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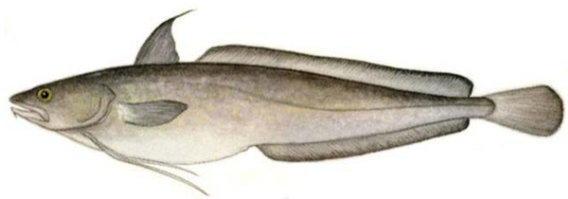
Maritimes, Newfoundland and Labrador, and Quebec Regions

Canadian Science Advisory Secretariat
Science Advisory Report 2016/035

RECOVERY POTENTIAL ASSESSMENT FOR WHITE HAKE (*Urophycis tenuis*): POPULATION OF THE ATLANTIC AND NORTHERN GULF OF ST. LAWRENCE



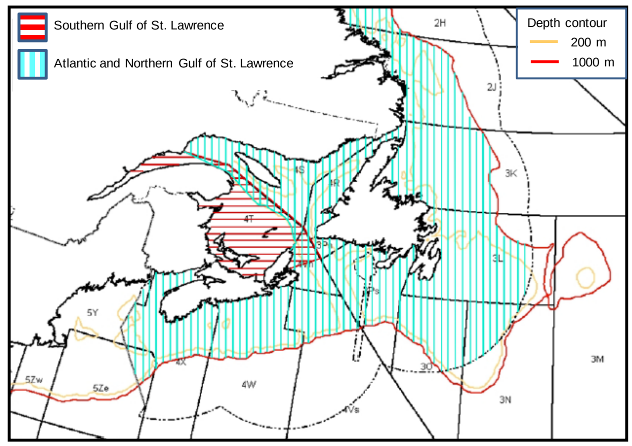


Figure 1. Geographic boundaries of the two Designatable Units of White Hake in eastern Canada as defined by COSEWIC (2013). The figure was extracted from COSEWIC (2013).

Context:

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) conducted its first assessment of White Hake (Urophycis tenuis Mitchill 1815) in Canadian waters in November 2013. Two populations or Designatable Units (DU) were identified: the southern Gulf of St. Lawrence (sGSL) population and the Atlantic and northern Gulf of St. Lawrence (ANGSL) population. COSEWIC assessed the sGSL population as endangered and the ANGSL population as threatened.

When a species is assessed as Threatened or Endangered by COSEWIC, Fisheries and Oceans Canada (DFO) undertakes a number of actions required to support implementation of the Species at Risk Act (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery, and this advice has typically been developed through a Recovery Potential Assessment (RPA). In support of listing recommendations for White Hake 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 updates and consolidates any existing advice regarding White Hake in the ANGSL DU.

This Science Advisory Report is from the January 14 to 16, 2015 science peer review meeting of the Recovery Potential Assessment of White Hake 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 COSEWIC Marine Fish Subcommittee and US National Marine Fisheries Service (NOAA).

SUMMARY

Biology, Abundance, Distribution and Life History Parameters

- White Hake in the Atlantic and northern Gulf of St. Lawrence (ANGSL) Designatable Unit (DU) was assessed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2013. Adult abundance was estimated to have declined by approximately 70% over the past three generations, with most of the decline occurring before the mid1990s.
- The ANGSL DU covers a very large geographic area of eastern Canada and several fisheries management units (Northwest Atlantic Fisheries Organization (NAFO) Divisions 3NO, Subdivisions 3Ps and 3Pn, Division 4RS, part of Division 4T, Divisions 4VWX and Canadian portions of Subarea 5), which have area-specific fisheries characteristics and management measures. The portion of the White Hake ANGSL DU that extends into US waters of Divisions 5Y and 5Z and the portion in Division 4T that overlaps with the southern Gulf White Hake DU were not included in abundance and trends analyses for the ANGSL DU.
- Indices of abundance from DFO research surveys available for four management units within the DU were used to characterize trends in abundance, for population modelling of abundance, and to define recovery targets for each management unit.
- Biomass and abundance indices for Divs. 3NOPs White Hake have been stable at low levels since 2003. Trends in abundance are characterized by occasional large recruitment that is quickly removed by fisheries targeting this species in Canadian waters and in the NAFO Regulatory Area of Divs. 3NO.
- The abundance index for Divs. 4VW White Hake peaked in the 1980s, and has been low since the mid1990s. The juvenile abundance index declined by 33% each decade since 1982, while the adult index declined by 73% per decade in 1982 to 1995 and remained stable afterwards.
- The abundance index for Divs. 4X5Zc White Hake peaked in the 1980s and 1990s, and has been variable at low levels in the 2000s. The juvenile abundance index declined by 31% each decade since 1991, while the adult index declined by 46% per decade during 1982 to 2004, and remained stable afterwards.
- The abundance index for Divs. 4RST* White Hake was higher in 1985 to 1990, declined to a minimum in 1994, then remained low. Total population abundance decreased by 80% over 1985 to 2014, while declines in abundance of mature and immature components were 64% and 69% (respectively) over 1987 to 2014.
- Although area occupied decreased over a short time period (1985 to 1992) in Divs. 4RST*, at a coarse geographic scale, there has not been any change in general distribution of White Hake in this DU.
- Recruitment of juveniles remains high in Divs. 4X5Zc, while the last three years showed low recruitment in Div. 4VW.
- In the past two decades, a primary source of mortality for White Hake in Divs. 4RST*, Divs. 4VW, and Divs. 4X5Zc was natural mortality (*M*), as indicated by high total mortality estimates (*Z*), correspondingly low relative fishing mortality values (*F*), and an ongoing decline or lack of increase (Divs. 4RST*) in adult indices. For Divs. 3NOPs, highly variable recruitment followed by directed fishing for White Hake (in Canadian waters and the NRA) appear to determine subsequent changes in adult biomass.

Threats and Limiting Factors to the Survival and Recovery of White Hake

- The only quantified threat to recovery of White Hake over the entire ANGSL DU is ongoing fishing mortality, which occurs in Canadian directed fisheries in Divs. 3NOPs and Subdiv. 3Pn, in the NRA by NAFO-member countries, and as bycatch in other commercial groundfish fisheries. However, fishing mortality presently appears not to be a limiting factor to White Hake survival and recovery.
- Habitat does not appear to be, nor is likely to become, a limiting factor to White Hake survival and recovery. There are no known anthropogenic threats that have reduced habitat quantity or quality for White Hake in the ANGSL DU.
- The causes of high natural mortality (*M*) of White Hake are largely unexplained in all units of the ANGSL DU. Seal predation is proposed as an important source of increased natural mortality of White Hake in the sGSL DU but available evidence is not conclusive for White Hake of the ANGSL DU.

Recovery Targets

- The proposed recovery target for the White Hake ANGSL DU is for indicators of abundance in the four management units to be sustained at levels above the proposed management unit-specific recovery targets. These recovery targets may include a distribution component.
- Abundance targets were defined for four management units in this DU, and correspond to an increase to sustained abundance at or above 40% of B_{MSY} (biomass at maximum sustainable yield).
- The proposed distribution target for White Hake recovery is to maintain current distribution and, specifically for Divs. 4RST*, to return to a distribution similar to the area covered during its most recent productive period (1987 to 1990).

Projections

- For Divs. 3NOPs, there is a 97% probability of remaining above the recovery target over the next fifteen years, under current conditions, and at a fishing rate of F_{MSY}.
- For Divs. 4VW, there is a 66% probability of reaching its recovery target under current conditions and at average recruitment, however, at recent low levels of recruitment, there is a 63% probability of the biomass being below the recovery target. Trajectories and probabilities of achieving this recovery target do not differ from conditions when $F = 0$ (no fishing related mortality).
- For Divs. 4X5Zc, there is an 84% probability of maintaining spawning stock biomass above the recovery target under current conditions. Trajectories and probabilities of remaining above the recovery target do not differ from conditions when $F = 0$.
- No projections are possible for the Divs. 4RST* management unit. Under current conditions, the adult abundance index has varied without trend since 1995.

Scenarios for Mitigation of Threats and Alternatives to Activities

- Possible mitigation measures to decrease fishing mortality in Canadian waters include: closing White Hake directed fisheries, closing bycatch (groundfish) fisheries, implementing White Hake bycatch protocols, increasing at-sea fisheries observer coverage to record otherwise unreported discards, and limiting fishing gear type, size, and amounts by fishery, season, and location.

Allowable Harm Assessment

- White Hake mortality due to fishing continues in all management units. Consequences of current fishing rates on adult abundance trends and population projections do not differ from conditions when *F* = 0 (no fishing related mortality).
- For Divs. 3NOPs, abundance is above its recovery target under current conditions and fishing rates, and current levels of fishing mortality are not jeopardizing survival or recovery.
- For Divs. 4VW, adult abundance is below its recovery target. However, consequences of current fishing rates on adult abundance trends and population projections (relative to its recovery target) do not differ from conditions when *F* = 0.
- For Divs. 4X5Zc, adult abundance is above its recovery target under current conditions and fishing rates, and current levels of fishing mortality are not jeopardizing survival or recovery. White Hake biomass is expected to increase at recent levels of fishing mortality.
- For Divs. 4RST*, abundance indices of recent years are below the abundance recovery target. Consequences of the current relative fishing rate of *F* = 0.007 are considered to have a negligible impact on White Hake recovery potential.

INTRODUCTION

White Hake (*Urophycis tenuis* Mitchill 1815) is a commercially exploited species in Canadian Atlantic waters, and its directed fisheries are managed by several jurisdictions: a portion of Divs. 3NO in the Northwest Atlantic Fisheries Organization (NAFO) Regulatory Area (NRA; outside of Canada's 200-mile limit) is managed by NAFO; NAFO Subdivision 3Ps by DFO Newfoundland and Labrador Region; NAFO Divs. 4RS by DFO Quebec Region; NAFO Div. 4T by DFO Gulf Region; and NAFO Divs. 4VW and the Canadian portions of NAFO Divs. 4X5Zc are managed by DFO Maritimes Region (Fig. 1). White Hake is also present but in low abundance in more northern waters and in NAFO Subdiv. 3Pn along the southwest coast of Newfoundland.

In November 2013,the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) concluded that White Hake in Canadian waters comprised two populations, or Designatable Units (DUs): the southern Gulf of St. Lawrence (sGSL) population, and the Atlantic and northern Gulf of St. Lawrence (ANGSL) population (COSEWIC 2013). The two DUs overlap in deep water along the Laurentian Channel. The White Hake ANGSL population was designated as threatened, due to an estimated 70% decrease in adult abundance over the past three generations (i.e. 23 years). Most of this decline occurred before the mid1990s, and adult abundance has remained relatively stable since then, with little overall change in area of distribution. Restrictions on White Hake directed fisheries over most of its range since the mid-to-late 1990s may be responsible for stabilizing abundance levels. A review of scientific information on the status of White Hake in Canadian Atlantic waters was completed in 2011, in support of the COSEWIC 2013 assessment (Simpson et al. 2012; Swain et al. 2012; Simon and Cook 2013).

Biology and Distribution

White Hake is a demersal gadoid fish of the Family Phycidae, and is distributed from Cape Hatteras in the south to Labrador in the north and throughout the Gulf of St. Lawrence (Scott and Scott 1988).

Spawning is known to broadly occur from the Gulf of Maine to waters off of Newfoundland, with specific locations found in Canadian Atlantic waters. The spawning patterns and behaviours of this species in the ANGSL DU are not well understood. White Hake are pelagic spawners that are highly fecund, producing several million eggs per female (Beacham and Nepszy 1980). Their eggs are buoyant, and remain in the upper water layer where they are dispersed by ocean currents (Han and Kulka 2007). Pelagic larvae hatch at 2 to 4 mm, and drift in the upper 50 meters of the water column for two to three months before settling to the bottom in shallow water (Markle et al. 1982; Fahay and Able 1989; Lang et al. 1996). Inshore areas and eelgrass beds are thought to be important nursery habitats for demersal immature White Hake (Horne and Campana 1989; Ings et al. 1998; Lazzari and Stone 2006). Juveniles appear to stay in shallow water for a year and migrate to offshore locations during their second year (Fahey and Able 1989; Simon and Cook 2013).

There is evidence of age-based segregation in White Hake populations; in one study, young-of-the-year were found in shallow water (2 to 18 m) while older, larger juveniles were found in deeper water (28 to 73 m; Markle et al. 1982). Adults tend to occupy deeper water than juveniles; although both juveniles and adults move inshore in summer, and disperse to deeper waters in winter (Sosebee 1998).

Maximum age of White Hake was reported to be 14 to 16 years by Petrov (1973), and 23 years by Beverton and Holt (1959).

ASSESSMENT

Abundance and Life History Parameters

Information in this section is presented by fisheries management unit. Percent change in abundance over selected time periods was calculated as $100*(\exp(b*\Delta t)-1)$ where b is the regression slope (negative value infers decline, positive value represents an increase) and Δt is the time period (number of years) over which the percent change is calculated.

Newfoundland (NL; NAFO Divisions 3NLOP)

Research survey indices

Indices of White Hake abundance and biomass in NL waters were obtained from Canadian bottom trawl research surveys conducted by DFO-NL during spring in Divs. 3LNOP (1971 to 2014), and fall in Divs. 2J3KLNO (1977 to 2013), which included waters beyond Canada’s Exclusive Economic Zone (EEZ; Fig. 2). Both indices were estimated by areal expansion of stratified arithmetic mean catch per tow (Smith and Somerton 1981). The abundance index was expressed as mean fish number per standard tow, and the biomass index as mean weight (kg) per standard tow; both are reported for spring (Divs. 3NOP) and fall (Divs. 3NO) surveys, which are not directly comparable.

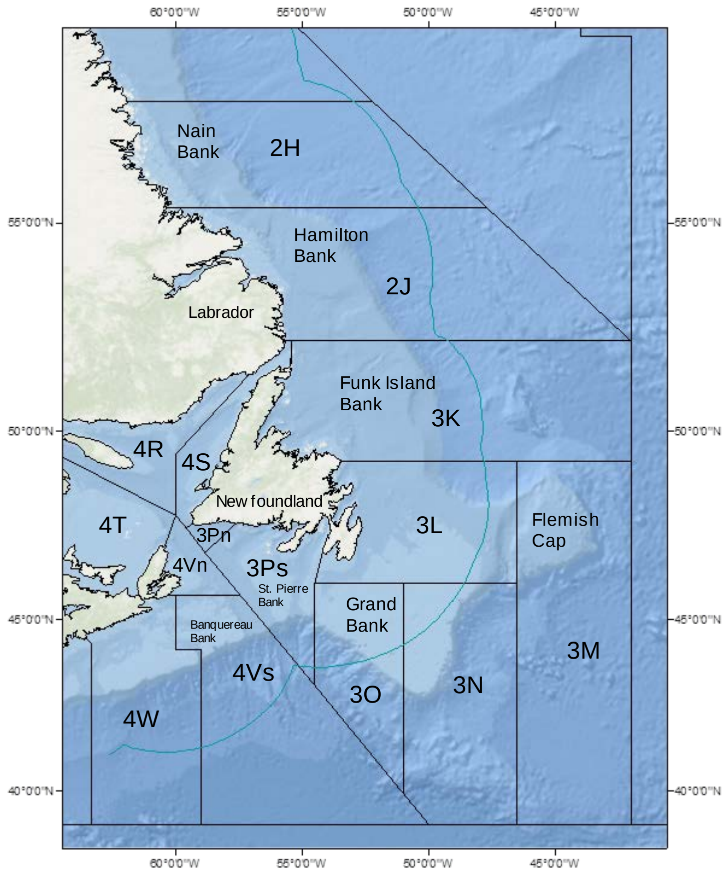


Figure 2. Map of the continental shelf off Eastern Canada and NAFO areas mentioned in the text. Depth range: < 100 m (light grey) to > 1000 m (light blue). Canada's Exclusive Economic Zone is delineated by the thin curved line, and NAFO Divisions by solid lines.

The DFO-NL spring survey covers the entire stock area, and thus serves as the primary source of information for White Hake in Divs. 3NOP. Spring abundance and biomass indices from 1972 to 2014 are presented for Divs. 3NOPs combined (Fig. 3), and for each of Divs. 3NO, Subdiv. 3Ps, and Subdiv. 3Pn (Fig. 4). Biomass and abundance indices in Divs. 3NOPs have been stable at low levels since 2003. Trends in abundance for this unit are characterized by occasional large recruitment that is quickly removed by fisheries targeting this species in Canadian waters and in the NRA of Divs. 3NO. Highly variable recruitment followed by White Hake directed fishing (in Canadian waters and the NRA of Divs. 3NO) appear to determine subsequent changes in adult biomass.

Fall abundance and biomass indices for Divs. 3NO in 1990 to 2013 are presented in Figure 5. Similar to spring survey indices, fall indices have varied without trend after recruitment of a very large year-class in 1999.

Estimated percent change in abundance indices from spring and fall surveys in Divs. 3NOP for various time periods are presented in Table 1. Since 2004, both spring and fall abundance indices for Divs. 3NO White Hake have increased. For Div. 3P, after introduction of the Campelen trawl in 1996, the spring abundance index decreased in Subdiv. 3Ps but increased in Subdiv. 3Pn.

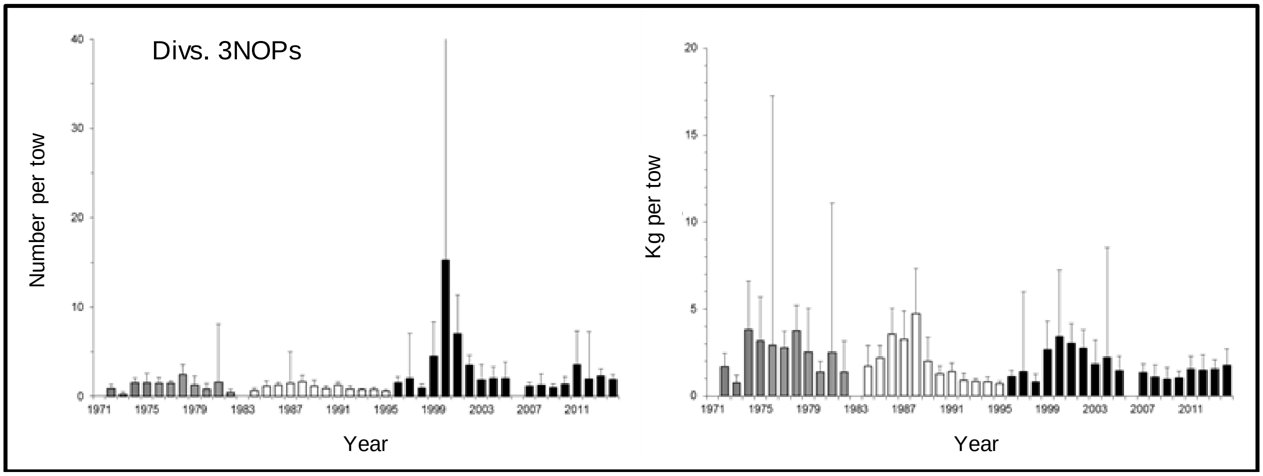


Figure 3. Mean numbers (left panel) and mean weights (right panel; kg) per tow (+ 95% CI) of White Hake from Canadian spring research surveys in Divs. 3NOPs. Survey trawl gear changed from Yankee (grey bars) to Engel (white bars) in 1983, and to Campelen (black bars) in 1996. The survey was incomplete in 2006. Indices were not adjusted for changes in survey gear or vessel.

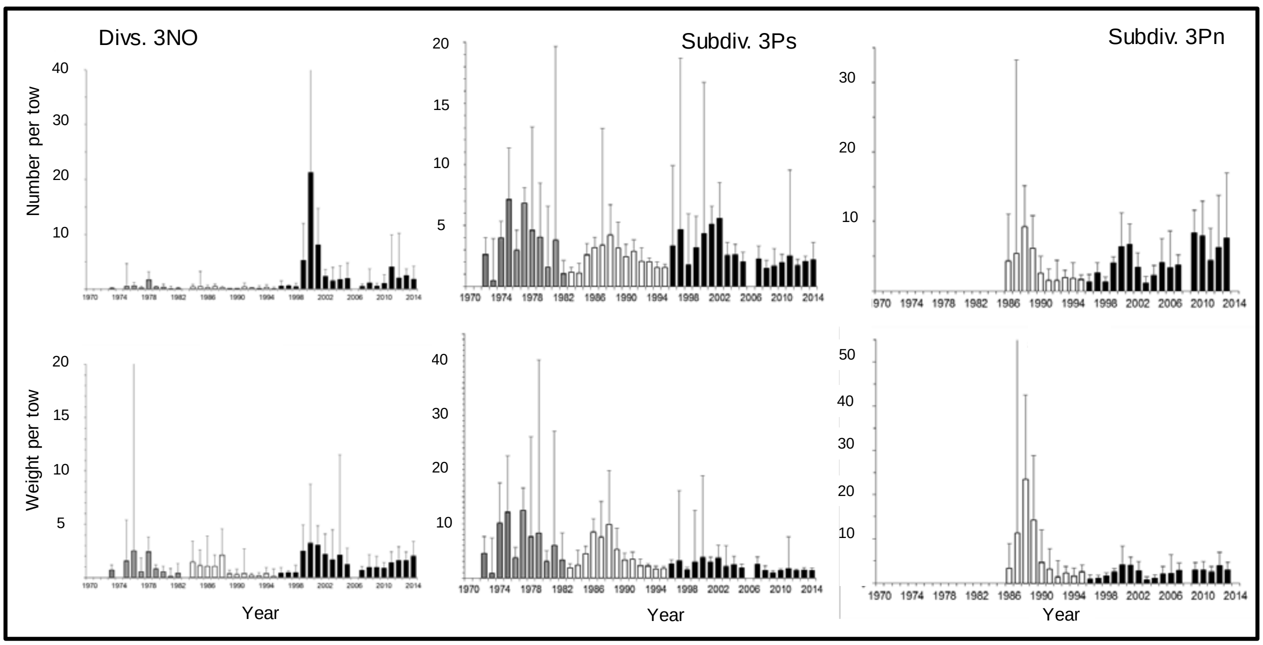


Figure 4. Mean numbers (upper row of panels) and mean weights (lower row of panels; kg) per tow (+ 95% CI) of White Hake from Canadian spring research surveys in Divs. 3NO (left column), Subdiv. 3Ps (middle column), and Subdiv. 3Pn (right column). Survey trawl gear changed from Yankee (grey bars) to Engel (white bars) in 1983, and to Campelen (black bars) in 1996. The survey was incomplete in 2006. Indices were not adjusted for changes in survey gear or vessel.

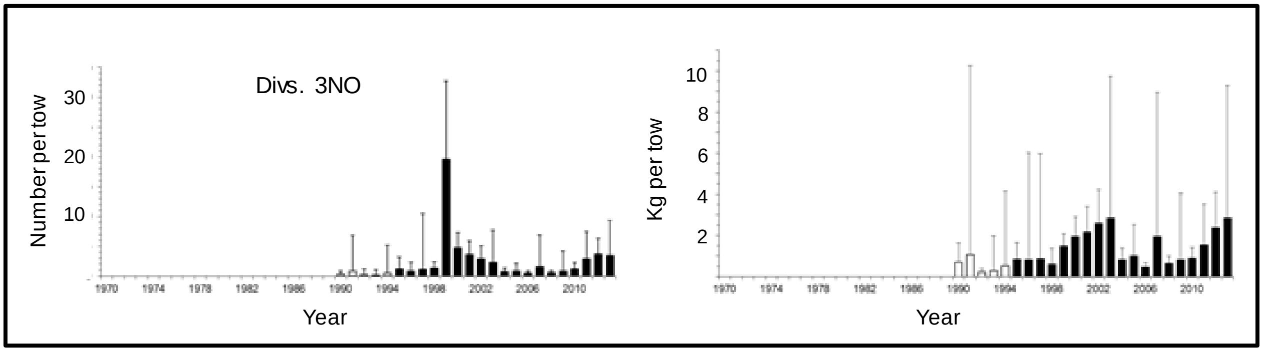


Figure 5. Mean number (left panel) and mean weight (right panel) per tow (+ 95% CI) of White Hake from Canadian fall research surveys in Divs. 3NO. Survey trawl gear changed from Engel (white bars) to Campelen (black bars) in 1995. Indices were not adjusted for changes in survey gear or vessel.

Table 1. Estimated percent change (negative is a decline; positive is an increase) in White Hake abundance indices for all sizes, juveniles, and adults per time period from research surveys conducted in Divs. 3NO, Subdiv. 3Ps, Subdiv. 3Pn, Divs. 4RST, Divs. 4VW, and Divs. 4X5Zc.*

Management unit	Survey	Size group	Time period	Instantaneous rate of change over period	Total change over period (years)
3NO	Spring survey - Engel	All sizes	1984-1995	- 0.004	- 4% (11)
	Spring survey - Campelen	All sizes	1996-2014	< 0.001	0% (18)
	Spring survey - Campelen	All sizes	2004-2014	0.020	+ 22% (10)
3NO	Fall survey - Engel	All sizes	1990–1994	- 0.024	- 9% (4)
	Fall survey - Campelen	All sizes	1995-2013	- 0.003	- 5% (18)
	Fall survey - Campelen	All sizes	2004-2013	0.086	+ 117% (9)
3Ps	Spring survey - Engel	All sizes	1984-1995	- 0.005	- 5% (11)
	Spring survey - Campelen	All sizes	1996-2014	- 0.020	- 30% (18)
3Pn	Spring survey – Engel	All sizes	1986–1995	- 0.060	- 42% (9)
	Spring survey - Campelen	All sizes	1996-2013	0.030	+ 67% (17)
4RST*	August survey - Campelen	All sizes	1985–2014	- 0.060	- 82% (29)
		Adult (>=45 cm)	1987–2014	- 0.046	- 71% (27)
		Juvenile (< 45 cm)	1987-2014	-0.053	- 76% (27)
4VW	July survey Western IIA	All sizes	1982-1991	- 0.101	- 60% (9)
		All sizes	1991-2013	- 0.034	- 52% (22)
		Adult (>=42 cm)	1982-1995	- 0.132	- 82% (13)
		Adult (>= 42 cm)	1995-2013	- 0.011	- 19% (18)
		Juvenile (< 42 cm)	1982-2013	- 0.040	- 71% (31)
4X5Zc	July survey Western IIA	All sizes	1982-2013	- 0.037	- 68% (31)
		Adult (>= 42 cm)	1982-2006	- 0.059	- 75% (24)
		Adult (>= 42 cm)	2006-2013	0.057	+ 49% (7)
		Juvenile (< 42 cm)	1982-1991	0.035	+ 37% (9)
		Juvenile (< 42 cm)	1991-2013	- 0.047	- 65% (22)

Population model estimates

Population dynamics of White Hake in NAFO Divs. 3NO and Subdiv. 3Ps were modeled with a Bayesian Surplus-Production model, using vague priors for carrying capacity, population growth rate, and survey catchabilities. NAFO-reported landings were assumed known without error. Population biomass indices from Canadian research surveys, and from EU-Spain surveys (i.e., the latter conducted in the NRA) for Divs. 3NO were incorporated into the model as observed data with error.

The final model fit the data well, and indicated a generally declining trend in White Hake biomass through the 1980s and early 1990s (Fig. 6). Biomass increased in 1999 and the early 2000s, and then subsequently declined. Although biomass in Div. 3NO and Subdiv. 3Ps has increased in recent years, it remains significantly below the peak levels observed in the late 1970s or late 1980s. As estimated by the model, current biomass is above B_{lim} (i.e., defined as 40% B_{MSY} following the DFO Precautionary Approach Framework; DFO 2009).

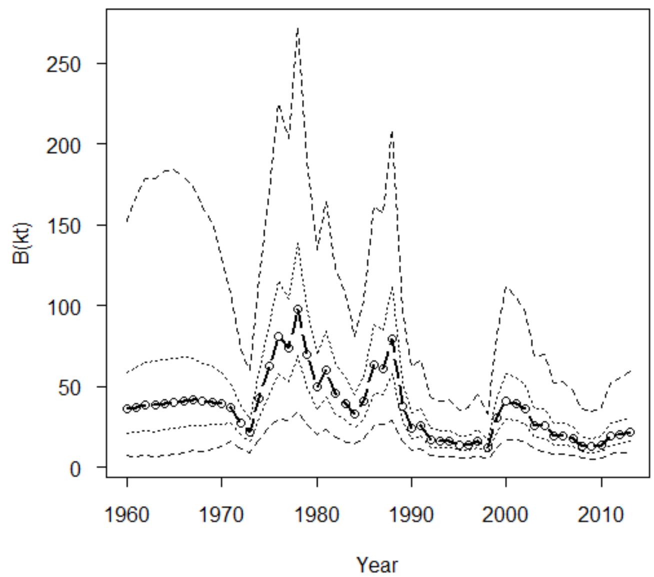


Figure 6. Schaefer surplus production model estimates of biomass (kt = 1,000 tonnes) of White Hake in Divs. 3NOPs, 1960 to 2013. Median values are shown as symbols and the dashed thick black line. Stippled lines and dashed lines represent 50% and 95% credible intervals, respectively.

Maritimes (NAFO Divisions 4VW and 4X5Zc)

Research survey indices

Indices of abundance and biomass of White Hake for Divs. 4VW and the Canadian portions of Divs. 4X5YZc, hereafter referred to as Divs. 4X5Zc (Fig. 7), are monitored by the DFO-Maritimes Region summer research survey. This survey has been conducted annually on the Scotian Shelf (Divs. 4VW and the Canadian portion of Divs. 4X5Zc) since 1970, using a stratified random design based on depth and geographic area. Indices are stratified mean numbers (abundance) and weights (biomass) multiplied by number of trawlable units in the survey area.

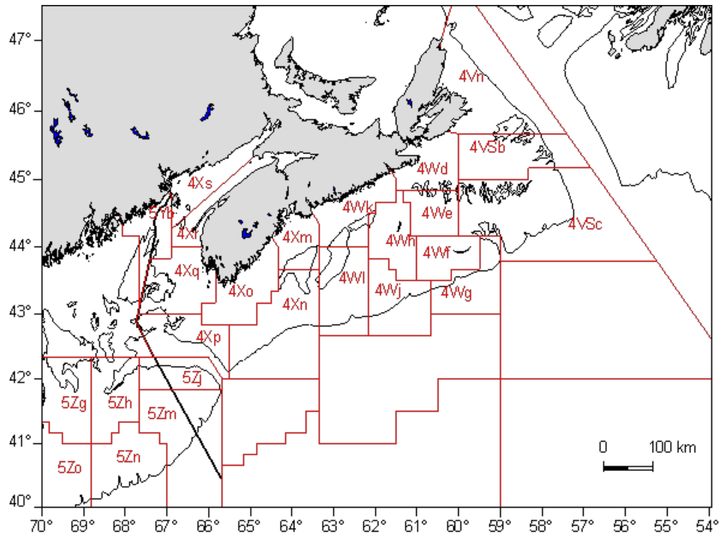


Figure 7. Map of NAFO Divs. 4VW, 4X, and 5YZc.

Biomass indices for all sizes of White Hake from this survey of Divs. 4VW and Divs. 4X5Zc are shown in Figure 8. For both management units, biomass was relatively low in the 1970s, peaked in the mid 1980s, and then declined to levels near those observed in the 1970s.

Figure 9 indicates stratified indices of abundance and decadal averages for juvenile (< 42 cm total length) and adult (>= 42 cm) size groups. Trends in total abundance were similar to biomass trends. In Divs. 4VW, abundance of juveniles decreased since the 1980s (15.5 million to 6.6 million; Fig. 9), but remained above the 1970s levels (5.5 million), while adult abundance has decreased to a very low level since the 1990s. Apparent good recruitment in the mid 1990s did not result in a subsequent increase in adult abundance (Fig. 9). Since the 1980s, average adult abundance remained below 1.9 million; lower than that of the 1970s (6.6 million). In Divs. 4X5Zc, adult abundance decreased from 13 million in the 1980s to 5 million in recent years; slightly lower than in the 1970s (8.4 million; Fig. 9). Juvenile White Hake were most abundant in the 1980s and 1990s (8 to 9 million), and their numbers declined over the last decade to 4.7 million; lower than that of the 1970s (6 million; Fig. 9).

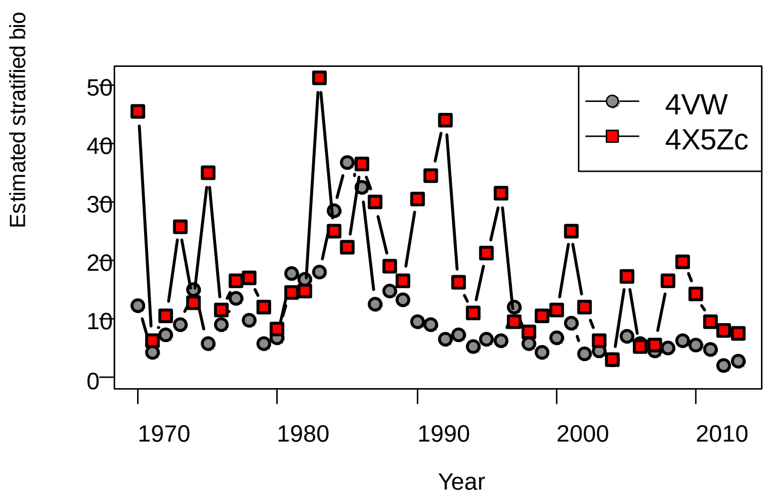


Figure 8. Estimated stratified survey biomass (1,000 tonnes) of White Hake in Divs. 4VW and Divs. 4X5Zc, 1970 to 2013.

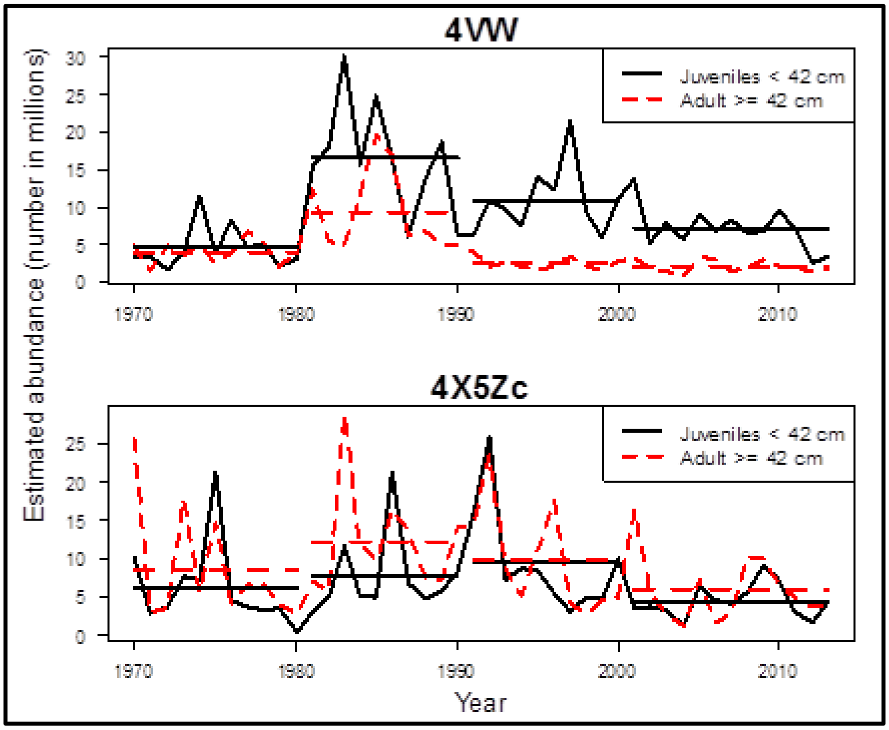


Figure 9. White Hake abundance (number in millions) by size class (solid thin black lines: juveniles < 42 cm; dashed thin red lines: adults >= 42 cm) in Divs. 4VW (top panel) and Divs. 4X5Zc (bottom panel), 1970 to 2013. Thick horizontal lines are approximate decadal (1970 to 1980, 1981 to 1990, 1991 to 2000, 2001 to 2013) averages for each size group.

The survey stratified abundance index was used to derive linear trends of abundance (on the natural log scale) for the entire survey time period (1970 to 2013), and since 1982 (when overall abundance peaked; Figs. 9, 10; Table 1). In Divs. 4VW, there was a significant linear decreasing trend for juveniles (< 42 cm) since 1982 ($p < 0.001$); although the percentage of variation explained was low due to high inter-annual variation ($R^2 = 0.46$; Fig. 10). Adult declining trends were significant in both time periods, although the instantaneous decline rate (slope) was twice as steep in the last 30 years (slope = -0.0264 as compared to -0.0135 for the entire time period). In Divs. 4X5Zc, linear declines in juvenile and adult abundances were significant only since 1982 (Fig. 10). Juvenile indices in Divs. 4VW and Divs. 4X5Zc did not show the same rates of decline as those estimated for adults.

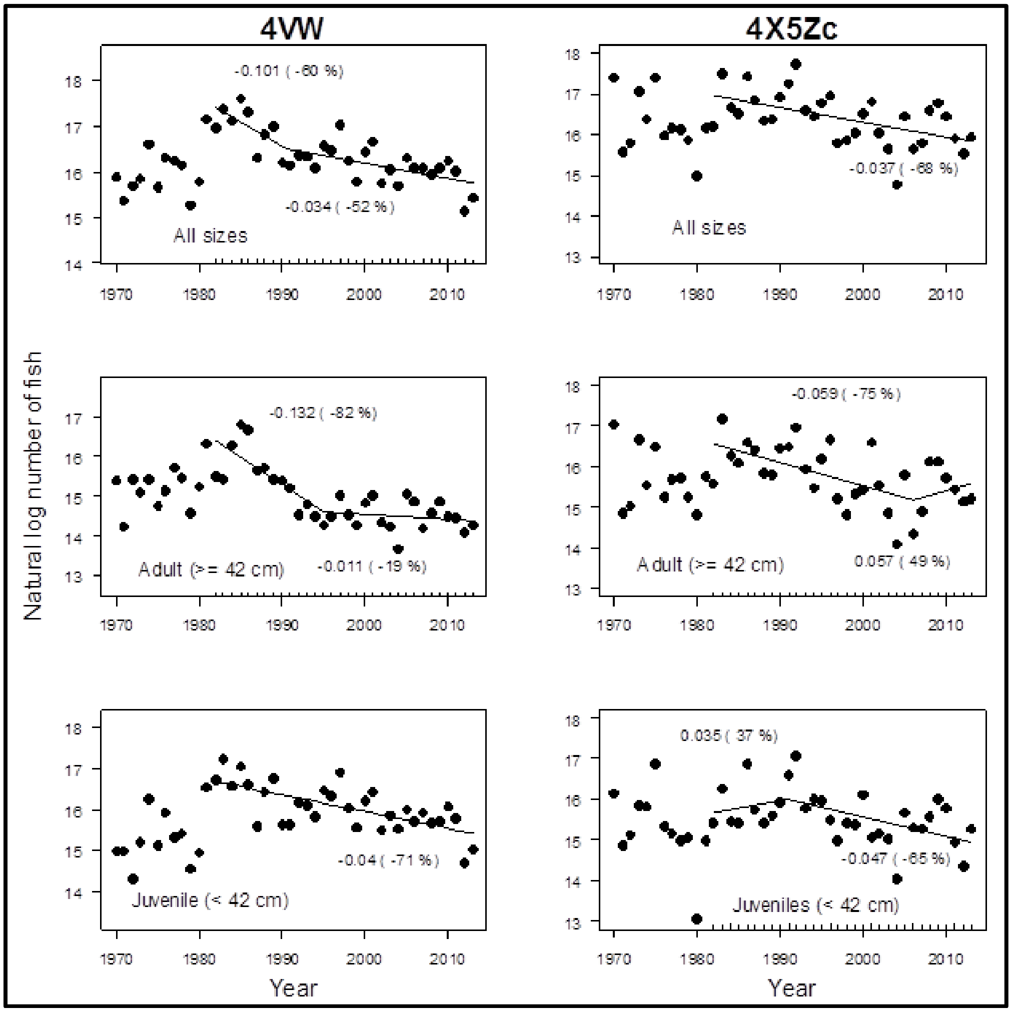


Figure 10. Trends in natural log-transformed estimates of White Hake survey abundance (number) for all sizes (top row), adults (>= 42 cm; middle row), and juveniles (< 42 cm bottom row) for Div. 4VW (left column) and Div. 4X5Zc (right column). Linear changes were estimated for 1982 to 2013, or by segments (starting in 1982) when applicable. The instantaneous rate of change over year (slope) is displayed beside each line, and percent change (in parentheses) over each regression time period.

Scaled abundance estimates

Research survey data were scaled, assuming that survey abundance indices at age were equal to or less than true population sizes (Fig. 11). Abundances of ages 2 to 4 (i.e., not yet fully recruited to survey gear) were approximated using the ratio of estimated abundances (abundance at age 5 raised to ages 4 to 2 along the cohort; assuming $Z = 1.0$) to the numbers of White Hake caught in the survey (Guenette and Clark 2016). The ratio for each age was the average by age overall years (i.e., 1998 to 2010; when age data available). Ratios for ages 2, 3, and 4 were 8.11, 2.7, and 1.03 (respectively) for Divs. 4VW, and 6.91, 5.35, and 2.37 (respectively) for Divs. 4X5Zc. Figure 11 shows stratified survey biomass estimates and population biomass estimates from both raising methods for Divs. 4VW and Divs. 4X5Zc, respectively. The second method (i.e., B2 wprop) estimated biomass that was closer to the survey trend: 7,201 t for Divs. 4VW in 2013, and 16,829 t for Divs. 4X5Zc in that same year.

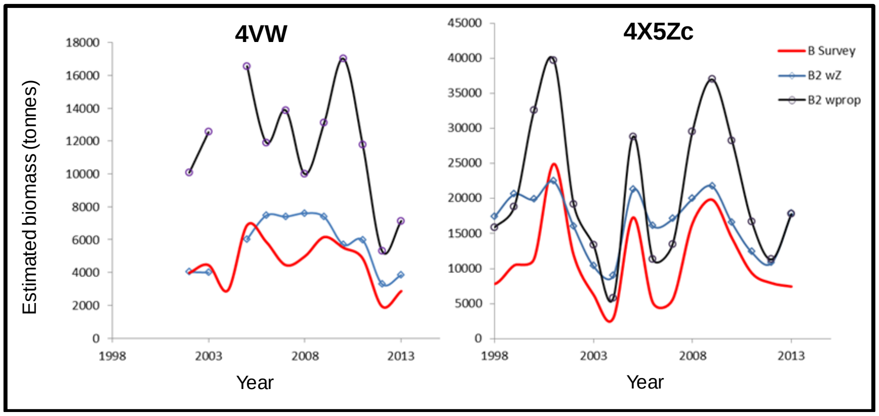


Figure 11. Comparison of White Hake (ages 2+) survey biomass index (tonnes: solid red line, no symbols) and raised biomass estimates using back calculation with Z= 1.0 (B2 wZ: solid blue line, triangle symbols), and average proportions (B2 wprop: solid black line, open circles) for Divs. 4VW (left panel) and Divs. 4X5Zc (right panel) (Guenette and Clark 2016).

Northern Gulf of St. Lawrence (Divisions 4RST*)

Research survey indices

Trends in abundance and biomass were derived from two DFO-Quebec Region bottom trawl research surveys: a January survey conducted for the period 1978 to 1994, and an August survey conducted over the period 1985 to 2014. Both surveys used the same stratified random design, covering Divs. 4RS and part of Div. 4T which includes the St. Lawrence Estuary and strata with depths greater than 200 m in the Laurentian Channel that are not covered in the southern Gulf DU (Fig. 12). This combined area is noted as Divs. 4RST*. The area in Subdiv. 3Pn was only consistently covered by the January survey.

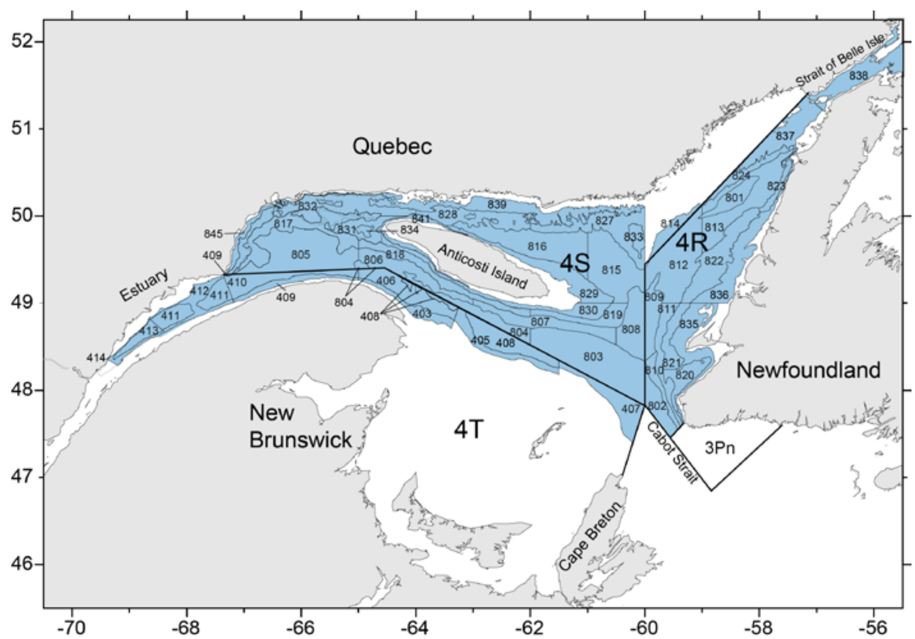


Figure 12. Stratification scheme used for the northern Gulf of St. Lawrence DFO groundfish trawl surveys showing strata included in the analyses of the abundance indices of the Divs. 4RST component of the ANGSL DU.*

Abundance and biomass indices were estimated using the January survey, with surveyed area varying greatly inter-annually, due primarily to ice cover. Therefore, survey data are presented here only for Div. 4R and Subdiv. 3Pn, which were consistently sampled (Fig. 13). In Div. 4R, mean number per tow varied between 2 and 6 fish during 1978 to 1986, decreased in 1987, and remained low at an average of 0.4 fish per tow until the end of this survey in 1994. In Subdiv. 3Pn, mean number per tow fluctuated, with a peak of 12.6 fish in 1987, and decreased to low but relatively stable levels during 1988 to 1994 (averaging 4 fish per tow).

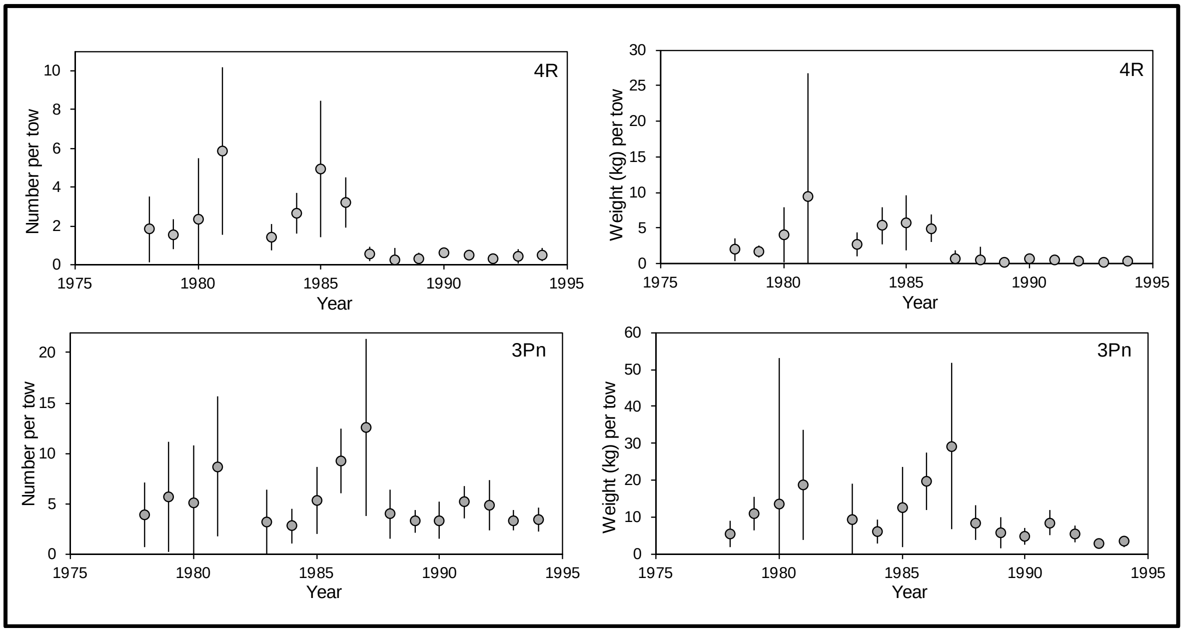


Figure 13. White Hake indices of abundance (mean number per tow ± 95% CI; left panels) and biomass (mean weight in kg per tow ± 95% CI; right panels) in Div. 4R (upper row) and Subdiv. 3Pn (lower row) in the January survey, 1978 to 1994.

The August survey entailed three research vessel trawl types. Comparative fishing experiments were conducted to develop species-specific conversion factors thereby allowing for a continuous 1985 to 2014 time series. Minimum trawlable abundance estimates indicated that total White Hake numbers were highest in 1985 to 1990 and then declined to a low level in 1993 (Fig. 14). Abundance remained low over the period 1994 to 2014. Similar trends were observed for adult and immature abundance and biomass (Fig. 14). Total abundance in 2014 was approximately 9 million fish, with 1.6 million estimated to be adults (>= 45 cm).

Changes in White Hake abundance, based on a linear regression through natural-log transformed abundance indices, were estimated with the August survey data (Fig. 15). Over the period 1985 to 2014, total abundance decreased by 82% (Table 1). Adult and immature fish declined over the period 1987 to 2014 by 71% and 76%, respectively. These declines were largely associated with higher abundances in 1985 to 1991.

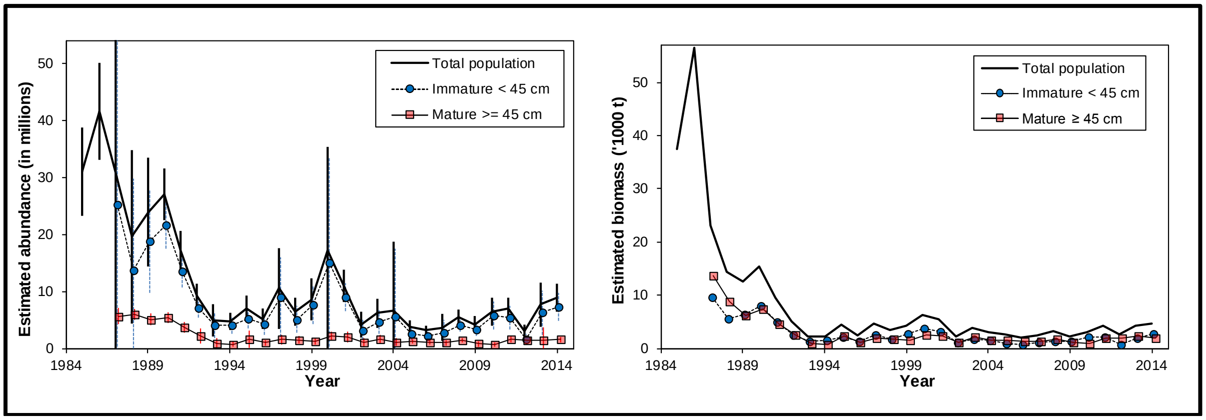


Figure 14. Estimated abundance (total number in millions ± 95% CI; left panel) and biomass (by 1,000 t; right panel) for total (solid black line), mature (>= 45 cm; thin solid line, red square symbols), and immature (< 45 cm; dashed line, blue circle symbols) White Hake in Divs. 4RST from the August survey, 1985 to 2014. The immature and mature data plots were jittered slightly to improve legibility.*

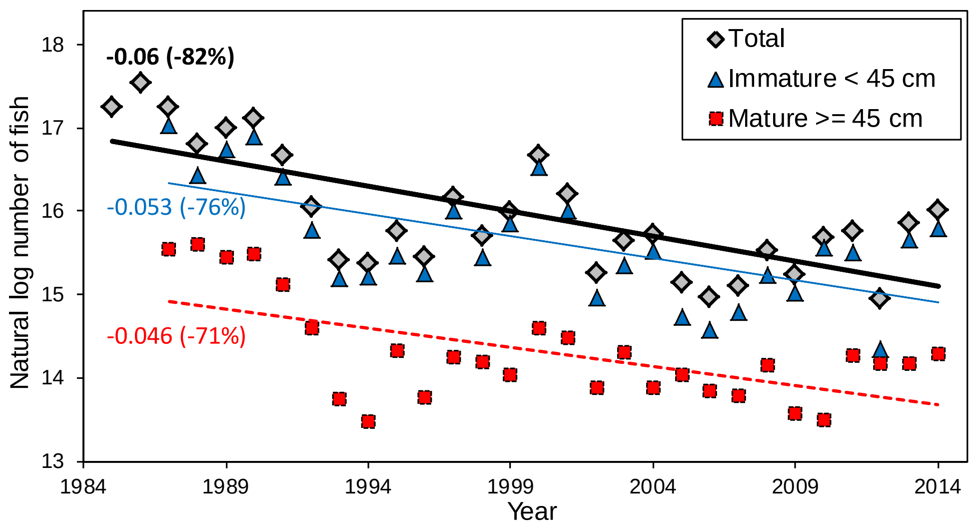


Figure 15. Trends in natural log-transformed White Hake abundance indices (number in millions) and their linear regression for total (solid black line, diamond symbols), mature (>= 45 cm; dashed red line, square symbols), and immature (< 45 cm; blue line, triangle symbols) fish in Divs. 4RST from the August survey, 1985 to 2014. Instantaneous rate of change over year (slope) is displayed beside each line, and percent change (in parentheses) over each regression time period.*

Recent species distribution

Catches from Canadian research surveys of Subareas 2-5 indicated that White Hake in Newfoundland waters were mainly found along the continental shelf slope of the southwestern Grand Bank (Div. 3O), and in the Laurentian and Hermitage Channels (Div. 3P). Survey catch distributions in 2000 to 2013 were consistent with historic data (1977 to 1990; Fig. 16). These maps also show the connectivity of White Hake in Divs. 4RS with those in adjacent areas of Subdiv. 3Pn of southwestern Newfoundland and Div. 4T along the Magdalen Shelf and into the Estuary (Fig. 16).

White Hake were broadly distributed across the Scotian Shelf and into the Bay of Fundy, with a number of concentrated areas: the eastern edge of the Scotian Shelf, especially along the

Laurentian Channel; the Gully and southern edge of the shelf; the central Scotian Shelf; Gulf of Maine; and Bay of Fundy. Survey catch distributions did not indicate any changes in the general geographic range of the species during 2000 to 2013, relative to the 1977 to 1990 time period (Fig. 16).

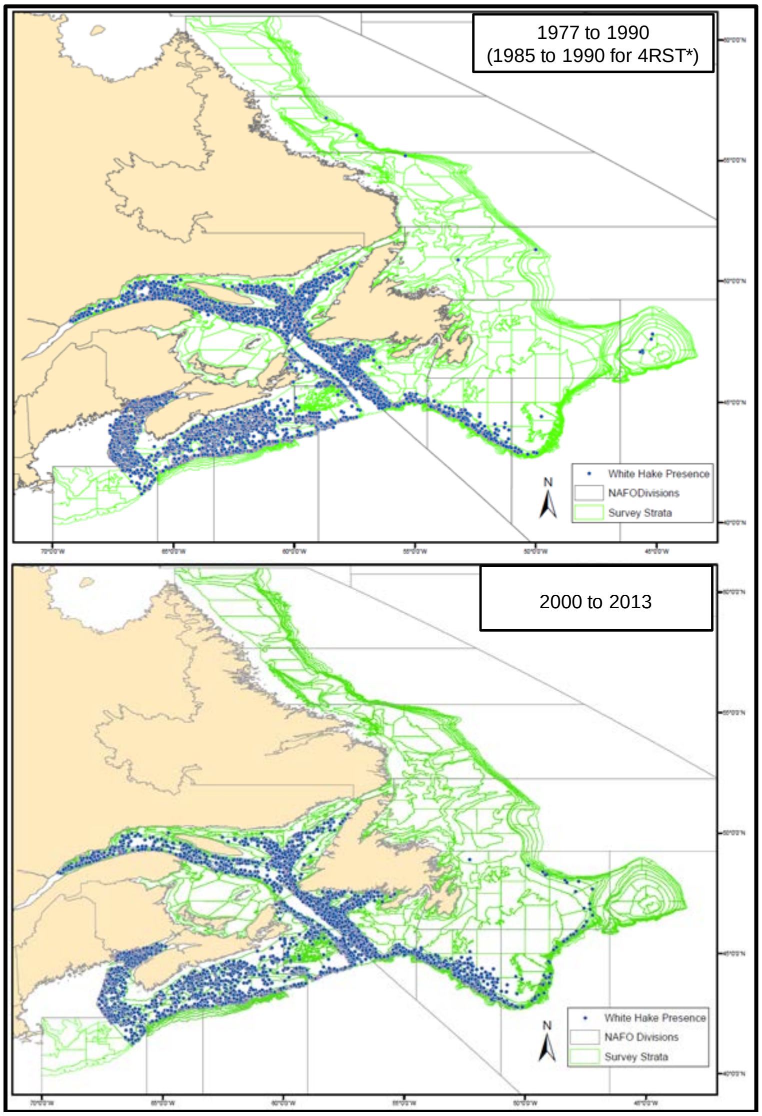


Figure 16. Geographic distribution of White Hake catches in Subareas 2, 3, 4, and 5Zc from DFO research surveys, 1977 to 1990 (upper panel) and 2000 to 2013 (lower panel).

White Hake in the Gulf of St. Lawrence was typically found on the slopes of the Laurentian Channel and the eastern slope of the Esquiman Channel (i.e., near southwest Newfoundland). White Hake was usually absent from water depths <150 m, the inshore west coast of Newfoundland up to the Strait of Belle-Isle, the lower north shore of Quebec, and north of Anticosti Island (Fig. 17). August research surveys of Divs. 4RST* indicated a greater distribution of nGSL White Hake in earlier years (1985 to 1991; Fig. 17). This species was less concentrated at the head of the Laurentian, Esquiman, and Anticosti Channels in recent years. Since 2011, there were minor inshore occurrences in <100 m depths along the Newfoundland west coast (Fig. 17).

Area occupied by Divs. 4RST* White Hake was calculated using a Design-Weighted Area Occupied (DWAO) index based on summer research trawl catches in strata consistently surveyed over 1985 to 2014 (Fig. 18). Area occupied by White Hake was at a maximum in 1985 to 1991 (averaging 47,500 km^2), and then decreased over 1992 to 2014 (averaging 27,000 km^2). Similar trends were observed for adult and immature components (Fig. 18).

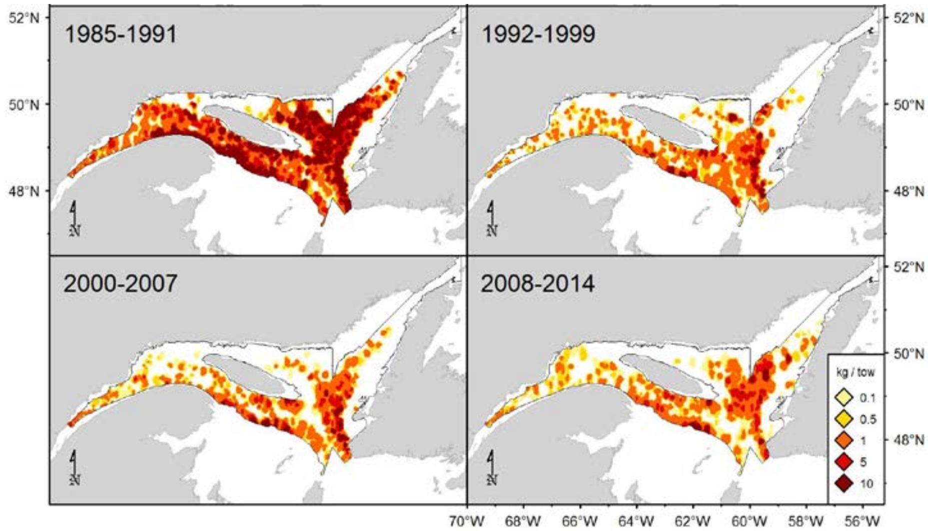


Figure 17. Geographic distribution of White Hake catches (standardized weight in kg per tow; Teleost-Campelen equivalents) in Divs. 4RST from the August survey, 1985 to 2014.*

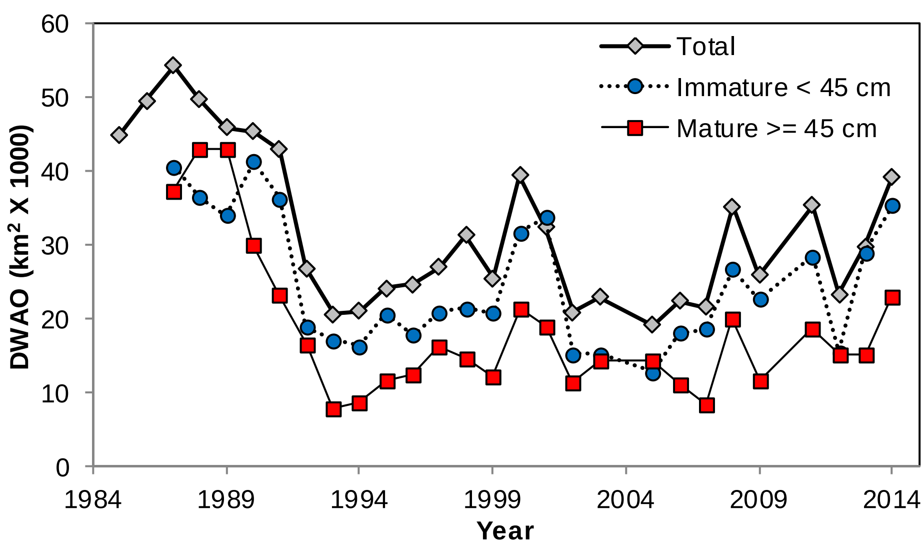


Figure 18. Design-Weighted Area Occupied (DWAO; 1,000 km^2) for total (solid thick black line), mature (>= 45 cm; solid thin gray line), and immature (< 45 cm; stippled gray line) White Hake in Divs. 4RST from the August survey, 1985 to 2014.*

Current or recent life history parameters

Age and size

Newfoundland (NAFO Divisions 3NLOP)

Simpson et al. (2012) previously summarized life history parameters for White Hake in Newfoundland and Labrador waters. Size at first spawning was estimated to be 30 cm total length. Petrov (1973) found size-age relationships in Div. 3O to be 32 to 38 cm at age 3, 48 to 56 cm at age 4 and 5, and 66 to 74 cm at ages 6 and 7. Maximum age of White Hake was reported to be 14 to 16 years by Petrov (1973) and 23 years by Beverton and Holt (1959). No recent size at age data are available for this region.

Maritimes (NAFO Divisions 4VW and 4X5Zc)

On the Scotian Shelf, length at 50% (L_{50}) maturity was estimated to be 43 cm (Guenette and Clark 2016). This differs slightly from that reported by Simon and Cook (2013) who reported an L_{50} of 45 cm and age at 50% maturity of 4 years. Bundy and Simon (2005) summarized von Bertalanffy growth parameters for White Hake in the Bay of Fundy and on the Scotian Shelf for the 1970s, 1980s, and 2000s. Minor though not statistically significant differences in growth were reported.

Age structure of Divs. 4VW White Hake is currently truncated relative to the 1970s and 1980s (Fig. 19). Size range and abundance at all sizes from DFO research surveys also decreased, as compared to their long-term averages (Fig. 20). In Divs. 4X5Zc, no reduction in age range was apparent from the 1970s and 1980s to the past decade (Fig. 21). Abundance was low for large White Hake, while abundance of recruiting sizes (34 to 43 cm) in 2012 was below average, and this year-class was apparent in 2013 as 55 to 64 cm fish with an average abundance (Fig. 20).

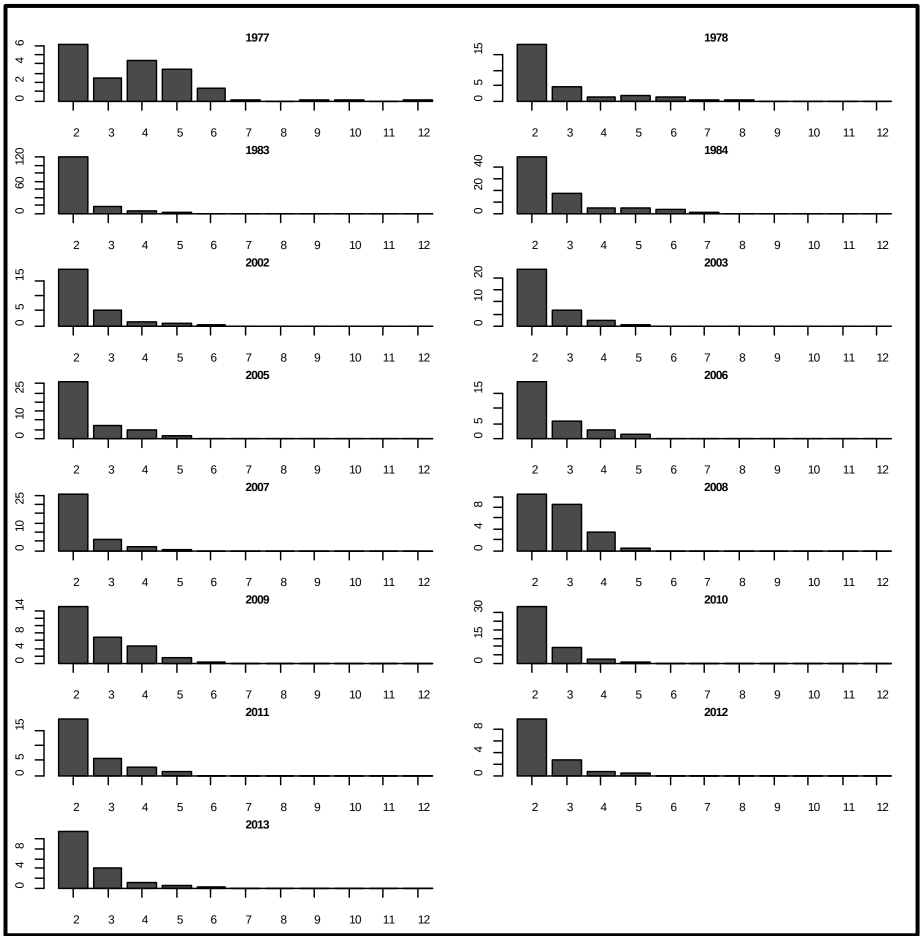


Figure 19. White Hake age structure, as percentage of total, in Divs. 4VW. Age 12 includes fish in age groups 12 to 16 years.

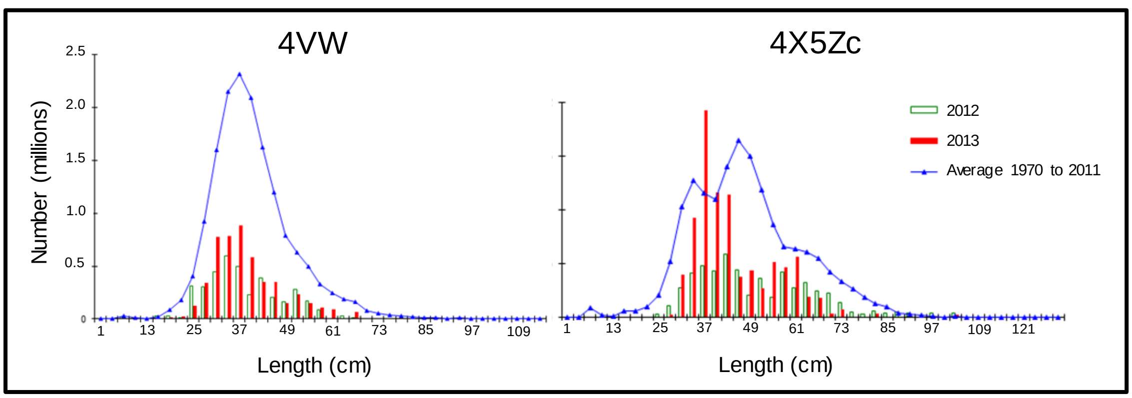


Figure 20. White Hake length distribution in Divs. 4VW (left panel) and Divs. 4X5Zc (right panel) from the summer survey. Solid red bars represent numbers at length in millions from the 2013 survey. Open green bars represent numbers at length in millions from the 2012 survey. The solid blue line represents the median abundance at length (in millions) for 1970 to 2011.

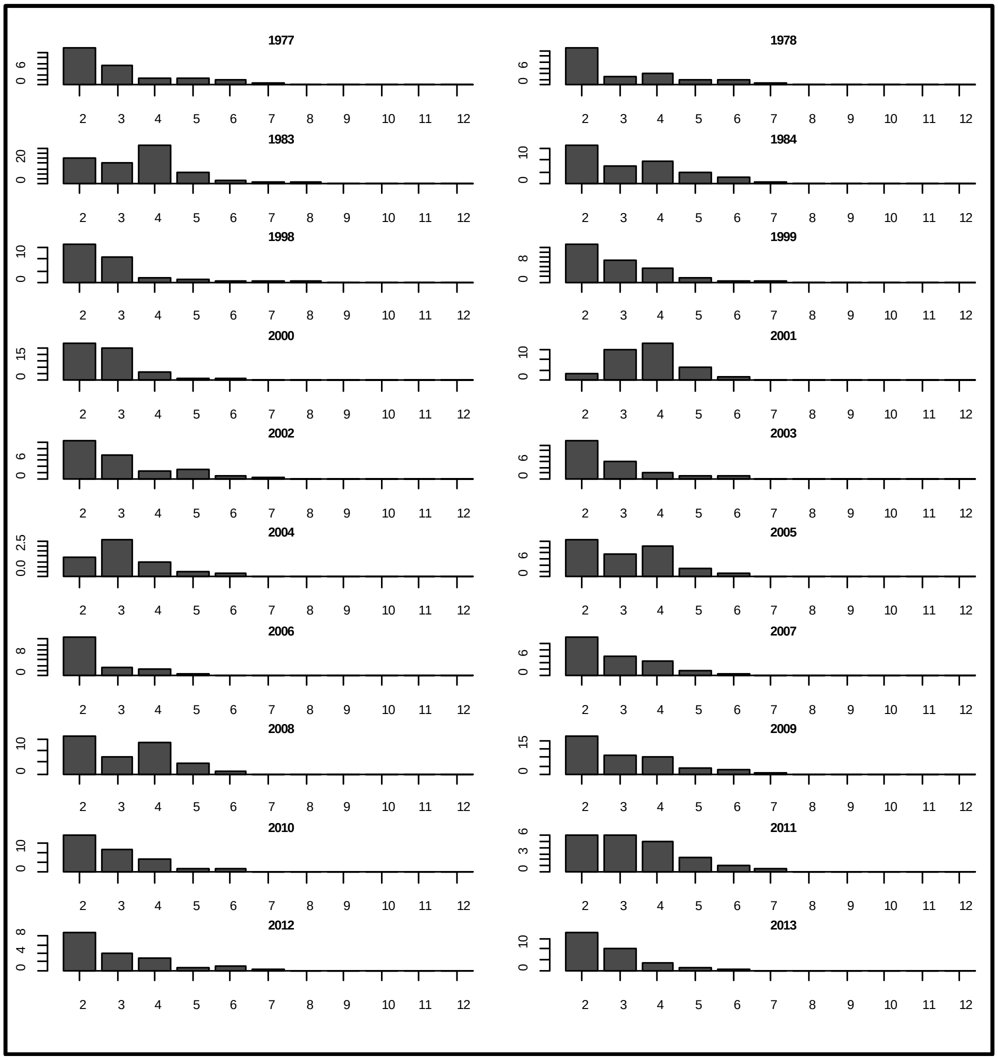


Figure 21. White Hake age structure, as percentage of total, in Divs. 4X5Zc. Age 12 includes fish in age groups 12 to 16 years.

Northern Gulf of St. Lawrence (NAFO Divisions 4RST*)

Biological data on White Hake were not systematically collected during early years of the northern Gulf of St. Lawrence (nGSL) survey but sampling efforts have been greatly increased since 1991, Length data indicated that White Hake ranged from 10 to 70 cm with a peak abundance at 39 cm in 2014. Size range remained constant over the survey time series, with no differences before or after the population decline (Fig. 22).

The sex ratio for nGSL White Hake was close to one. Females reached larger sizes than males and constituted the majority of fish > 50 cm (Fig. 23). Females also matured at larger sizes than males with 50% reaching maturity at approximately 45 cm compared to 33 cm for males. The absence of age data precluded any analyses of mean size-at-age, age of maturity, and age-based mortality.

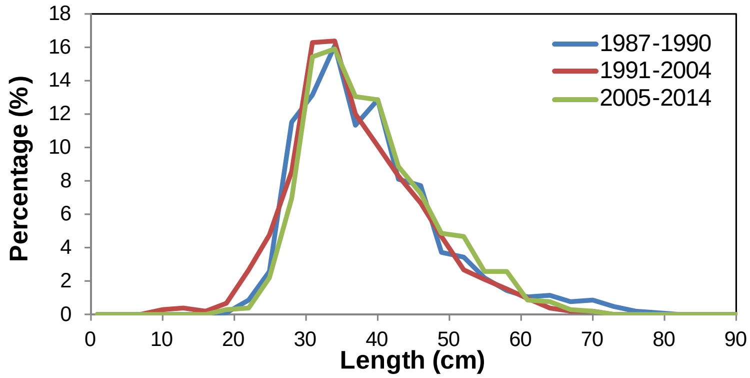


Figure 22. White Hake length distribution (% at length) per time period in the Divs. 4RST summer survey, 1987 to 2014.*

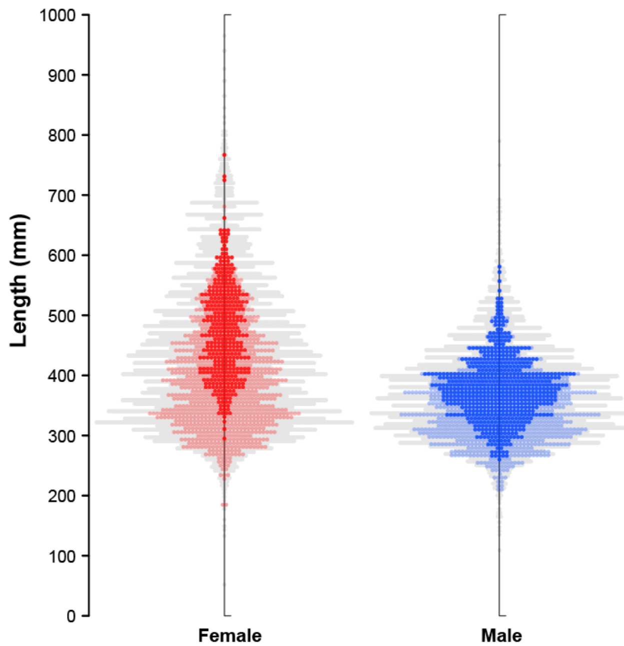


Figure 23. Frequency dot plots of White Hake females and males by length (mm) and maturity stage from the nGSL (Divs. 4RST) August surveys in 1987 to 2014. Dark colour = mature fish; light colour = total number of fish examined for maturity; and gray = additional fish examined only for sex.*

Mortality rates

Newfoundland (NAFO Divisions 3NLOP)

Modeled values for fishing mortality (*F*) in Divs. 3NOPs for the period 1960 to 2013 are shown in Figure 24. In peak periods of abundance, the median value of *F* remained below 0.3, but exceeded the F_{MSY} value (0.087). Since the mid-to-late 2000s, estimated *F* has declined to values below F_{MSY}, corresponding to the recent period of increasing biomass (Fig. 24).

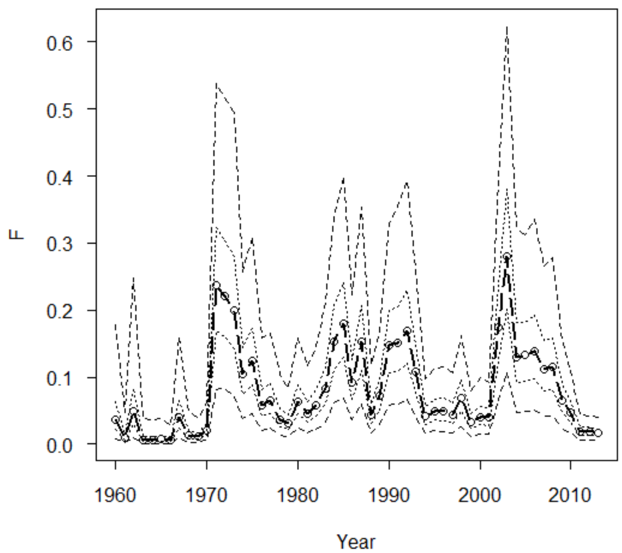


Figure 24. Modeled values for fisheries mortality (F) for White Hake in Divs. 3NOPs, 1960 to 2013. The dashed thick black line and open symbols represent median values, while stippled lines and dashed lines represent 50% and 95% credibility intervals, respectively.

Maritimes (NAFO Divisions 4VW and 4X5Zc)

Total mortality (*Z*) for Divs. 4VW White Hake significantly increased from the 1970s and 1980s to the 2000s (Fig. 25). Average *Z*, based on an analysis of covariance using cohorts from 1992 to 2007 was estimated at 1.6 (79% per year). In contrast, relative *F* significantly decreased to 0.03 in the 2000s, as reported landings and biomass decreased (Fig. 26). White Hake landings in 2013 were 128 t and relative *F* was estimated at 0.045.

In Divs. 4X5Zc, there was no significant trend in total mortality over time (Fig. 25). Average *Z* (using the same method as above) was estimated as 1.03 (64.3% per year). In contrast, relative *F* significantly decreased in the last five years to 0.12 (Fig. 26). Low relative *F* reflected reductions in total allowable catch in recent years as the TAC was reduced to 1,300 t in 2012 and to 650 t in 2013.

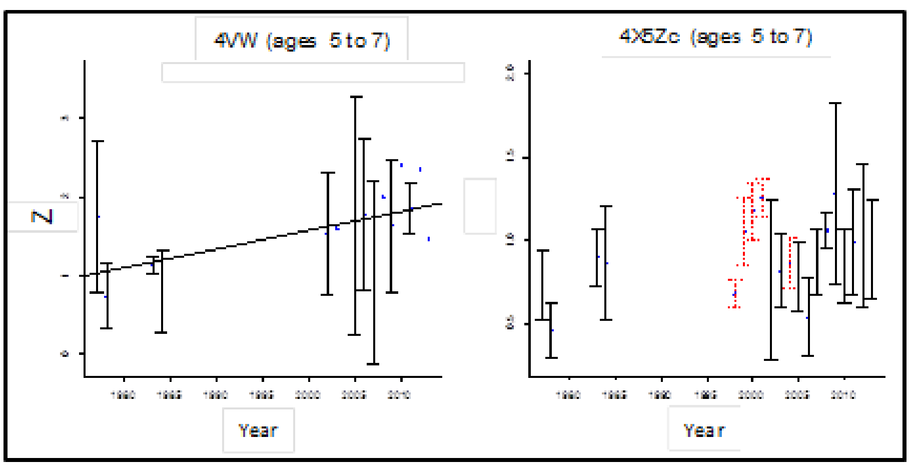


Figure 25. Average total mortality (Z; ± 95% CIs) for White Hake ages 5 to 7 using catch-at-age data from Divs. 4VW (left panel) and Divs. 4X5Zc (right panel) surveys. Red stippled lines (right panel) indicate years for which the age structure was derived using commercial age-length keys.

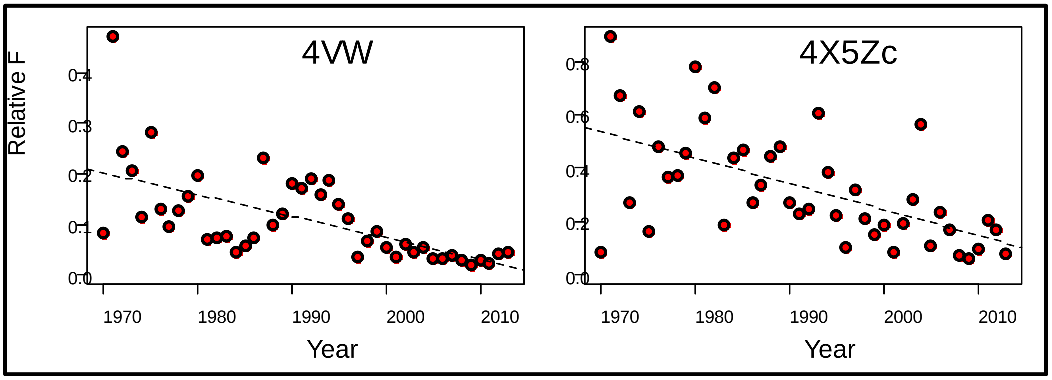


Figure 26. Relative F (reported commercial landings / survey biomass) for White Hake in Divs. 4VW (left panel) and Divs. 4X5Zc (right panel).

Northern Gulf of St. Lawrence (NAFO Divisions 4RST*)

Relative F was calculated for nGSL White Hake as reported annual landings of this species divided by the minimum trawlable biomass of adults estimated from the DFO research survey (Fig. 27). Average relative *F* before a 1994 groundfish moratorium (1987 to 1993) was estimated at 0.051, which decreased to an average of 0.007 in post-moratorium periods (1997 to 2002, 2004 to 2014).

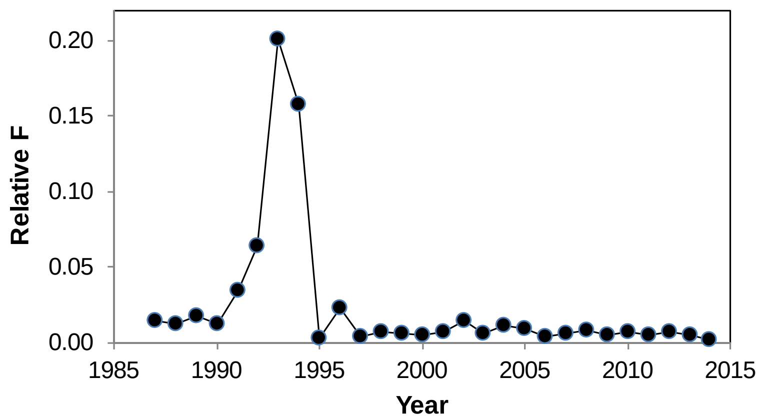


Figure 27. Relative F (reported commercial landings / research survey adult biomass) for White Hake in Divs. 4RST, 1987 to 2014.*

Recruitment and recruitment rates

Newfoundland (NAFO Divisions 3NLOP)

An index of recruitment at age 1, White Hake <= 26 cm, was derived from DFO-NL spring survey catches in Divs. 3NOPs (Fig. 28). Except for a very large recruitment index in 2000, the recruitment index was generally very low in all years, with small peaks in 1999 and 2011 (Simpson and Miri 2013*a*). A relative recruitment rate index, expressed as the recruitment index of 1-year-old White Hake (sexes combined) in year i divided by the relative index of adult females in year i-1 from the Divs. 3NOPs spring survey, was highly variable with values ranging from 0.35 to 10.1 recruits per adult female. The exception was a value of 48.7 recruits per female for the 1999 year-class (i.e., age 1 recruits in 2000).

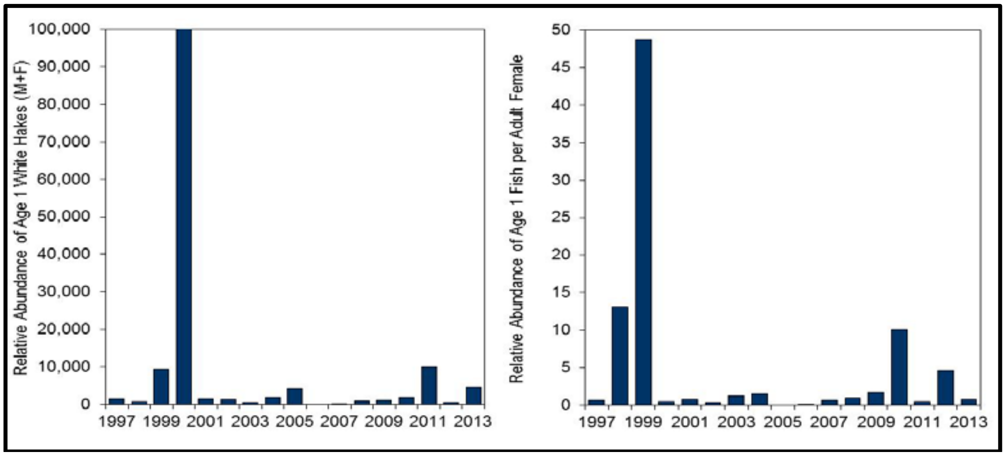


Figure 28. White Hake recruitment index for 1-year olds (sexes combined; left panel) and relative recruitment rate index (right panel) from the DFO-NL spring survey in Divs. 3NOPs, 1997 to 2013. Estimates from 2006 are not shown, since survey coverage in that year was incomplete.

Maritimes (NAFO Divisions 4VW and 4X5Zc)

Average recruitment at age 2 in Divs. 4VW over the time series was 29.2 million White Hake, but only 20.2 million in the 2000s (Fig. 29). This difference was mainly due to the very large 1983 recruitment estimate. In Divs. 4X5Zc, recruitment at age 2 ranged from 2 to 29 million in 1978 to 2013; averaging 14.6 million fish (Fig. 29). Although variable, a general decline in recruitment for Divs. 4VW and Divs. 4X5Zc was not apparent, with no relationship to spawner biomass. The recruitment rate increased as spawning stock biomass (SSB) decreased thereby maintaining overall recruitment at fairly stable levels. This high recruitment rate prevented further declines in abundance, despite very high total mortality rates.

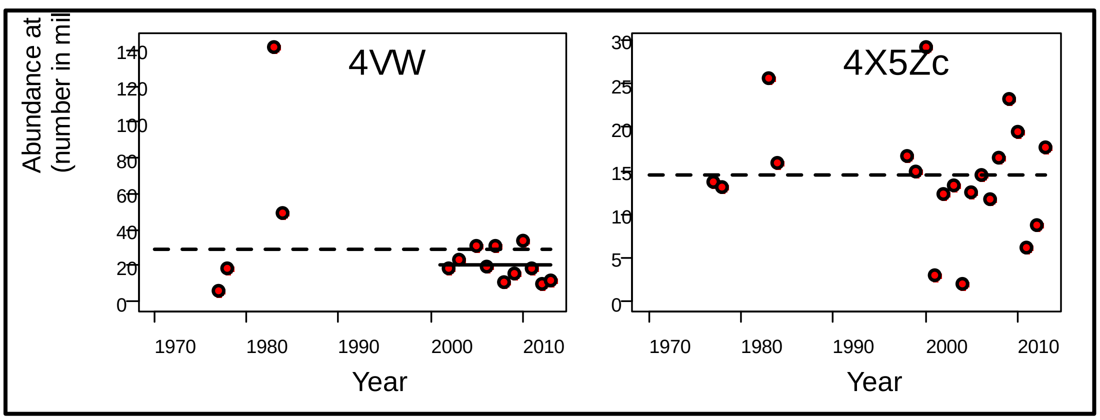


Figure 29. Relative abundance (number in millions) of age 2 recruits in Divs. 4VW (left panel) and Divs. 4X5Zc (right panel) for years with survey data. Dashed black lines represent the time series average, and the solid black line is the average for 2001 to 2013 for 4VW data series.

Habitat and Residence Requirements

Habitat properties

White Hake are temperature keepers, showing a preference for water temperatures above 4°C. Analyses of habitat associations for White Hake in the ANGSL DU suggest that this species is most commonly associated with temperatures of 3° to 9°C. Depth and salinity associations are likely influenced by water temperature, but are generally 100 to 350 m and 33 to 35 ppt, respectively.

Juvenile White Hake retention on the southern Grand Banks (Divs. 3NO and Subdiv. 3Ps) is increased by weak along-slope currents and strong on-bank flows, as well as spawning below the Ekman layer (i.e., a vertical region of the ocean affected by movement of wind-driven surface waters) in late spring.

Inshore sites (including eelgrass beds) appear to be used by immature White Hake in the nGSL, and in Newfoundland and Labrador waters. White Hake adults in the nGSL are found preferentially near slopes along deep channels with fine sediments.

There is some evidence of widespread nursery areas for juvenile White Hake in coastal areas of the Scotian Shelf and Bay of Fundy. Small fish have been caught along the southern shore of Nova Scotia, in inshore areas off of Cape Breton, and inshore in the Bay of Fundy.

In general, White Hake appear to stay in shallow water for a year, and then migrate to offshore areas during their second year.

Spatial extent of the habitat areas

Suitable habitat for White Hake is widespread throughout the ANGSL DU, as indicated by the continued broad distribution of this species. There has been no apparent reduction in the spatial extent of suitable habitat.

Presence and extent of spatial configuration constraints

There does not appear to be discontinuity across this species' range or any barriers to its access of specific areas in the ANGSL DU. Catches of White Hake in Subdiv. 3Pn indicate connectivity between nGSL Divs. 4RST* and the rest of the DU (Fig. 16). Connectivity across the Laurentian Channel is also evident by research data from the Atlantic Halibut longline survey (Fig. 30).

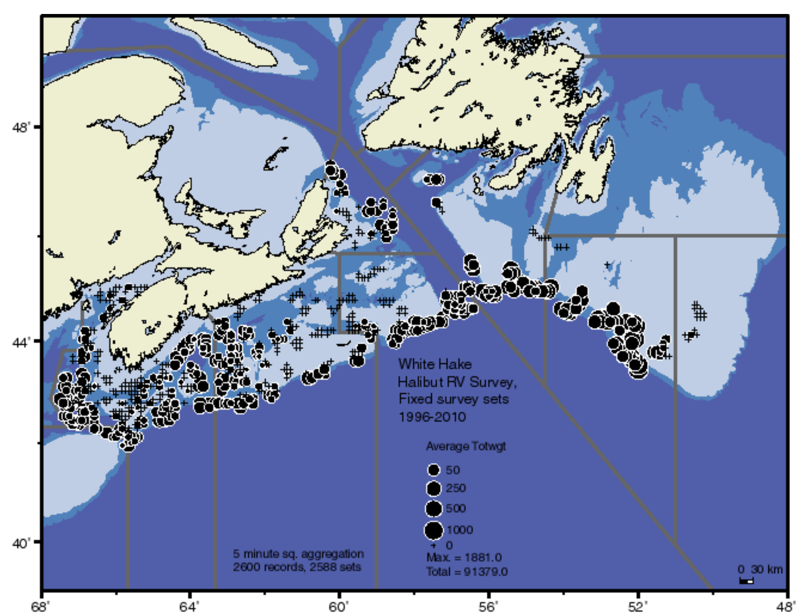


Figure 30. Distribution of White Hake across the Laurentian Channel as indicated by fixed stations of the Halibut Industry Longline Survey, 1998 to 2010 (Simons and Cook 2013).

Concept of residence for White Hake

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)).

White Hake does not have any known dwelling-place similar to a den or nest during any part of their life cycle. In accordance with the DFO June 2013 policy statement on the “Application of Species at Risk Act Section 33 (Residence) to Aquatic Species at Risk”, the concept of residence thus does not apply to this species.

Threats and Limiting Factors to Survival and Recovery

Threats

The only quantified anthropogenic threat to the recovery of this species over its entire DU is ongoing fishing mortality, which occurs in White Hake directed fisheries in Divs. 3NOPs, as bycatch in groundfish fisheries, and as bycatch in other fisheries such as lobster, scallop and recreational groundfish fisheries. However, fishing mortality presently appears to be a limited threat to White Hake survival and recovery.

Fishing

Newfoundland (NAFO Divisions 3LNOP)

Commercial fisheries removals of White Hake in Subareas 1-3 were obtained from three data sources:

- NAFO STATLANT-21A White Hake landings, reported by NAFO-member countries fishing mainly outside Canada’s 200-mile limit (EEZ);
- DFO-NL ZIFF (Zonal Interchange File Format) White Hake landings, recorded in logbooks and on fish plant purchase slips by Canadian fishers operating in Canada’s EEZ; and
- Canadian At-Sea Fisheries Observers’ catches and discards by species, collected in a standardized format on a set-by-set basis on board commercial fishing vessels at sea.

Although occasionally reported from Divs. 2J3KL, landings of White Hake occur mainly in Divs. 3NOP (Fig. 31). In the NRA of Divs. 3NO, this population is fished primarily by Canada, EU-Portugal, EU-Spain, and Russia, and is managed with a Total Allowable Catch (TAC) set by NAFO. In 1988, Canada commenced a directed fishery for White Hake in Divs. 3NO of Canada’s EEZ. In Div. 3P, White Hake is fished almost exclusively by Canada, is managed by DFO with input controls (effort and gear rather than TAC), and landings are reported mainly from Subdiv. 3Ps.

NAFO-reported landings (all member countries combined) in Divs. 3NO increased abruptly to 7,200 t in 1971, with 93% from Div. 3O (Fig. 31). Landings then peaked in 1987 at approximately 8,100 t, with 66% from Div. 3N. Reported landings in Divs. 3NO remained above 2,000 t until 1992, when a further decrease to roughly 1,700 t (99% from Div. 3O) coincided with the restriction of fishing by other countries to areas outside Canada’s 200-mile limit and, consequently, foreign reported landings fell to zero in the Canadian EEZ. Following recruitment of a very large 1999 year-class of White Hake, NAFO reported landings in Divs. 3NO increased to 6,200 t (almost equally from both divisions) in 2003, but then decreased sharply. Reported landings in Divs. 3NO have not exceeded 500 t since 2009, with approximately 94% from

Div. 3O. During 2009 to 2013, landings annually averaged 15 t from Div. 3N and 237 t from Div. 3O.

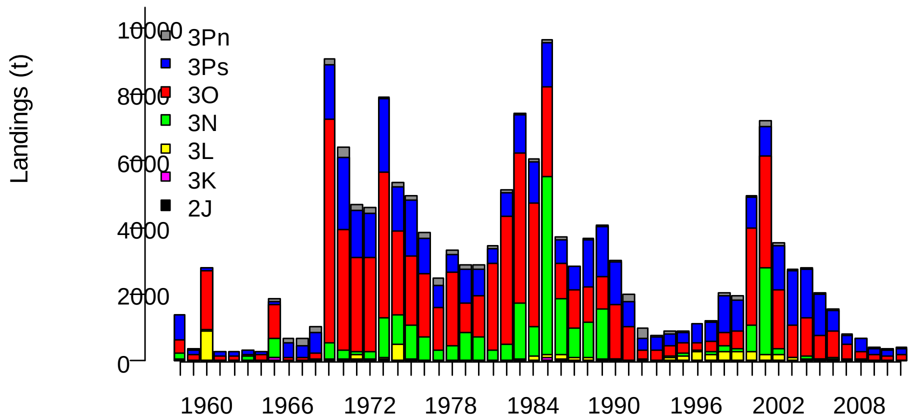


Figure 31. NAFO reported landings (tonnes) of White Hake in Divs. 2J3KLNOP, 1960 to 2013.

NAFO reported landings of White Hake in Subdiv. 3Ps were generally lower than those from Divs. 3NO (Fig. 32). However, most of the reported landings during the mid-1980s to the early 1990s should be interpreted with caution, as landings of Atlantic Cod by Canadian longline fisheries during this period were misreported as White Hake. Reported White Hake landings in Subdiv 3Ps have not exceeded 400 t since 2009. In 2009 to 2013, landings annually averaged 269 t from Subdiv 3Ps. In Subdiv. 3Pn, landings of this species were reported exclusively from Canadian vessels since 1971, and annually averaged 26 t over 2009 to 2013 (Fig. 32).

ZIFF-reported landings, excluding discards, of White Hake in Divs. 3NOP were from fisheries targeting this species with gillnets and longlines, and as bycatch primarily in commercially important groundfish fisheries directing for Atlantic Cod (*Gadus morhua*), Atlantic Halibut (*Hippoglossus hippoglossus*), Monkfish (*Lophius americanus*), and Redfish (*Sebastes* spp.; Fig. 33). Combined annual landings have not exceeded 250 t since 2011, with 74% reported from gillnets and 24% from longlines (Fig. 34). Discards are rarely reported, except by At-Sea Fisheries Observers (ASOs). Annual Observer coverage of White Hake directed and bycatch fisheries is usually low to non-existent.

Total annual catches of White Hake (i.e., landings + discards at sea) in directed and bycatch fisheries within Canada's EEZ of Divs. 3NOP were estimated using a method based on Campana et al. (2011) with NL-ASO data and DFO-NL ZIFF landings for 1985 to 2012 (see Simpson and Miri 2013b for detailed methodology). However, catch estimates were dependent on the percentage of actual At-Sea Observer coverage of each fishery in each year, as well as whether the NL ZIFF database contained reported landings of this species for each year of ASO coverage. In 1985 to 2012, most catches were observed in the White Hake directed gillnet and longline fisheries (Table 2). In Divs. 3NOP fisheries targeting other species during 1997 to 2008, the highest average annual bycatch of White Hake was estimated for Atlantic Cod longline and Redfish gillnet fisheries, and smaller estimates (in decreasing order) for the Atlantic Cod gillnet fishery, Atlantic Halibut longline fishery, and Monkfish gillnet fishery (Table 2). Combined bycatch estimates for this period peaked in 2008. During 2009 to 2012, annual bycatch estimates for White Hake did not exceed 500 t in total and were primarily in the Atlantic Cod longline fishery. They were significantly smaller for the Atlantic Halibut longline and Atlantic Cod gillnet fisheries and negligible for otter trawl fisheries directing for Witch Flounder (*Glyptocephalus cynoglossus*), Atlantic Cod, and Redfish.

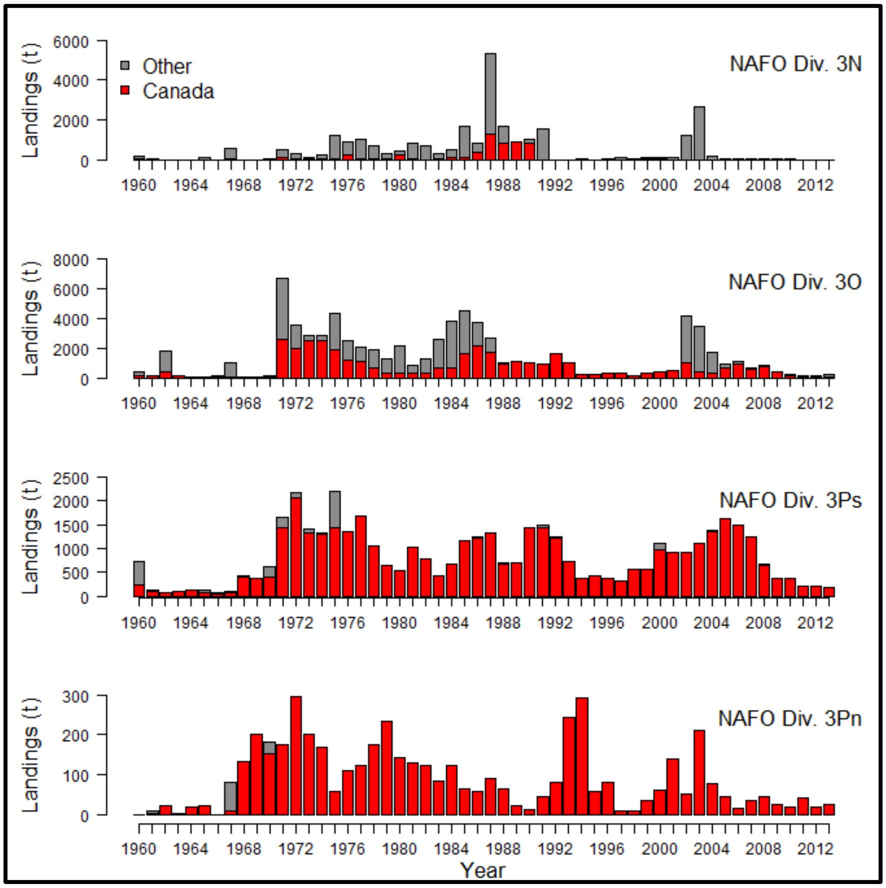


Figure 32. Reported landings (tonnes) of White Hake by Canadian fleets in Canada's EEZ (Canada), and by other countries (Other) in Div. 3N, Div. 3O, Subdiv. 3Ps, and Subdiv. 3Pn, 1960 to 2013.

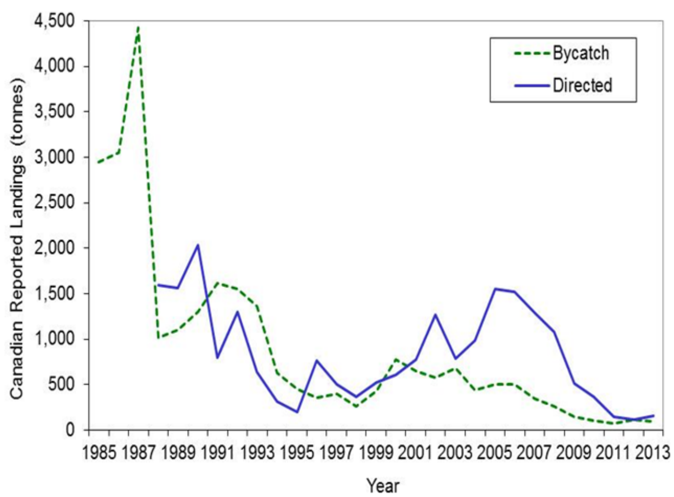


Figure 33. ZIFF-reported directed and bycatch landings (tonnes) of White Hake in Canada's EEZ of Divs. 3NOP, 1985 to 2013.

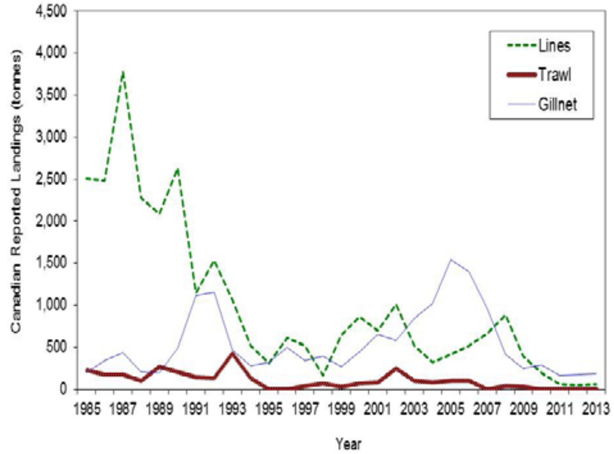


Figure 34. ZIFF-reported landings (tonnes) of White Hake by gear type in Canada's EEZ of Divs. 3NOP, 1985 to 2013.

Table 2. Estimated total annual catch (tonnes; average and 95% CI) of White Hake in several Divs. 3NOP fisheries for 1985 to 2012, 1997 to 2008, and 2009 to 2012. Data are from Canadian At-Sea Fisheries Observers and DFO-NL ZIFF in comparable years.

		Estimated annual catch (t) 1985 - 2012		Estimated annual catch (t) 1997-2008	Estimated annual catch (t) 2009-2012
Fishing gear	Directed species	Average	95% Confidence Interval	Average	Average
Gillnets	White Hake	393	243 – 543	561	199
	Atlantic Cod	109	61 – 156	146	29
	Monkfish	40	11 – 69	32	5
	Redfish	163	73 – 253	216	5
Longlines	White Hake	253	172 – 334	365	153
	Atlantic Cod	228	149 – 307	219	250
	Atlantic Halibut	54	26 – 82	68	42
Otter trawl	Atlantic Cod	6	3 – 9	7	5
	Redfish	38	16 – 59	74	2
	Witch Flounder	19	5 – 33	11	12

Maritimes (NAFO Divisions 4VW and 4X5Zc)

There is no directed fishery for White Hake in NAFO Divs. 4VW and 4X5Zc.

White Hake occurs as bycatch in all groundfish fisheries in Divs. 4VW and Divs. 4X5Zc, and landings in 2013 were 128 t and 520 t, respectively (i.e., less than 10% of peak landings reported in the 1980s). Reported landings in all areas peaked in the mid-to-late 1980s, and then declined until the mid-1990s (Fig. 35). A TAC was first introduced in 1996 and since 1999 fisheries have been limited to White Hake bycatch only, with quota caps to restrict landings. The cap for the Div. 4X5Zc management unit varied annually, but was reduced to 650 t in 2013. Relative *F* (an approximate measure of exploitation) in Divs. 4VW and Divs. 4X5Zc showed similar trends.

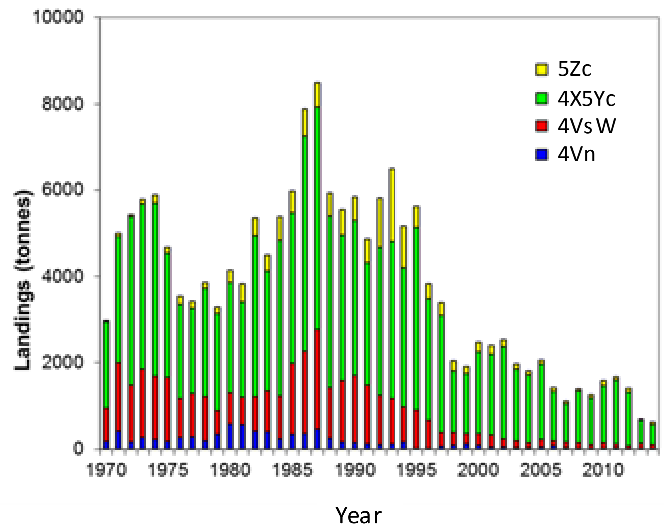


Figure 35. Reported landings (tonnes) of White Hake by Canadian fleets in NAFO Subdiv. 4Vn, and Divs. 4VsW, 4X5Yc and 5Zc, 1970 to 2014.

The majority of Canadian White Hake landings were taken by the fixed gear fleet (Fig. 36).

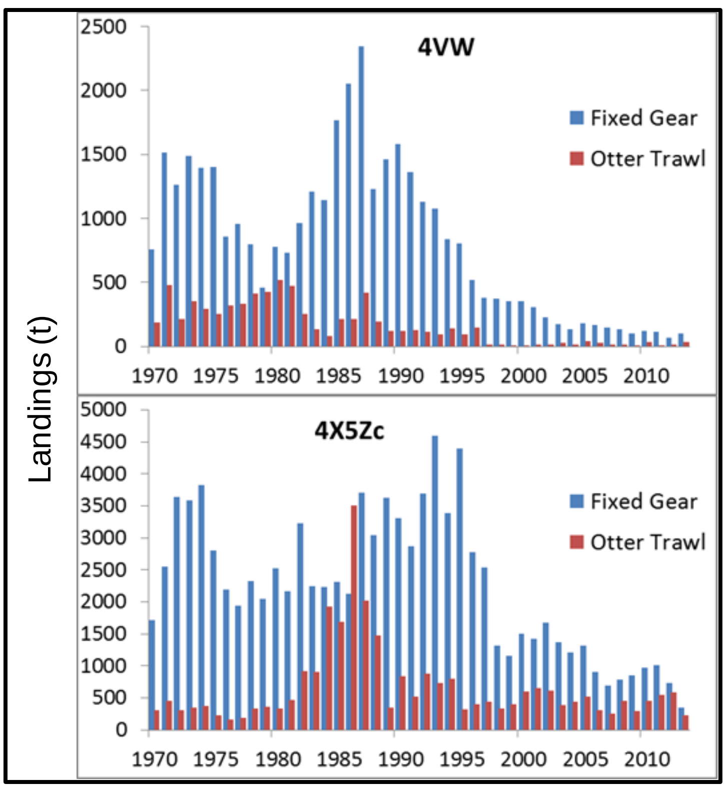


Figure 36. Reported landings (tonnes) of White Hake by Canadian fleets fishing with mobile and fixed gears in Divs. 4VW and 4X5Zc, 1970 to 2013.

White Hake can be retained in recreational fisheries and Aboriginal Food, Social, and Ceremonial (FSC) fisheries. Although catches in these fisheries are largely not reported, removals are thought to be low, and controls or limits exist for managing these fisheries.

Northern Gulf of St. Lawrence (NAFO Divisions 4RS)

There has never been a major fishery for White Hake in Divs. 4RS although there was a directed fishery in the mid-1980s to mid-1990s with an annual average landing of 15 t. This White Hake directed fishery was not managed with quotas. Reported landings increased from 46 t in 1960 and peaked at 454 t in 1982 (Fig. 37). Annual reported landings averaged 137 t in 1960 to 1993. With fishing effort reduced by the first moratorium on groundfish in 1994, annual White Hake landings averaged 11 t in 1997 to 2014 (8 t in Div. 4R, 3 t in Div. 4S), occurring as bycatch from the Atlantic Halibut, Cod, Redfish, and Greenland Halibut (Turbot; *Reinhardtius hippoglossoides*) fisheries (Fig. 38). White Hake were caught mainly by longlines (56%), gillnets (19%), and otter trawls (17%; Fig. 38).

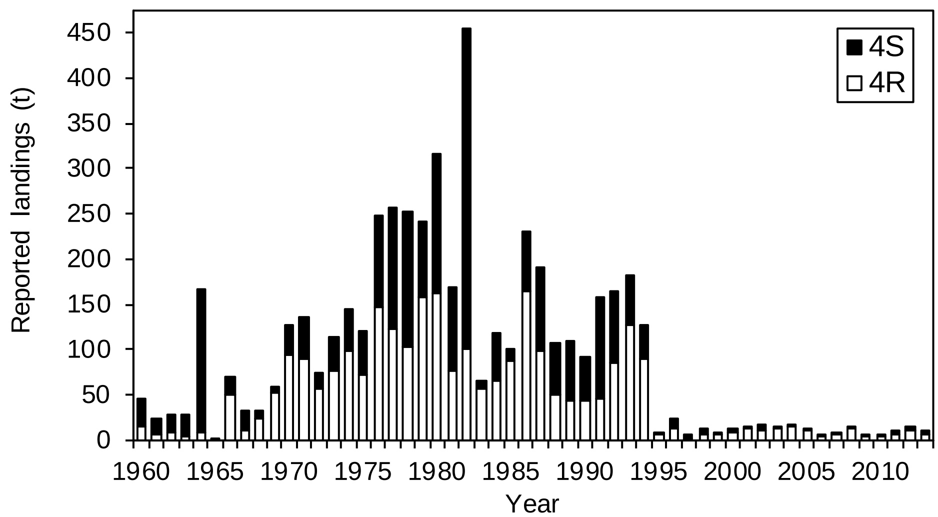


Figure 37. Reported landings (tonnes) of White Hake in Divs. 4RS, 1960 to 2013.

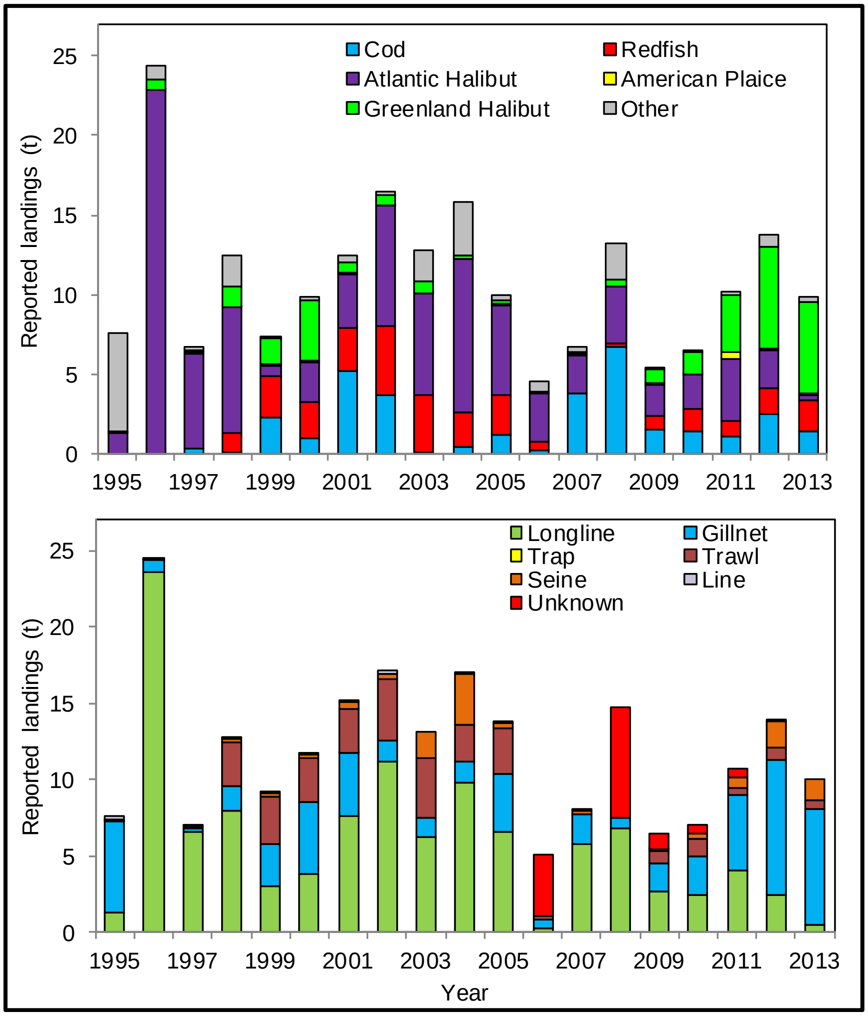


Figure 38. Reported landings (tonnes) of White Hake bycatch in other fisheries in Divs. 4RS, by main species landed (upper panel) and gear type (lower panel), 1995 to 2013.

Bycatch of White Hake in the shrimp fishery was investigated using the at-sea fisheries observer database. In 2000 to 2012, White Hake bycatch was mainly reported in Div. 4S (i.e., south of Anticosti Island) and most was discarded at sea (i.e. not recorded in fishers' logbooks or fisheries statistics). White Hake was estimated as bycatch in 6% of observed shrimp fishing sets with most catches of the order of 1 to 2 kg, and an estimated annual bycatch of 0.7 t (<1% of White Hake biomass estimated for this region). The size of White Hake was 20 to 26 cm total length, based on as-sea observer samples of this bycatch before discarding.

Bycatch of White Hake in recreational or FSC fisheries in this DU was negligible, due to the distribution of this species and the fishing practices.

Offshore Oil Development

There are no data available on the impact of oil and gas drilling, or of oil pollution, on White Hake or its habitat.

Currently, there are no oil and gas activities in the NL portion of this DU. However, there are significant drilling license (SDL) areas immediately north of Divs. 3NO. Hibernia, Terra Nova, White Rose, and North Amethyst oil fields are in operation in the Jeanne d'Arc Basin. The Hebron oil field is anticipated to become operational in 2017. Any significant oil pollution north of

Divs. 3NO could be transported by the Labrador Current into this DU, and thus potentially negatively impact White Hake (especially pelagic eggs and larvae) and their habitat.

Of future concern is the planned exploratory drilling for oil and gas at the offshore Old Harry site in the Laurentian Channel of the Gulf of St. Lawrence. The license areas are situated between areas of the largest remaining catches of White Hake situated in the northern Gulf, on the slopes of the Laurentian Channel to the southwest (i.e., primarily Div. 4T), and to the coast of Newfoundland.

Activities most likely to damage or destroy the habitat properties

Oil spills or blow-outs from any offshore oil development could pose a risk to habitat used by offshore spawning White Hake, and to habitat used by the pelagic juvenile phase of this species. No other anthropogenic activities were identified that could negatively impact habitat for White Hake.

Natural factors that may limit survival and recovery

The causes of high natural mortality (*M*) of White Hake are largely unexplained in all units of the ANGSL DU. Seal predation is proposed as an important source of increased natural mortality in the southern Gulf of St. Lawrence DU (DFO 2016), but available evidence is not conclusive for the ANGSL DU.

Higher M in Divs. 3NOPs is also likely while infrequent strong year classes are rapidly fished out and not sustained for more than a few years in the White Hake directed fishery.

High M is also assumed to be occurring in Div. 4RS, due to continued low abundance indices relative to the early portion of the time series. Similarly, high natural mortality may be limiting recovery in Divs. 4VW, and no increase in White Hake biomass is anticipated for this unit. In both of these areas, fisheries removals are very small in relation to natural mortality.

Recovery Targets

Candidate abundance and distribution target(s) for recovery

Recovery of the White Hake ANGSL DU could be achieved when the indicators of stock status in the four management units are sustained at levels above the management unit-specific recovery targets.

Abundance target

Abundance targets were defined for each management unit (Table 3), and correspond to an increase in biomass to a sustained abundance at or above 40% of B_{MSY} (biomass at maximum sustainable yield), an estimate expected to sufficiently reduce the risk of population extinction.

Table 3. Summary of recovery targets for abundance of White Hake for the four management units in the ANGSL DU.

Management unit	Abundance recovery target (40% B_{MSY})		
	Source	Based on period	Value (t)
Div. 3NOPs	Surplus Production Model	1960 to 2013	13,000
Div. 4VW	DFO survey trawlable biomass	1970 to 1992	3,885
Div. 4X5Zc	DFO survey trawlable biomass	1970 to 1998	6,867
Div. 4RST*	DFO survey trawlable biomass	1987 to 1990	3,606

For Divs. 3NOPs, the proposed abundance recovery target of 13,000 t of White Hake biomass, was estimated using a Bayesian surplus production model over the time period 1960 to 2013 (Table 3). White Hake biomass is currently above this target (Fig. 39).

For Divs. 4VW, B_{MSY} (9,711 t) was estimated as the average survey adult (>= 42 cm) biomass index during the productive period 1970 to 1992 with the recovery target of 40%B_{MSY} at 3,885 t (Table 3). Adult biomass, based on a 3-year geometric mean of the research survey biomass index, has been below this recovery target since 2003 (Fig. 39).

For Divs. 4X5Zc, B_{MSY} (17,167 t) was estimated as the average survey adult (>= 42 cm) biomass index during the productive period 1970 to 1998 (i.e., after which biomass declined below levels observed in the 1970s). Adult biomass decreased below the recovery target of 6,867 t (40% B_{MSY}) in 2004, 2005, 2006, and 2008 (Table 3). While the biomass index has remained above this target since 2009, it was very close to it in 2013 and 2014 (Fig. 39).

For Divs. 4RST*, B_{MSY} (9,016 t) was estimated as the average survey adult (≥45 cm) biomass in 1987 to 1990, i.e. for years when size data were collected and before a large decline after 1990. A recovery target was estimated at 3,606 t (40% B_{MSY}) (Table 3). Adult biomass remained below this target since 1993, and is currently at 55% of the recovery target (Fig. 39).

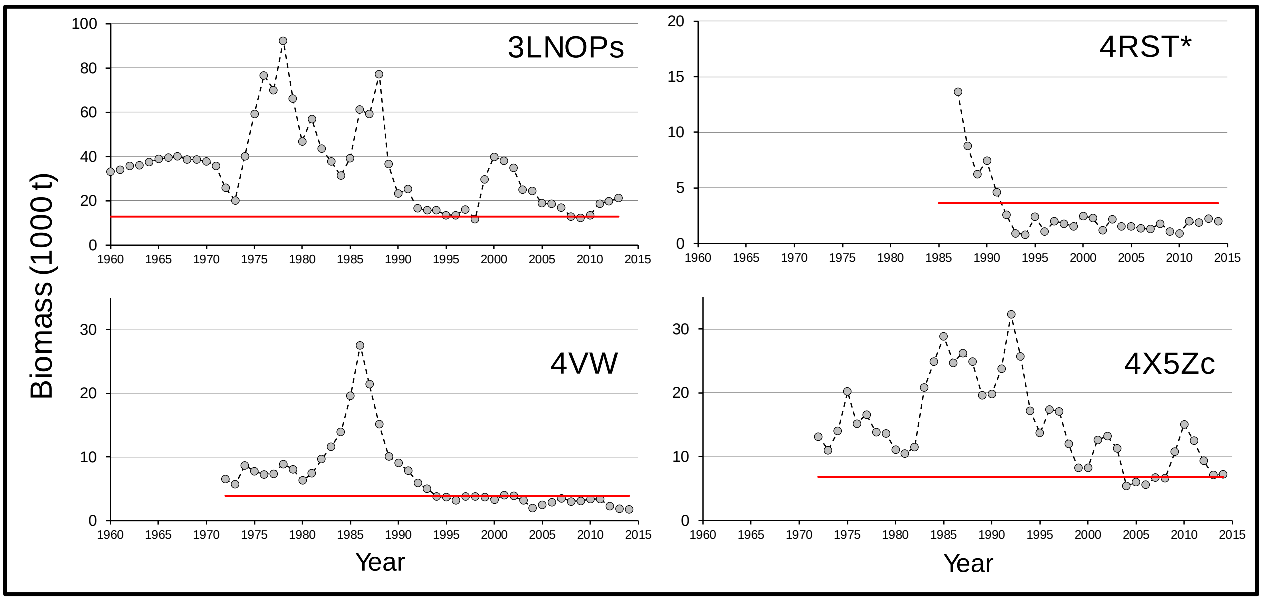


Figure 39. Estimated biomass of White Hake relative to the abundance recovery target (40% B_{MSY}) in the four management units of the ANGSL DU (for available time series). The solid horizontal red line in each panel is the management unit specific abundance recovery target value.

Distribution target

For White Hake in Divs. 3NOPs, Divs. 4VW, and Divs. 4X5Zc, overall distribution has not changed. However, there was a reduction in design-weighted area of occupation (DWAO) for Divs. 4RST*. A distribution target for recovery is proposed for White Hake in Div. 4RST* corresponding to the DWAO index value observed during its productive period (1987 to 1990). The objective is to maintain the current geographic distributions of White Hake in the other management units of the ANGSL DU.

Expected population trajectories over three generations

Newfoundland (NAFO Divisions 3NLOP)

For Divs. 3NOPs, White Hake population biomass was estimated to presently be above its recovery target (Fig. 40). Model projections from 2014 forward were conducted using $F_{current}$ = 0.03 and F_{MSY} = 0.087. At current F (0.03), the biomass is expected to increase. At higher F (F_{MSY} = 0.087), biomass is projected to rise slightly and remain at low levels but above the recovery target. Furthermore, there is a 73% percent chance that biomass could exceed 80% of B_{MSY} by 2020 at current F (0.03; Fig. 40; Table 4). However, these projections encompassed a very broad range of possible values (i.e., represented by large credibility intervals), and thus should be considered with caution.

In summary, there is a very high probability that White Hake biomass will remain above the Divs. 3NOPs recovery target over the next fifteen years under current conditions, and at its estimated F_{MSY} fishing rate. At F_{MSY}, median biomass is projected to be relatively stable with neither an increasing nor decreasing trend.

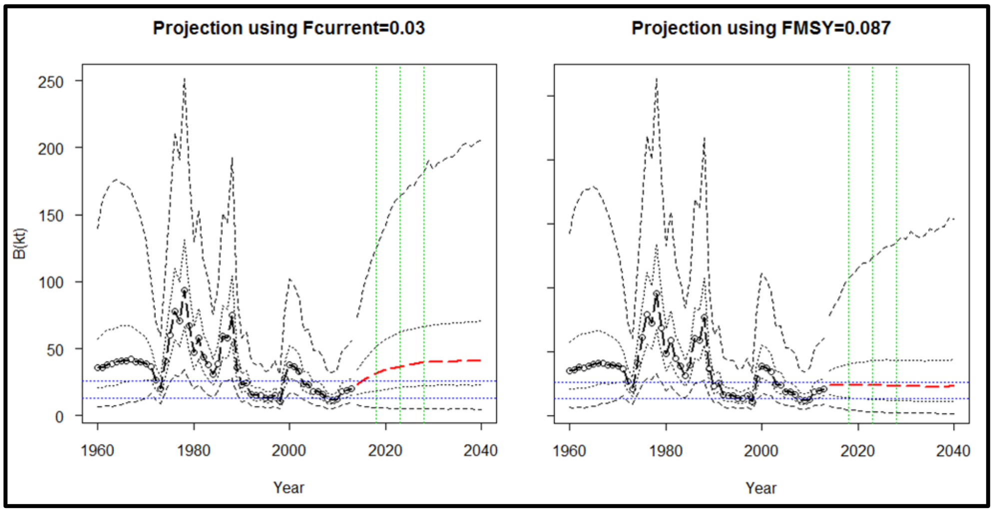


Figure 40. Bayesian surplus production model estimates of historical (1960 to 2013; dashed thick black line, circle symbols) and predicted biomass (1,000 t) for the next 27 years at $F_{current}$ = 0.03 (left panel) and F_{MSY} = 0.087 (right panel) for Divs. 3NOPs White Hake. Stippled blue horizontal lines indicate the recovery target of 40%B_{MSY} and biomass at 80%B_{MSY}. Stippled green vertical lines represent time horizons of 5, 10, and 15 years forward. Stippled black lines indicate 25 % and 75% credibility intervals, and dashed black lines represent 2.5 % to 97.5% CIs. A dashed thick red line is the median biomass for projected years.

Maritimes (NAFO Divisions 4VW and 4X5Zc)

For Divs. 4VW, at a current estimated total mortality rate (Z = 1.6) and essentially no fishing (relative F = 0.01), White Hake spawning stock biomass (SSB) is predicted to increase to a level slightly above its abundance recovery target, but with a 34% chance of biomass being at or below the recovery target by 2016 (Fig. 41; Table 5). A reduction in total mortality to Z = 0.7 results in the projected SSB increasing to 9,756 t (i.e., close to B_{MSY}), with a low probability (8%) of being below its recovery target (Fig. 41). A reduction in Z to 0.6 would be required for the median of projected biomass to exceed B_{MSY}. Projected biomass increases in Div. 4VW are dependent on assumed recruitment levels. If actual recruitments are less than the average for the time period (Fig. 29), biomass increases may not occur. If recruitment is similar to that over the last three years, projected SSB will have a 63% probability of being below its recovery target (low R scenario; Fig. 41).

Table 4. Population status indicators for Divs. 3NOPs White Hake after 5, 10, 15, and 27 years. Fishing mortality scenarios were based on two levels of constant F ($F_{current}$=0.03; F_{MSY}=0.087). B_{year} is yearly biomass for the time period (i.e., biomass for each of 2014 to 2018 for the first 5-year projection). B_{FINAL} is biomass in the final year of this projection (i.e., 2018 for the 5-year horizon). Probabilities (P) are presented for three population status indicators: (1) B_{year} will be above the recovery target of 13,000 t at some time during the time period; (2) B_{FINAL} (i.e., B_{year} in the final year of the time period) will be above the recovery target; and (3) B_{FINAL} (i.e., B_{year} in the final year of the time period) will be above the 80% B_{MSY} value of 26,300 t.

F value	Projection	P (B_{year}>40%B_{MSY})	P (B_{FINAL}>40%B_{MSY})	P (B_{FINAL}>80%B_{MSY})
$F_{current}$ =0.03	5 years	0.92	0.83	0.58
	10 years	0.96	0.86	0.66
	15 years	0.97	0.87	0.70
	27 years	0.99	0.88	0.71
F_{MSY} =0.087	5 years	0.91	0.77	0.46
	10 years	0.95	0.74	0.46
	15 years	0.96	0.73	0.46
	27 years	0.98	0.71	0.46

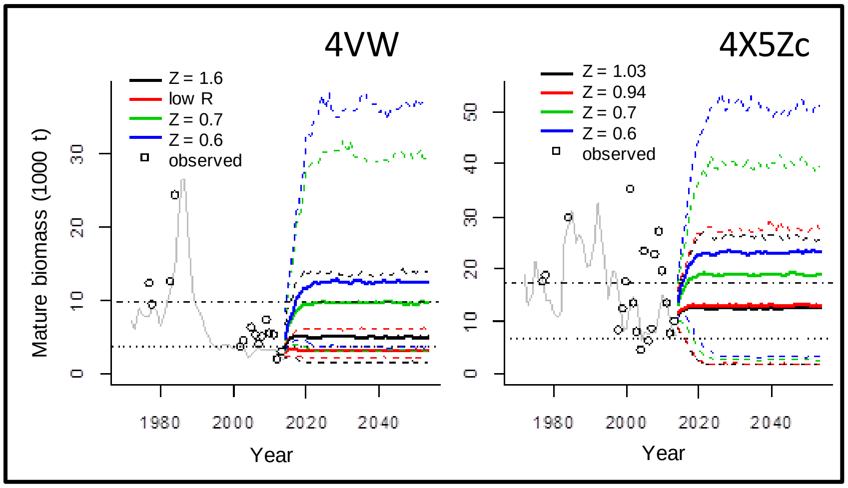


Figure 41. Results of stochastic projections of mature biomass (X 1000 t) for different mortality rate and recruitment scenarios for White Hake in Divs. 4VW (left panel) and Divs. 4X5Zc (right panel). Medians are represented by solid lines, with 2.5th and 97.5th percentile ranges as stippled lines. The solid gray thin line in each panel shows a three-year moving average of observed estimates for spawning stock biomass.

For Divs. 4X5Zc, with no fishing and a total mortality rate (Z) of 0.94, there is a high probability (84%) of projected equilibrium White Hake SSB being at or above its abundance recovery target (Table 5; Fig. 41). Projected SSB at the current total mortality rate (Z = 1.03) does not differ noticeably from a scenario without fishing. A reduction in total mortality to 0.7 (including fishing at the average relative fishing mortality rate over the last five years of 0.12) projects an equilibrium SSB of 18,800 t, (i.e., slightly above B_{MSY}) and a 90% probability of being above the abundance recovery target (Fig. 41; Table 5).

Table 5. Spawning stock biomass (SSB) projections for White Hake in Divs. 4VW and Divs. 4X5Zc for different total mortality rate and recruitment scenarios.

Management unit	Scenario	Equilibrium SSB (t) (median)	Prob. SSB < 40%B_{MSY}
Divs. 4VW	$Z_{current}$ = 1.6	4,973	34%
	Z = 0.7	9,756	8%
	Z = 0.6	11,644	4%
	low recruitment ($Z_{current}$)	3,275	63%
Divs. 4X5Zc	$Z_{current}$ = 1.03	12,419	16%
	Z = 0.94 (F = 0)	12,930	16%
	Z = 0.7	18,800	10%
	Z = 0.6	23,180	9%

Northern Gulf of St. Lawrence (NAFO Divs. 4RST)*

In Divs. 4RST*, White Hake landings have been approximately 11 t per year since 1995, representing a relative fishing mortality of 0.007. This level of mortality probably has a negligible impact on the abundance trajectory of this species in Divs. 4RST*. No population projections were conducted for this management unit. Given the low level of reported landings and relatively stable adult population size (summer survey index) since 1995, no change in abundance indices is anticipated in the near future under current conditions.

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 White Hake population in the ANGSL DU; presently and when recovery occurs.

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

Projections were conducted at reduced levels of total mortality (Z), and are previously described in the section “Expected population trajectories over three generations”.

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 White Hake. There are no known gear modifications to reduce catches of White Hake in any fishery. Mitigation measures to decrease commercial fishing mortality could include reducing fishing effort targeting this species and reduced landings of White Hake bycatch. However, given the high post-release mortality associated with releasing this species from several gear types, this measure would probably not increase White Hake abundance. More effective Canadian regulations to control catch in Divs. 3NOPs White Hake directed fisheries would include DFO setting a significantly reduced TAC, increasing minimum mesh sizes of otter trawls and gillnets (to allow newly-recruited fish to swim through commercial gear and survive to at least their first reproductive season), and reducing the total number of hooks used in longline fleets. However, such DFO-legislated measures cannot be applied to foreign fisheries that significantly harvest White Hake in the NRA of Divs. 3NO, which is managed by NAFO.

As a NAFO-member country, Canada could also petition the NAFO Fisheries Commission to significantly reduce its White Hake TAC in the NRA of Divs. 3NO to an effective, precautionary level. Combined with sufficient enforcement (e.g., fishing vessel inspections by Fishery Officers) in international waters, this measure would drastically limit mortality of immature White Hake in those unpredictable, sporadic years with high recruitment to the fishery. Given that this species in Divs. 3NO is a “straddling stock” across Canada’s 200-mile limit, any NAFO precautionary approach adopted for the NRA will also increase White Hake abundance in adjacent NL waters.

Eliminating White Hake landings in recreational or Food, Social, and Ceremonial fisheries could also be considered, but these fisheries catches are unreported and, if as low as assumed, will have an insignificant effect on this population

An effective measure to mitigate White Hake mortality due to fishing would be to increase Canadian at-sea fisheries observer (ASO) coverage of directed and relevant bycatch (groundfish) fisheries conducted in the ANGSL DU by Canadian fishers. Given that discards are never reported by Canadian and foreign fishers (i.e., only landings are recorded), at-sea observers constitute the sole source of data on commercial discarding and total catch, in addition to sampling the catch (i.e., before discarding occurs) for gender and otoliths (fish “ear bones” for subsequent ageing by DFO); all of which would allow DFO to quantify discard mortality and monitor changes in White Hake population structure (e.g., male/female sex ratio, gender-specific growth rates, age-based abundance) for this DU. Such analyses would prove crucial to informing management decisions on effective measures to reduce activities that pose significant threats to White Hake in the ANGSL DU. It should be noted that annual observer coverage of relevant fisheries in the ANGSL DU remains low to non-existent, while the Canadian fishing industry must pay 100% of the costs for Canadian at-sea observers deployed in Canada’s EEZ.

Inventory of activities that could increase the productivity or survivorship parameters

As previously discussed, seal predation could be a cause of high natural mortality for White Hake. However, lack of evidence from diet studies of potential predators of the ANGSL White Hake precludes identification of actual causes for this high mortality. Therefore, there are no activities considered to increase productivity or survivorship parameters.

Feasibility of restoring the habitat to higher values

As habitat is not a limiting factor to the White Hake population in the ANGSL DU, discussion of the feasibility of restoring its habitat to higher values was not considered further.

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

No mitigation measures or alternatives were proposed for increasing productivity or survivorship of White Hake population of the ANGSL DU.

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 total mortality (Z), and are previously described in the section “Expected population trajectories over three generations”.

Parameter values for population models for additional scenarios analyses

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

Allowable Harm Assessment

White Hake mortality due to directed and bycatch fisheries continues in the ANGSL DU, and outside of Canadian waters in the NRA of Divs. 3NO. Recreational groundfish fisheries may also catch White Hake in some areas, but there are no estimates of removals in any area. White Hake bycatch and discarding has been reported in other fisheries in some areas including lobster and scallop fisheries but the levels of discarding are currently not estimable.

Newfoundland (NAFO Div. 3LNOP)

As indicated in the section under Threats, White Hake in Divs. 3NOP are caught in longline, otter trawl, and gillnet fisheries. Bycatch of this species occurs primarily in fisheries for Atlantic Cod (*Gadus morhua*), Atlantic Halibut (*Hippoglossus hippoglossus*), Monkfish (*Lophius americanus*), and Redfish (*Sebastes* spp.). Landings of White Hake occur mainly in Divs. 3NOP (Fig. 31), although they are occasionally reported in Divs. 2J3KL. In 1988, Canada commenced a directed fishery for White Hake in Divs. 3NO of Canada's EEZ. In the NRA of Divs. 3NO, this population is also fished by EU-Portugal, EU-Spain, Russia, and Canada, and is managed with a TAC set by NAFO. In Div. 3P, White Hake is fished almost exclusively by Canada, is managed with input controls (i.e. effort, rather than a TAC) by DFO, and landings are reported mainly from Subdiv. 3Ps (Fig. 32; Table 6).

Reported landings by Canada in Divs. 3NOP averaged 426 t in 2009 to 2013 (range: 274 to 691 t; Table 6). Reported landings by all jurisdictions in this area and time period averaged 547 t (range: 396 to 869 t). Canadian-reported landings of White Hake bycatch exceeded directed White Hake landings over the past two years (Fig. 33).

In Div. 3NOPs, White Hake biomass in Div. 3NOP is above its abundance recovery target, and under current conditions, current levels of fishing mortality are not jeopardizing its survival or recovery.

Maritimes (NAFO Divisions 4VW)

Although there are no commercial fisheries targeting White Hake in Divs. 4VW, this species is landed as bycatch in several groundfish fisheries. Estimates of discarded bycatch and White Hake used as bait were available for a few fishing fleets in this management unit (Table 7). A recreational groundfish fishery can retain White Hake, but there were no estimates of landed quantities. In 2009 to 2013, average reported landings of this species from Divs. 4VW were 109 t (range: 89 t to 130 t) with estimated total removals of White Hake in 2013 of approximately 130 t.

In Divs. 4VW, consequences of current fishing rates on adult abundance trends and population projections (i.e., relative to their recovery targets) do not differ from conditions when $F = 0$ (i.e., no fishing related mortality).

Table 6. Reported removals (tonnes) of White Hake in commercial fisheries, and from scientific research in Divs. 2J3KLNOP for 2009 to 2013.

NAFO Divisions and Subdivisions	Jurisdiction	Fishery	Age / size group	Average landings (t; range) 2009 to 2013
2J3KL	Canada	Directed	All sizes	0
		Bycatch		0
		Total		0
	Non-Canadian	Total	All sizes	10 (1 - 13)
3N	Canada	Directed	All sizes	0
		Bycatch		5 (1 - 8)
		Total		7 (3 - 13)
	Non-Canadian	Total	All sizes	11 (3 - 20)
3O	Canada	Directed	All sizes	133 (43 - 34)
		Bycatch		16 (2 - 52)
		Total		152 (50 - 389)
	Non-Canadian	Total	All sizes	85 (65 - 112)
3Ps	Canada	Directed	All sizes	128 (73 - 213)
		Bycatch		93 (62 - 110)
		Total		269 (167 - 378)
3Pn	Canada	Total	All sizes	26 (18 - 41)
3NOP	Canada	Total	All sizes	451 (274 - 780)
	Non-Canadian	Total	All sizes	96 (86 -122)
	All jurisdictions	Total	All sizes	547 (396 - 869)
Scientific	Canada (DFO Research Surveys)	Spring Divs. 3LNOP	All sizes	< 1 t
		Fall Divs. 2J3KLNO	All sizes	< 1 t
	Other (EU Spain)	Divs. 3NO	All sizes	< 1 t

Table 7. Reported removals (tonnes) of White Hake in commercial, Aboriginal, and recreational fisheries, and from scientific research in Divs. 4VW for 2013. For the fleet descriptors, FG signifies fixed gear, MG signifies mobile gear and the subsequent number is the maximum length of the vessel (in feet). ITQ signifies individual transferrable quota.

Fishery	Fleet	Gear	Reported (t)	Bait or discard (t)	Total landings (t) 2009 to 2013
Groundfish commercial bycatch	FG < 45 ft	Longline / gillnet	75.2	0.8	76.0
	FG 45 – 65 ft	Longline	1.8	4.5	6.3
	FG 65 – 100 ft	Longline	0.8	1.3	2.1
	FG > 100 ft	Longline	3.5	0.2	3.7
	MG 65 – 100 ft	Otter trawl	0.2	0	0.2
	MG > 100 ft	Otter trawl	9.9	0	9.9
	MG ITQ < 65 ft	Otter trawl	31.5	0	31.5
	All fleets	All gears	122.9	6.8	129.7
Groundfish recreational	Angling, handline			Unknown	
Aboriginal Food, Social and Cultural	Angling, handline, longline			Unknown	
Scientific (DFO Research Surveys)	Bottom trawl			< 1 t	

Maritimes (NAFO Divisions 4X5Zc)

Although there are no commercial fisheries targeting White Hake in Divs. 4X5Zc, this species is landed as bycatch in several groundfish fisheries. Estimates of discarded bycatch and White Hake used as bait were available for a few fishing fleets in this management unit (Table 8). The recreational groundfish fishery can also retain White Hake, but there were no estimates of landed quantities. During 2009 to 2013, average reported landings of this species from Divs. 4X5Zc were 1,205 t, with a range of 570 to 1,558 t occurring annually. In 2013, estimated total removals of White Hake in these fisheries was approximately 580 t.

Table 8. Reported removals (tonnes) of White Hake in commercial and recreational fisheries, and from scientific research in Divs. 4X5Zc for 2013. For the fleet descriptors, FG signifies fixed gear, MG signifies mobile gear and the subsequent number is the maximum length of the vessel (in feet). ITQ signifies individual transferrable quota.

Fishery	Fleet	Gear	Reported (t)	Bait or discard (t)	Total landings (t)
Groundfish commercial bycatch	FG < 45 ft	Longline / gillnet	332.4	0.0	332.4
	FG 45 – 65 ft	Longline	4.0	1.0	5.0
	FG 65 – 100 ft	Longline	0.4	0.2	0.6
	FG > 100 ft	Longline	0.1	0	0.1
	MG 65 – 100 ft	Otter trawl	0.0	0	0.0
	MG > 100 ft	Otter trawl	116.1	0	116.1
	MG ITQ < 65 ft	Otter trawl	119.2	0	119.2
	All fleets	All gears	578.5	1.2	579.7
Groundfish recreational	Angling, handline			Unknown	
Aboriginal Food, Social and Cultural	Angling, handline, longline			Unknown	
Scientific (DFO Research Surveys)	Bottom trawl			< 1 t	

In Divs. 4X5Zc, abundance indicators for White Hake are above the recovery target and under current conditions, the current levels of fishing mortality are not jeopardizing its projected survival or recovery. Although White Hake projected biomass is expected to increase at recent levels of fishing mortality, recovery would be contingent upon a sustained increase in adult biomass above its recovery target. Increases in fishing mortality rates relative to current levels would not be favourable to achieving the abundance recovery target.

Northern Gulf of St. Lawrence (NAFO Divisions 4RST*)

Reported landings of White Hake as bycatch in commercial groundfish fisheries in Divs. 4RS averaged approximately 8 t annually during 2009 to 2013. Estimated bycatch of juveniles was less than one tonne annually, and scientific surveys caught about 0.2 t annually (Table 9).

In Divs. 4RST*, consequences of the current relative fishing rate (0.007) are considered to have a negligible impact on White Hake recovery potential.

Table 9. Reported removals (tonnes) of White Hake in commercial fisheries and from scientific research in Divs. 4RST, average for 2009 to 2013. Removals from the sentinel fisheries are included in the respective longline and gillnet components for Atlantic cod.*

Fishery	Gear	Directed fishery	Age / size group	Average landings (t)	
				4R	4S
Groundfish commercial	Trawl	Redfish	Adult	0.5	0.2
	Gillnet	Cod	Adult	1.4	0.0
		American Plaice		0.1	na
		Greenland Halibut		1.3	2.3
		Unknown		na	0.0
	Handline	Cod	Adult	0.0	na
	Longline	Atlantic Halibut	Adult	2.0	0.2
		White Hake		0.0	na
		Cod		0.2	0.0
		Unknown		na	0.0

Fishery	Gear	Directed fishery	Age / size group	Average landings (t) 4R	4S
	Seine	Witch Flounder	Adult	0.3	na
		Redfish		0.6	na
		Greenland Halibut		0.0	na
	Unknown	Redfish	Adult	na	0.0
		Unknown		na	0.4
	All gears	All fisheries	Adult	6.5	2.7
Shrimp commercial	Shrimp trawl	Unreported bycatch	Juvenile (20 to 26 cm)	0.6	
Scientific	Trawl	DFO & Sentinel Research Surveys	All stages	0.1	0.1

Sources of Uncertainty

Status and recovery potential of the ANGSL population was assessed relative to indicators in the management units comprising the ANGSL DU. COSEWIC (2013) concluded that the ANGSL population was distributed throughout marine waters bordering Newfoundland, the Scotian Shelf to the US border, and northern Gulf of St. Lawrence (i.e., including deep waters of the Laurentian Channel in Div. 4T). Catch data from numerous DFO research surveys indicated connectivity of White Hake across the entire ANGSL DU.

In addition, Roy et al. (2012) reported that White Hake in the southern Gulf of St. Lawrence (sGSL) were genetically distinct from those in other Canadian Atlantic waters although the sGSL population overlapped with the neighbouring Scotian Shelf population in deep waters of the Laurentian Channel. Furthermore, the genetic identity of this species in the St. Lawrence Estuary (Div. 4Topq) remains unknown. White Hake in the Div. 4T area of the Estuary (i.e., excluded from the sGSL population assessment) were included in the Divs. 4RS assessment although their abundance and relative importance were very low relative to those in Divs. 4RS.

There are unknown levels of White Hake discard mortality in directed and bycatch (groundfish) fisheries conducted in the ANGSL DU by Canadian fishers, and in the NRA of Divs. 3NO by NAFO-member countries. Given that discards are never reported by Canadian and foreign fishers (i.e., only landings are recorded), at-sea fisheries observers constitute the sole source of data on commercial discarding and total catch. Annual observer coverage of relevant fisheries remains low to non-existent.

Highly variable and annually unpredictable recruitment in Divs. 3NOPs has been noted and the causes of these sporadic events are not fully understood. They are possibly related to variations in offshore currents and associated retention of larvae.

A survey biomass index was available for NAFO Subdiv. 3Pn, but was not included in the population model for Divs. 3NOP. The consequences of this on the population estimates for this area are unknown.

Locations of White Hake spawning and nursery areas and annual spawning seasons are not well-defined and consequently it is difficult to characterize the extent of the anthropogenic threats posed by anthropogenic activities such as oil spills and vessel ballast water discharges.

A lack of consistent, compulsory sampling of White Hake (e.g., length, sex, otoliths for ageing) in some DFO surveys limits the understanding of its population dynamics and trends. Minimal sampling for length, sex, and maturity state of White Hake in survey catches should be adopted to allow development of size and maturity-based indices for the survey time series.

The eastern Canadian distribution of this species along the southern edge of Divs. 4X5YZc is contiguous with White Hake in American waters. Consequently, the status of this species in

NAFO Divs. 4X5Zc, the southern portion of its range in Canada, may also be dependent on actions taken by US fisheries management in American waters.

White Hake are subject to high levels of non-fishing mortality in this population. Predation by grey seals is considered to cause elevated levels of natural mortality in the sGSL DU and it cannot be excluded as a source of elevated natural mortality of White Hake in the ANGSL DU.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 14 to 16, 2015 meeting on the Recovery Potential Assessment – White Hake (*Urophycis tenuis*), population of the southern Gulf of St. Lawrence and population of the Atlantic and northern Gulf of St. Lawrence. 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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