1 and 2 in 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/019.

Hall, M.A., Alverson, D.L., and Metuzals, K.I. 2000 By-catch: Problems and solutions. Mar. Pollut. Bull. 41: 204–219.

Hammill, M.O., Stenson, G.B., Swain, D.P., and Benoît, H.P. 2014. Feeding by grey seals on endangered stocks of Atlantic cod and white hake. ICES J. Mar. Sci. 71: 1332-1341.

Neuenhoff, R. D., D. P. Swain, S. P. Cox, M. K. McAllister, A. W. Trites, C. J. Walters, and M. O. Hammill. 2019. Continued decline of a collapsed population of Atlantic cod (Gadus morua) due to predation-driven Allee effects. Canadian Journal of Fisheries and Aquatic Sciences. 76: 168-184.

Ouellette-Plante, J., Chabot, D., Nozères, C. and Bourdages, H. 2020. Diets of demersal fish from the CCGS Teleost ecosystemic surveys in the estuary and northern Gulf of St. Lawrence, August 2015-2017. Canadian Technical Report of Fisheries and Aquatic Sciences, 3383: v + 121 p.

Roy, D., Hurlbut, T.R. and Ruzzante, D.E. 2012. Biocomplexity in a demersal exploited fish, white hake (Urophycis tenuis): depth related structure and inadequacy of current management approaches. Can. J. Fish. Aquat. Sci. 69: 415-429.

Senay, C., Gauthier, J., Bourdages, H., Brassard, C., Duplisea, D., and Ouellette-Plante, J. 2019. Redfsh (Sebastes mentella and S. fasciatus) stocks status in Unit 1 in 2017. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/002: viii + 61 p.

Senay, C., Ouellette-Plante, J., Bourdages, H., Bermingham, T., Gauthier, J., Parent, G., Chabot, D., and Duplisea, D. 2021. Unit 1 Redfish (Sebastes mentella and S. fasciatus) stock status in 2019 and updated information on population structure, biology, ecology, and current fishery closures. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/015. xi + 119 p.

Swain, D.P. & Benoît, H.P. 2015. Extreme increases in natural mortality prevent recovery of collapsed fish populations in a Northwest Atlantic ecosystem. Marine Ecology Progress Series, 519, 165-182.

Swain, D.P., Hurlbut, T.R. and Benoît, H.P. 2012. Pre-COSEWIC review of variation in the abundance, distribution and productivity of white hake (Urophycis tenuis) in the southern Gulf of St. Lawrence, 1971-2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/066. iii + 74 p.

Swain, D.P., Benoît, H.P., & Hammill, M.O. 2015. Spatial distribution of fishes in a northwest Atlantic ecosystem in relation to risk of predation by a marine mammal. J. Anim. Ecol. 84: 1286-1298. doi: 10.1111/1365-2656.12391.

Swain, D.P., Savoie, L., and Cox, S.P. 2016. Recovery potential assessment of the Southern Gulf of St. Lawrence Designatable Unit of White Hake (Urophycis tenuis Mitchill), January 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/045. vii + 109 p.

Swain, D.P., Benoît, H.P., Hammill, M.O., and J.A. Sulikowski. 2019. Risk of extinction of a unique skate population due to predation by a recovering marine mammal. Ecological Applications. 29(6) e01921 1282-1299.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Gulf Region
Fisheries and Oceans Canada
P.O. Box 5030, Moncton, NB, E1C 9B6

Telephone: 506-851-6253
E-Mail: DFO.GLFCSA-CASGOLFE.MPO@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-39804-4 Cat. No. Fs70-6/2021-033E-PDF

Correct Citation for this Publication:

DFO. 2021. Impact of an expanding Redfish (*Sebastes* spp.) fishery on southern Gulf of St. Lawrence White Hake (*Urophycis tenuis*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/033.

Aussi disponible en français :

*MPO. 2021 Impact de l'expansion de la pêche du sébaste (*Sebastes *spp.) sur la merluche blanche (*Urophycis tenuis*) du sud du golfe du Saint-Laurent. Secr. can. de consult. sci. du MPO. Avis sci. 2021/033.*