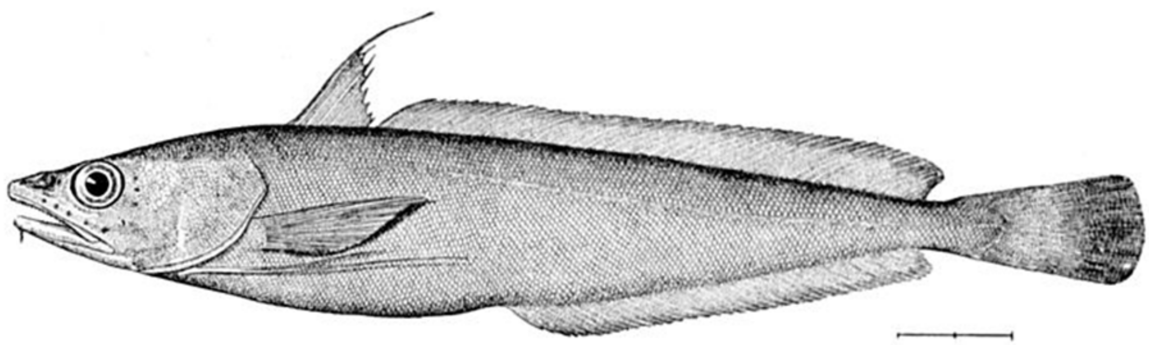
COSEWIC
Assessment and Status Report

on the

White Hake
Urophycis tenuis

Southern Gulf of St. Lawrence population
Atlantic and Northern Gulf of St. Lawrence population

in Canada



Southern Gulf of St. Lawrence population - ENDANGERED
Atlantic and Northern Gulf of St. Lawrence population - THREATENED
2013

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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White Hake — Illustration from plate 89 of Oceanic Ichthyology by G. Brown Goode and Tarleton H. Bean, published 1896.

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COSEWIC
Assessment Summary

Assessment Summary – November 2013

Common name
White Hake - Southern Gulf of St. Lawrence population

Scientific name
Urophycis tenuis

Status
Endangered

Reason for designation
This population increased during the mid-1970s to a peak in the mid-1980s before undergoing a steep decline, which levelled out by the mid-1990s. The overall decline rate has been 91% over the past 3 generations. The area of occupancy followed a similar though less dramatic trend, and one segment of the population seems to have disappeared. The non-fishing adult mortality rate of the population increased dramatically in the 1990s and it remains extremely high. If this continues, the population is unlikely to be viable in the long term. Thus, numbers remain low, with minimal recovery, despite the cessation of fisheries directed toward this species. While fisheries were the primary cause of the decline, it appears that high non-fishing mortality, perhaps by Grey Seal predation, may be preventing recovery since then.

Occurrence
Atlantic Ocean

Status history
Designated Endangered in November 2013.

Assessment Summary – November 2013

Common name
White Hake - Atlantic and Northern Gulf of St. Lawrence population

Scientific name
Urophycis tenuis

Status
Threatened

Reason for designation
Adults in this population are estimated to have declined by approximately 70% over the past three generations. Most of this decline occurred before the mid-1990s. The population has remained fairly stable since then, and there has been little overall trend in area of occupancy. Restrictions on fisheries since the mid- to late 1990s over most of their range may be responsible for stabilizing their numbers.

Occurrence
Atlantic Ocean

Status history
Designated Threatened in November 2013.

COSEWIC
Executive Summary

White Hake
Urophycis tenuis

Southern Gulf of St. Lawrence population
Atlantic and Northern Gulf of St. Lawrence population

Species Information

White Hake, *Urophycis tenuis* (Mitchill, 1815), is a member of the Family Phycidae, and is one of many cod-like (gadiform) fishes found on the east coast of Canada. Common names include White Hake, Ling, and merluche blanche (Fr). The combination of a single small barbel at the tip of the lower jaw, two dorsal fins, and elongated pelvic fins identifies fish from the western Atlantic in waters off Canada to the genus *Urophycis.* White Hake and Red Hake (*Urophysis chuss*) are distinguished by the number of lateral line scales and the number of gill rakers on the upper arm of the first gill arch.

Distribution

The main distribution of White Hake is from the Grand Banks to North Carolina. In Canada it occurs in the Bay of Fundy, the Scotian Shelf, the Gulf of St. Lawrence, the slopes of St. Pierre Bank, and on the southern Grand Banks. It is also found in coastal Newfoundland areas of Holyrood Pond and Conception Bay, and in the Saint John River system of New Brunswick in Kennebecasis Bay.

A combination of genetic, behavioural (spawning locations and seasons), and meristic information suggests the existence of 2 populations (designatable units) of White Hake in Canada. One occurs in the Southern Gulf of St. Lawrence where individuals have a distinct genetic composition as well as unique spawning distribution (shallow, inshore waters) and spawning season (June through September). The second population, referred to as the Atlantic and Northern Gulf of St. Lawrence population, occurs on the Scotian Shelf, Northern Gulf of St. Lawrence, and Southern Newfoundland.

Habitat

White Hake are found near the bottom and are commonly captured over fine sediment substrates such as mud but are also reported on sand and gravel. They adjust their depth distribution to find temperatures in the range of 4-8° C. Larger fish generally occur in deeper waters whereas juveniles typically occupy shallow areas close to shore or over shallow offshore banks. In the Gulf of St. Lawrence and Scotian Shelf, individuals of all sizes tend to move shoreward in summer and disperse to deeper water in winter. There is little seasonal movement off southern Newfoundland.

Biology

White Hake are highly fecund, with buoyant eggs that generally occur in the upper water layer. The species has an extended juvenile stage, remaining in the upper water layer for two to three months (depending on water temperature) prior to settlement. Spawning in the eastern Northumberland Strait occurs from June to September, with peak spawning in late June. Spawning in other areas occurs in early spring and a second summer spawning has been reported from the Scotian Shelf. Size at 50% maturity in Canadian waters ranges from 40-54 cm for females and 37-44 cm for males. Generation time is estimated to be 9 years.

Population Sizes and Trends

The estimated decline of adult abundance in the Southern Gulf of St. Lawrence population over the most recent 3 generations was 91%. Most of this decline occurred in the first two generations and there was essentially no change in adult abundance over the most recent generation. The area of occupancy declined over the most recent 3 generations to a minimum of 10,000 km^2 in recent years.

Determining a change in mature abundance of White Hake in the population from the Scotian Shelf, Northern Gulf of St. Lawrence, and Southern Newfoundland is complicated because there are 3 non-overlapping trawl survey time series, with differences in catchability, and with time series of various lengths. However, based on relative abundance indices in the 3 surveyed areas and the estimated change in mature abundance in each area, it was estimated that the mature numbers declined by 70% over the most recent 3 generations. Most of the change occurred over the first generation and the mature population has been stable since then. The area of occupancy for this population is approximately 116,000 km^2 with little trend over the last 3 generations.

Limiting Factors and Threats

The main threat to White Hake in the Southern Gulf of St. Lawrence is an exceedingly high level of non-fishing mortality, possibly due to increased predation by seals. Levels of fishing removals that were sustainable in the 1970s and early 1980s became unsustainable when non-fishing mortality increased in the late 1980s. Fishing in this area was reduced to negligible levels in the mid-1990s and overfishing is no longer a significant threat. A population analysis of future trends in abundance, which assumes that the current non-fishing mortality rate along with other demographics and fishery bycatch persists, indicates a greater than 20% probability of the population going extinct in the next 5 generations.

Overfishing in the late 1980s and early 1990s was the main reason for the decline in abundance in the Atlantic and Northern Gulf of St. Lawrence population, especially in the Scotian Shelf area. The threat of overfishing in this area is currently low. Little is known about non-fishing levels of mortality throughout this area.

Existing Protection

Directed fishing for White Hake in the southern Gulf of St. Lawrence has been prohibited since 1995. There is no directed fishery on the Scotian Shelf but this species is primarily landed by fixed gear as a bycatch of other directed fisheries. Various bycatch limits have been in place in this area since 1996. The Northwest Atlantic Fisheries Organization (NAFO) has set a total allowable catch in the Grand Banks. There is no directed fishery in the northern Gulf of St. Lawrence and bycatch is limited to 10% in other directed fisheries.

White Hake have not been assessed by the International Union for the Conservation of Nature (IUCN).

TECHNICAL SUMMARY (Southern Gulf of St. Lawrence population)

Urophycis tenuis
White Hake — Merluche blanche
Southern Gulf of St. Lawrence population — Population du sud du golfe du Saint-Laurent
Range of occurrence in Canada (province/territory/ocean): Atlantic Ocean (Southern Gulf of St. Lawrence primarily south of the Laurentian Channel)

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used)	9 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Decline of 35%
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Decline of 91%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	N/A
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	Greater than 20,000 km^2
Index of area of occupancy (IAO) *Based on design-weighted area of occupancy*	10,000 km^2
Is the total population severely fragmented?	No
Number of locations*	The number of locations is unclear. The main threat is a high rate of non-fishing mortality, which may be due to predation by Grey Seals.
Is there an observed continuing decline in extent of occurrence?	No
Is there an observed continuing decline in index of area of occupancy?	No
Is there an observed continuing decline in number of populations?	One spawning component in Baie Verte has disappeared
Is there an observed continuing decline in number of locations*?	N/A
Is there an observed continuing decline in area of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	N/A

Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
	977,000 minimum estimate from research surveys
Total	977,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	50% probability of extinction by 2035, 100% probability of extinction by 2070 if trends continue

Threats (actual or imminent, to populations or habitats)

High non-fishing mortality possibly due to seal predation

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Variable, evidence of decline	White Hake in US waters are overfished and at low abundance
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Unknown
Is rescue from outside populations likely?	No

Status History

COSEWIC: Designated Endangered in November 2013.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2b+3b+4b; E

Reasons for designation:

This population increased during the mid-1970s to a peak in the mid-1980s before undergoing a steep decline, which levelled out by the mid-1990s. The overall decline rate has been 91% over the past 3 generations. The area of occupancy followed a similar though less dramatic trend, and one segment of the population seems to have disappeared. The non-fishing adult mortality rate of the population increased dramatically in the 1990s and it remains extremely high. If this continues, the population is unlikely to be viable in the long term. Thus, numbers remain low, with minimal recovery, despite the cessation of fisheries directed toward this species. While fisheries were the primary cause of the decline, it appears that high non-fishing mortality, perhaps by Grey Seal predation, may be preventing recovery since then.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2b because there was a decline of more than 505 (91%) over the past three generations, and A3b because past declines combined with projected declines exceed 50%, and A4b because projected declines exceed 50%.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence greatly exceeds 20,000 km^2 and the area of occupancy greatly exceeds 2,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the number of mature individuals greatly exceeds 10,000.
Criterion D (Very Small or Restricted Total Population): Does not apply because the number of mature individuals greatly exceeds 1,000 and the area of occupancy is very large.
Criterion E (Quantitative Analysis): Meets Endangered E because a population analysis assuming the persistence of high natural mortality suggested greater than 20% probability of extinction over 5 generations.

TECHNICAL SUMMARY (Atlantic and Northern Gulf of St. Lawrence population)

Urophycis tenuis

White Hake — Merluche blanche

Atlantic and Northern Gulf of St. Lawrence population — Population de l'Atlantique et du nord du golfe du Saint-Laurent

Range of occurrence in Canada (province/territory/ocean): Atlantic Ocean (Northwest Atlantic from southern Labrador shelf to the border with the United States of America, excluding the southern gulf of St. Lawrence)

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used)	9 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	No change
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	70% decline
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	N/A
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible and understood and ceased?	Yes – reasonably well understood and ceased, and reversible
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	Greater than 20,000 km²
Index of area of occupancy (IAO) *Based on design-weighted area of occupancy*	116,000 km²
Is the total population severely fragmented?	No
Number of locations*	The number of locations is unclear. The main threats include bycatch mortality in diverse fisheries in a number of regions.
Is there an observed continuing decline in extent of occurrence?	No
Is there an observed continuing decline in index of area of occupancy?	No
Is there an observed continuing decline in number of populations?	No
Is there an observed continuing decline in number of locations*?	N/A
Is there an observed continuing decline in area of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No

Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
	12,669,000 minimum estimate from research surveys
Total	12,669,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not done

Threats (actual or imminent, to populations or habitats)

Overfishing, notably on the Scotian Shelf, probably caused the decline in this population. Overfishing appears to have ceased and little is known about other sources of mortality for the species in this area.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Variable, evidence of decline	White Hake in US waters are overfished and at low abundance
Is immigration known or possible?	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Status History

COSEWIC: Designated Threatened in November 2013.

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** Met criteria for Endangered, A1b, but designated Threatened, A1b, because abundance has stabilized over the past generation, in parallel with a reduction in fishing mortality.
Reasons for designation: Adults in this population are estimated to have declined by approximately 70% over the past three generations. Most of this decline occurred before the mid-1990s. The population has remained fairly stable since then, and there has been little overall trend in area of occupancy. Restrictions on fisheries since the mid- to late 1990s over most of their range may be responsible for stabilizing their numbers.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A1b because the causes of the decline are reasonably well understood and have mostly ceased, and there has been a rate of decline of 70% over 3 generations. However, designated Threatened A1b because there has been little change in the range size and there has been stability over the past generation, which matches reductions in fisheries. This suggests that the population is not in imminent danger of extinction and a status of Threatened is more appropriate.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence greatly exceeds 20,000 km^2 and the area of occupancy greatly exceeds 2,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the number of mature individuals greatly exceeds 10,000.
Criterion D (Very Small or Restricted Total Population): Does not apply because the number of mature individuals greatly exceeds 1,000 and the area of occupancy is very large.
Criterion E (Quantitative Analysis): Not undertaken.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2013)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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White Hake
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Southern Gulf of St. Lawrence population
Atlantic and Northern Gulf of St. Lawrence population

in Canada

2013

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

White Hake (*Urophycis tenuis,* Mitchill 1815) is a gadiform species (Family Phycidae) and is one of 20 cod-like fishes found off the east coast of Canada (Scott and Scott 1988, Klein-MacPhee 2002). Common names include White Hake, Ling, and merluche blanche (Fr).

Morphological description

White Hake is a slow-swimming species with an elongate body and rounded tail fin, with a maximum length of 133-135 cm and a maximum weight of 21.5-22.3 kg (Scattergood 1953, Markle *et al.* 1982). There is a single anal fin and long trailing pelvic fins that contain two thread-like rays that almost reach the vent. Pelvic fins are located in front of the pectoral fins (Scott and Scott 1988, Klein-MacPhee 2002). The combination of a single small barbel under the jaw in addition to two dorsal fins and the elongated pelvic fins identifies fish from the western Atlantic off Canada to the genus *Urophycis*. There have been problems distinguishing White Hake and Red Hake (*Urophycis chuss*). Two distinguishing features include the number of lateral line scales (119-148 for White Hake, 95-117 for Red Hake) and the number of gill rakers on the upper arm of the first gill arch (2 for White Hake and 3 for Red Hake) (Scott and Scott 1988).

As with many demersal fishes, colour varies depending on diet and habitat. Bigelow and Schroeder (1953) and Klein-MacPhee (2002) describe White Hake as being muddy or purple-brown above, the sides sometimes bronze or golden, and the belly dirty or yellowish white peppered with tiny black dots. Dorsal, anal and caudal fins are often edged with black.

Population Spatial Structure and Variability

A combination of genetic, demographic, biological tagging, and spawning behaviour information was used to assess the population structure of White Hake in Canada.

Roy *et al.* (2012) identified three genetically distinguishable populations of White Hake using microsatellite markers (Figure 1). One population (Gulf) was associated with the Southern Gulf of St. Lawrence (SGSL) (NAFO Div. 4T, Figure 2) and the area northeast of Cape Breton Island in NAFO Subdiv. 4Vn. A second population (Newfoundland) was predominantly located off southern Newfoundland[1] in NAFO Div. 3O and 3P. The third population (Scotian) was located mainly in NAFO Div. 4RSVWX throughout the Bay of Fundy, on the Scotian Shelf[2], but also along both slopes of the Laurentian Channel including waters within the northern Gulf of St. Lawrence (NGSL,

[1] The abbreviation SN is used to indicate waters off southern Newfoundland and includes NAFO Di. 3NOP.
[2] The abbreviation SS is used to indicate the Bay of Fundy and Scotian Shelf and includes NAFO Div. 4VWX.

NAFO Div. 4RS). It should be noted that while the sampling sites used by Roy *et al.* (2012) were extensive, they do not represent the full distribution of White Hake in Canada, which is described later in the Distribution section. In addition, sampling in the northern Gulf of St. Lawrence was limited compared to sampling in the other areas.

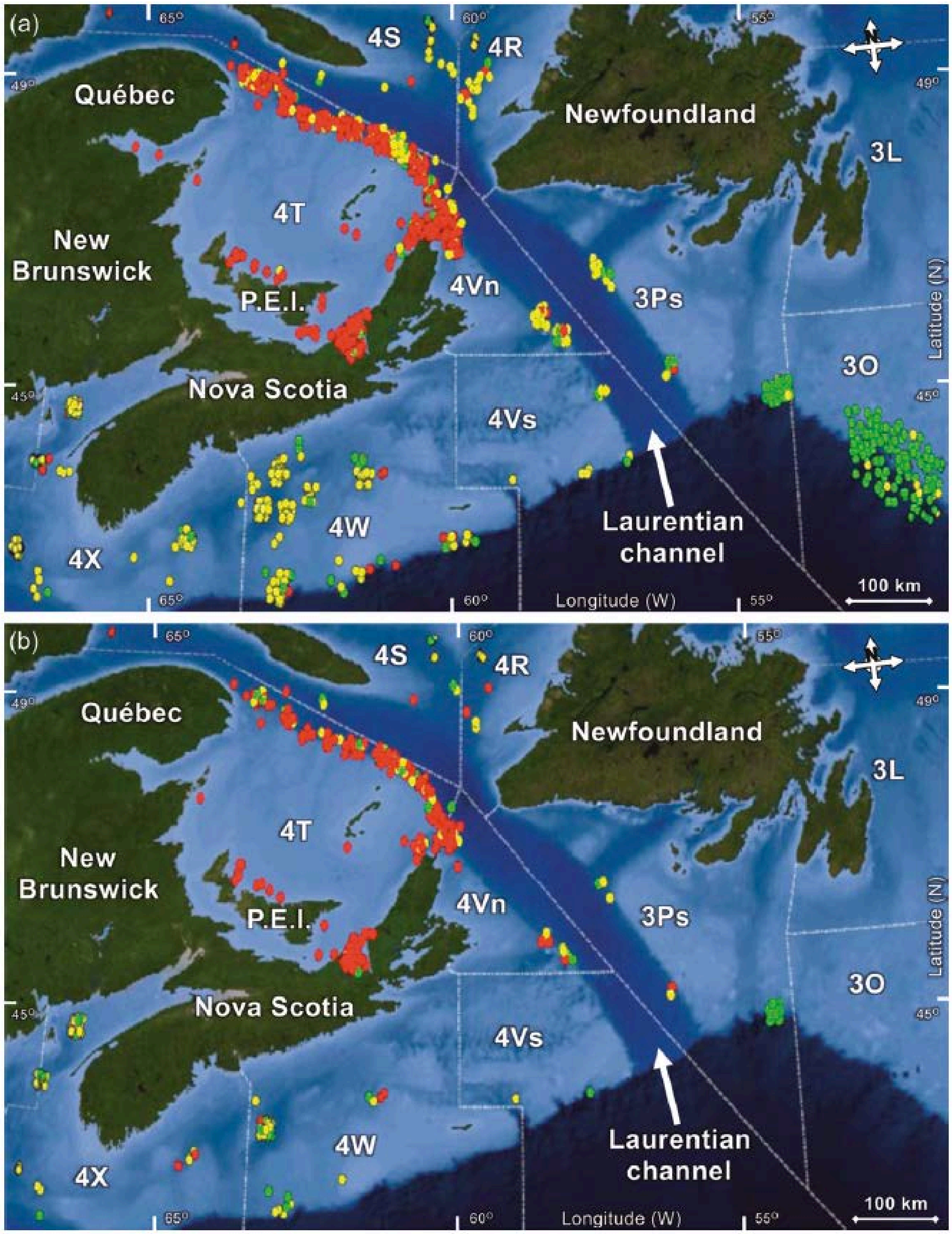

Figure 1. Distribution of (a) all sampled White Hake and (b) only spawning individuals, where colour assignments are based on the genetically determined populations: Gulf (red) correspond to DU1 in this report. Scotian (yellow), and Newfoundland (green) correspond to DU2. From Roy *et al*. (2012).

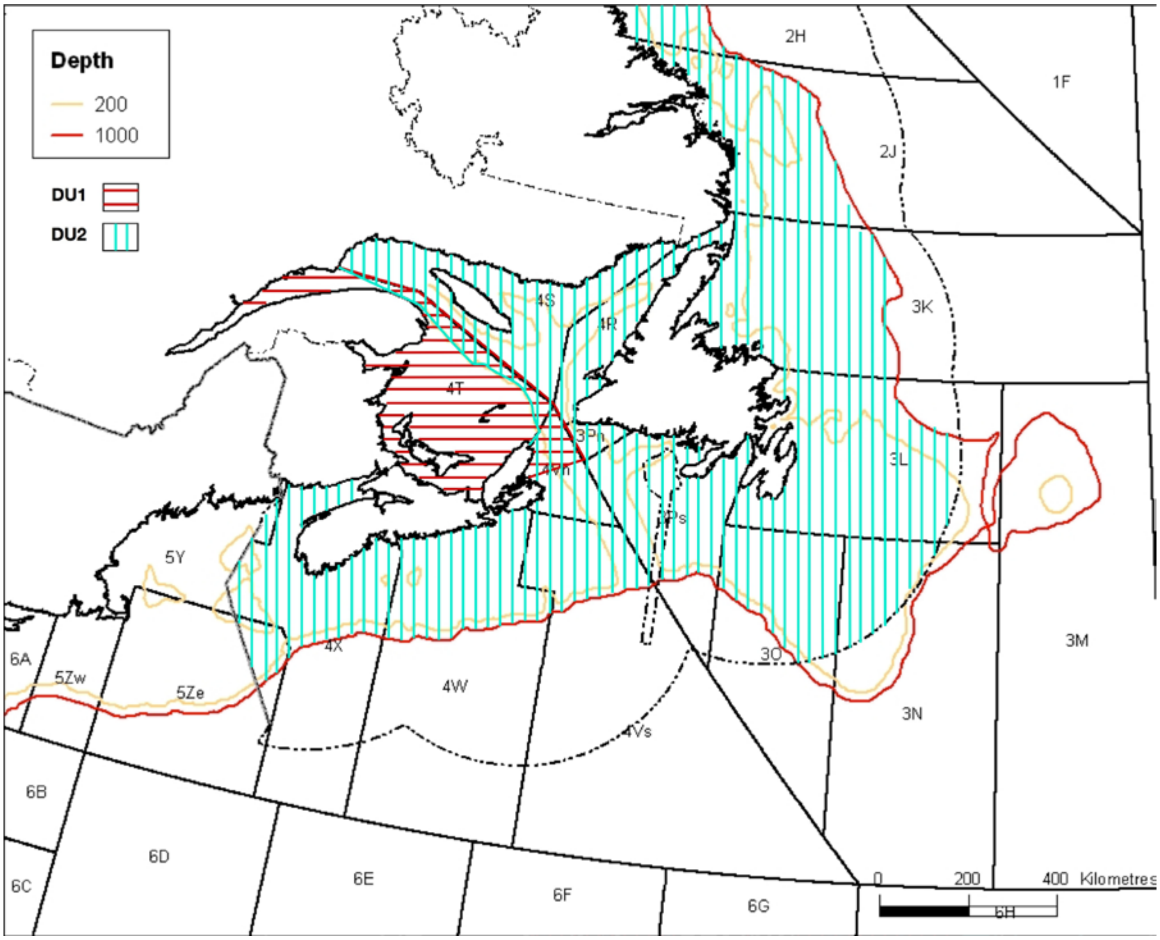

Figure 2. The southern portion of the NAFO convention area with the two designatable unit boundaries and the area of overlap between them.

Pairwise genetic distances estimated among the three populations were significantly different ($p < 0.001$) and indicated that the Gulf population was the most distinct of the three. The Gulf population was genetically more differentiated from the Newfoundland (Fst = 0.053) and Scotian (Fst = 0.043) populations, while the Scotian and Newfoundland populations were the least differentiated (Fst = 0.015).

Genetic estimates of migration rates between the Scotian and Newfoundland populations were comparable and relatively high in either direction (i.e. between 11% and 17% per generation). Migration rates between the Newfoundland and Gulf populations (i.e. between 0.2% and 2.6% per generation) and Scotian and Gulf populations (i.e. between 2.8% and 6.4% per generation) were considerably lower, indicating that gene flow between the Gulf and the other populations was more restricted.

Members of both the Gulf and Scotian genetic populations were found within the southern Gulf of St. Lawrence. Using data from Roy *et al.* (2012), Swain *et al.* (2012) found that over 90% of the fish sampled from depths less than 200 m were of the Gulf type and this proportion declined as depth increased from about 80% in the 200 – 250 m range to 34% at depths greater than 350 m. Taking into account the depth distribution of White Hake in the surveys and the relative composition of genetic populations by depth, Swain *et al.* (2012) estimated that about 80% of White Hake in the Southern Gulf of St. Lawrence survey were of the Gulf type.

Both morphometric and parasite infection data have been used to examine population structure within the Southern Gulf of St. Lawrence and NAFO Subdiv. 4Vn. Hurlbut and Clay (1998) found differences in snout length to be the most important factor in discriminating White Hake from the deeper "Channel" stations from those taken from shallower stations in the Northumberland Strait. Melendy *et al.* (2005) reached similar conclusions using infection rates of protozoan and metazoan parasites. They were able to discriminate White Hake taken in waters deeper than 100 m along the southern edge of the Laurentian Channel in the southern Gulf of St. Lawrence and in the Laurentian Trough in NAFO Subdiv. 4Vn from those in shallow waters (<50 m) in the eastern portion of Northumberland Strait.

White Hake in the Southern Gulf of St. Lawrence and Scotian Shelf areas mature at similar sizes. Swain *et al.* (2012) report lengths at 50% maturity (L_{50}) of SGSL fish of 40.7 cm for males and 48.2 cm for females. Simon and Cook (2011) report an L_{50} for Scotian Shelf fish of 45 cm for both sexes. Simpson *et al.* (2012) report a number of published L_{50} values for White Hake off SN. The most recent and reliable estimates are 39 cm for males and 54 cm for females. There is no information on length at maturity for White Hake in the Northern Gulf of St. Lawrence (Gauthier 2011).

Spawning locations and seasons vary among areas. White Hake peak spawning occurs in June in the Southern Gulf of St. Lawrence but the spawning season extends from June to September (Swain *et al.* 2012). Spawning has been reported from shallow inshore areas on the central and eastern portions of Northumberland Strait. However, spawning has not been reported from the central Northumberland Strait in recent years and this suggests a spawning component in this area is extirpated (Hurlbut 2011). Spawning in other areas (SS, NGSL, SN) occurs in offshore areas in deeper waters and along shelf breaks (Markle *et al.* 1982, Fahay and Able 1989, Kulka *et al.* 2005). The spawning seasons in these areas are also mainly in spring, earlier than in the SGSL. However, Markle *et al.* (1982) and Bundy and Simon (2005) also report summer spawning on the Scotian Shelf.

Designatable Units

The DUs proposed below represent the best approximation of likely discrete and significant components of this species' distribution in Canada, based on the available data. The characteristics of the DUs are summarized in Table 1. Genetic data are limited to rapidly evolving neutral genetic markers (i.e., microsatellite), while data on life history, behaviour and parasite communities are primarily limited to a relatively small portion of the species' Canadian range in the SGSL. There are no discrete geographic breaks in the distribution of this species (Figure 3) and there appears to be contiguous distribution across major bathymetric features such as the Laurentian Channel. The genetic data provided in Roy *et al.* (2012) provided the primary basis for this DU structure, and they suggest three genetically discrete populations. However, the results also suggest relatively high exchanges of genetic material between the Scotian and Newfoundland populations. There is little indication of difference in life history between these populations. Thus, the evidence for significant evolutionary differences between these two populations is slight. On the other hand, the spawning behaviour and distribution of White Hake in the southern Gulf of St. Lawrence is quite different than elsewhere. Therefore, 2 DUs are proposed for White Hake, one in the Southern Gulf of St. Lawrence (DU1) and the second in the areas of the Scotian Shelf, Northern Gulf of St. Lawrence and Southern Newfoundland (DU2). This DU will be referred to as Atlantic and Northern Gulf of St. Lawrence.

Table 1. Summary of genetic, size at maturity, spawning season, and spawning grounds information relevant to the proposed population structure of White Hake in Canada. SGSL is the southern Gulf of St. Lawrence, SS is the Bay of Fundy and Scotian Shelf, NGSL is the northern Gulf of St. Lawrence, and SN is southern Newfoundland. L50 is the average length at 50% maturity.

	Geographic Location			
	DU1	**DU2**		
Character	**SGSL**	**SS**	**NGSL**	**SN**
Genetic population (Roy *et al.* 2012)	Gulf (80%), Scotian (20%)	Scotian plus migration with SN	Scotian plus migration with SN	SN plus migration with SN
Size at maturity	L50: 40.7 male, 48.2 female (Swain *et al.* 2012)	L50: 45 cm (Simon and Cook 2011)	not available (Gauthier 2011)	L50: 39 cm male, 54 cm female (Simpson *et al.* 2012)
Spawning season	peak spawning mid-June, spawning from June to September (Markle *et al.* 1982)	early spring (Fahay and Able 1989) and mid-summer (Markle *et al.* 1982)	early spring (Markle *et al.* 1982, Fahay and Able 1989)	spring (Kulka *et al.* 2005) and summer (Simpson *et al.* 2012)
Spawning grounds	inshore, shallow water (Swain *et al.* 2012)	offshore deep water	offshore deep water	offshore, southern Grand Banks (Kulka *et al.* 2005)

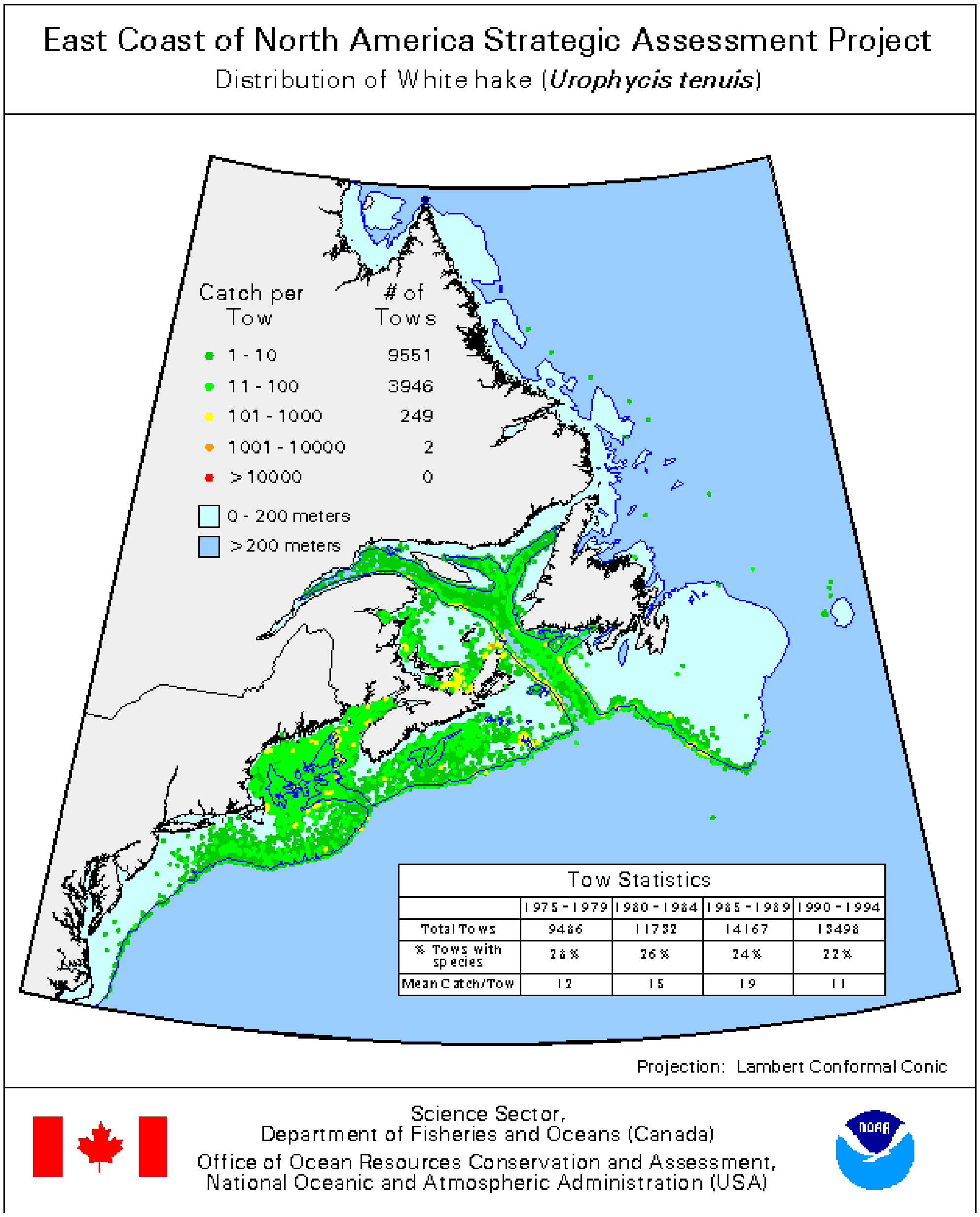

Figure 3. Global distribution of White Hake (from Brown *et al*. 1996).

To summarize in relation to the COSEWIC guidelines for recognizing designatable units:

- the two identified DUs are discrete because of clear genetic differences between them. They occupy eco-geographically distinct regions, although there is an area of overlap where individuals of both DUs occur. It is noteworthy that this genetic distinctness occurs in spite of physical overlap of individuals from both designatable units.

- they are considered significant because the spawning distribution and behaviour of the southern Gulf of St. Lawrence population are substantially different from those in other areas, suggesting evolutionary divergence of the two DUs leading to local adaptations. Loss of the southern Gulf of St. Lawrence population would result in an extensive gap in the range of the species in Canada.

Defining geographic boundaries between these two DUs is complicated because there is spatial overlap among the populations. No single set of lines can completely separate fish of the two designatable units and it is important to recognize areas that are uniquely occupied by each DU as well as the area of overlap. One area of considerable overlap is along the southern edge of the Laurentian Channel in NAFO Div. 4T at depths greater than 200 m where fish of the genetic Gulf and Scotian populations have been found. Another is within NAFO Subdiv. 4Vn where, in the northern portion, fish of the Gulf population dominate while fish of the Scotian population dominate catches from the south.

In summary, fish of DU1 belong to the genetically defined population “Gulf” as characterized by Roy *et al.* (2012). They occupy all of NAFO Div. 4T and the northern portion of Subdivision 4Vn defined by a line extending from the southern apex of NAFO Subdiv. 3Pn (46° 20.5’ N, 58° 49.0’W) to the Cape Breton coast at Cape Dauphin (46° 20.5’ N, 60° 25.0’ W) (Figure 2). DU2 fish belong to the genetically defined populations “Newfoundland” and “Scotian” (see Roy *et al.* 2012). They are found on the Scotian Shelf (NAFO Div. 4VWX), Northern Gulf of St. Lawrence (NAFO Div. 4RS) and waters off southern and eastern Newfoundland, as well as in waters greater than 200 m in NAFO Div. 4T.

Special Significance of This Species

White Hake is endemic to the northwest Atlantic, and has perhaps the highest level of genetic population structure of any widespread, long-lived, commercially exploited fish (Roy *et al.* 2012). It is a relatively minor component of Atlantic Canadian groundfish fisheries. It was at one time the third most abundant species landed in the southern Gulf of St. Lawrence but the directed fishery is currently closed due to low abundance. The only ongoing directed fishery for White Hake occurs in the Grand Banks (NAFO Div. 3NO) and this fishery is managed by NAFO.

DISTRIBUTION

Global Range

White Hake are found primarily from Labrador to North Carolina (Figure 3) with rare catches reported from Iceland in the north and Florida in the south (Musick 1974, Scott and Scott 1988, Klein-MacPhee 2002). Outside Canada, the highest abundance of White Hake is in the Gulf of Maine and on Georges Bank (NAFO Div. 5YZ).

Canadian Range

White Hake are broadly distributed in the Bay of Fundy, Scotian Shelf, the perimeter of the southern Gulf of St. Lawrence, deeper waters of the northern Gulf of St. Lawrence, as well as the slopes of St. Pierre Bank and the southern Grand Banks (Figure 3). White Hake are not found in the central portion of the southern Gulf of St. Lawrence where the waters are cold and unsuitable for the species. The Gulf of St. Lawrence has an unusual vertical temperature structure where very cold water, often below 0º C resulting from ice cover in winter, is found at intermediate depths. This intermediate cold layer reaches the bottom in the central portion of the southern Gulf. In addition to the mainly offshore distribution shown in Figure 3, the species also occurs in coastal and estuarine environments. There once was a minor local fishery for White Hake in Kennebecasis Bay of the lower Saint John River system (Markle *et al.* 1982), where they were fished under the ice. Coastal bays and inlets with constricted connections to the ocean such as the relatively deep Holyrood Pond on the south coast of Newfoundland also contained White Hake (O'Connell *et al.* 1984, Bradbury *et al.* 2009). Large juveniles and spawning adults were also taken in relatively shallow waters of Baie Verte in the southern Gulf of St. Lawrence in the 1970s (Koeller and LeGresley 1981) although recent survey vessel catches in the southwestern Gulf of St. Lawrence are essentially zero, suggesting the disappearance of a spawning component in this area (Hurlbut and Poirier 2001, Hurlbut 2011). Small juveniles (<100 mm) occur in shallow water (<2 m) throughout Atlantic Canada as far north as 56° 30' N (McAllister 1960, Markle *et al.* 1982, MacDonald *et al.* 1984, Methven *et al.* 2001, Wroblewski *et al.* 2007).

White Hake and Red Hake co-occur in the western Scotian Shelf (NAFO Div. 4X) and misidentification has occurred. However, the maximum length of Red Hake corresponds to the length of maturity of White Hake. Thus, estimates of the number of mature individuals of White Hake are not likely to be affected by misidentification (Bundy and Simon 2005).

The extent of occurrence for White Hake is derived from the minimum convex polygon of trawl research survey data (Brown *et al.* 1996), excluding terrestrial areas. The extent of occurrence is 1,171,782 km² (Figure 4).

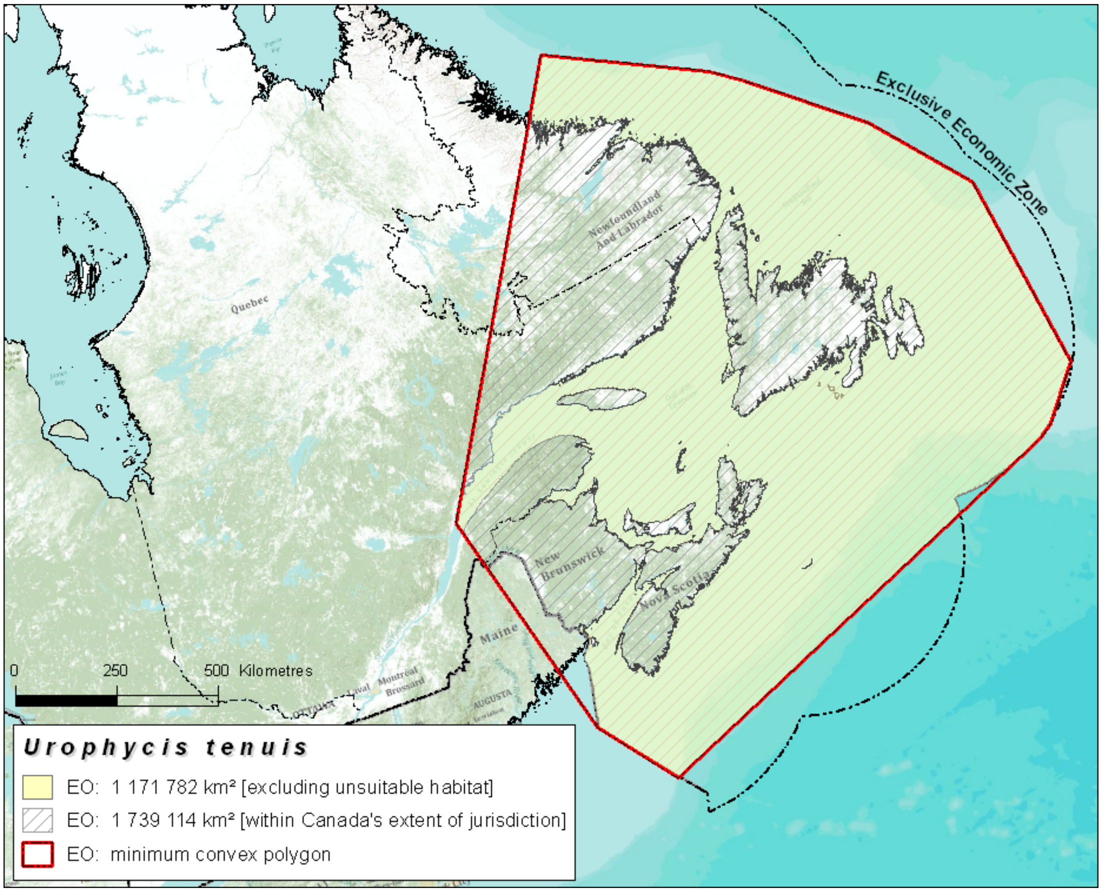

Figure 4 Estimated extent of occurrence for White Hake in Canadian waters.

HABITAT

Habitat Requirements and Trends

Adult White Hake are demersal and are not reported to make vertical migrations off the bottom (Klein-MacPhee 2002). Adults and large juveniles are most commonly located in habitats with fine substrates, such as mud at the bottoms of basins on the Scotian Shelf (Scott 1982a, MacDonald *et al.* 1984). White Hake were noted as absent from gravel and sand substrates on the Scotian Shelf by Scott (1982a). Bigelow and Schroeder (1953) treated White Hake and Red Hake together but noted: "that both of these hake haunt soft bottom chiefly, few being caught on the gravelly or shelly grounds that are so prolific of Cod and Haddock [*Melanogrammus aeglefinus*], or on rocky grounds. And it has been our experience that the whites [i.e., White Hake] are the more strictly mud fish of the pair." In nearshore areas of Newfoundland, White Hake can occur in relatively high densities and are known to depart these nearshore areas when water temperatures decline below 2ºC (R. Gregory, DFO, Newfoundland Region, pers. comm., 2013).

White Hake are taken over a wide range of depths but over a more restricted range of temperatures (Chang *et al.* 1999). Kulka *et al.* (2005) noted that they are found in relatively warmer waters and this influences their depth distribution in southern Newfoundland. Simon and Cook (2011) report that they are found in relatively warmer, deeper, and more saline waters on the Scotian Shelf, and within a temperature range of 5-9° C. Scott (1982b) noted preferred depths occur at 144-358 m in water of 5-9°C and 33-34 psu salinity off Nova Scotia. Off southern Newfoundland they are largely confined to an area associated with the warmest bottom temperatures (4-8°C) along the southwest fringe of the Grand Banks (Kulka *et al.* 2005). Their temperature selection leads to a wide range of depths along the slope to 800 m. Off the northeastern United States, adults were caught at temperatures from 6-11°C in spring and autumn and were most abundant at depths of 50-325 m (Chang *et al.* 1999). Schroeder (1955) and Musick (1974) report White Hake as deep as 1000 m on the continental slope of the mid-Atlantic Bight. MacDonald *et al.* (1984) reported large juveniles and adults occur in salinities of 29.5-32.5 psu in Passamaquoddy Bay.

Larger fish generally occur in deeper waters (Klein-MacPhee 2002, Herder *et al.* 2005). Hence, depth, temperature and salinity preferences change with body size. Newly settled juveniles (c. 50-80 mm) are not reported from deep water collections offshore. The shallow coastal zone and shallow offshore areas on the Grand Banks appear to be areas that small White Hake are transported to while still pelagic (Fahay and Able 1989, Han and Kulka 2007). Settlement to the bottom occurs at a length of approximately 50 mm or smaller. Newly settled juveniles are associated with a variety of substrate types including gravel, mud, sand and eelgrass off the northeastern United States and New England (Fried 1973, Targett and McCleave 1974, Fahay and Able 1989), Bay of Fundy (Markle *et al.* 1982, MacDonald *et al.* 1984), Gulf of St. Lawrence (McAllister 1960), Newfoundland (Huntsman *et al.* 1954, Methven *et al.* 2001, R. Gregory, DFO Newfoundland Region, pers. comm., 2013) and Labrador (Wroblewski *et al.* 2007) from approximately May to October (MacDonald *et al.* 1984) when water temperatures were warmest. Horne and Campana (1989) report trawling juveniles off southwest Nova Scotia where they were associated with warmer, less saline and more turbid water and finer-grained substrates.

BIOLOGY

Life Cycle and Reproduction

White Hake may be among the most fecund of commercially exploited fish in the northwest Atlantic. A 90 cm female in the Gulf of St. Lawrence was reported to produce as many as 15 million eggs (Beacham and Nepszy 1980). Eggs are buoyant, between 0.72-0.82 mm in diameter (Beacham and Nepszy 1980, Markle 1982), and generally occur in the upper water layer and are dispersed by currents. The eggs, larvae and pelagic juveniles remain planktonic for two to three months depending on water temperature and the proximity of suitable settlement areas (Markle *et al.* 1982, Lang *et al.* 1996, Han and Kulka 2007).

Han and Kulka (2007) concluded that success of year classes in southern Newfoundland may be strongly affected by how the currents disperse the eggs and larvae. Currents that carry the eggs, larvae, and post-larvae onto the southern Grand Bank lead to large year classes. Large pelagic juvenile White Hake (>40 mm SL) were reported to be entrained in warm core Gulf Stream rings (up to 20°C) off the Scotian Shelf. Warm core rings may contribute to the offshore advection and eventual loss of these fish (Wroblewski and Cheney 1984), although evidence of warm core rings affecting recruitment is limited (Myers and Drinkwater 1989).

Spawning seasons, locations and size at maturity of White Hake are described earlier in the Population Structure and Variability section of this report.

Generation time was estimated as the age of 50% maturity plus 1/M with M being the instantaneous rate of non-fishing (“natural”) mortality. M is assumed to be in the vicinity of 0.2 over much of their range in Canadian Atlantic. However, M has recently been considerably higher than this in the southern Gulf of St. Lawrence (see threats section). Aging data are available for the southern Gulf of St. Lawrence where the age of 50% maturity was estimated to be between 4 and 5 years (Clay and Clay 1991) Generation time is approximately 9 years using an M of 0.2 and an age at 50% maturity of 4 years. The maximum observed age in fished populations in recent years is about 20 years (Bundy and Simon 2005).

Physiology and Adaptability

Information available on the physiology and specific adaptability of White Hake is limited, though comparisons with other species of the genus *Urophycis* may be useful. Markle *et al.* (1982) suggested that White Hake may have a physiology that leads to rapid early growth and delayed maturation relative to Red Hake. White Hake blood serum indicators suggest they do poorly when brought to the surface (Griffith 1981). Inflation of swim bladders also makes return to depth very difficult, suggesting that these fish would not survive release after capture.

Dispersal and Migration

In southern areas, there is an inshore (or towards shallower water) movement in warmer months with dispersal to deep water in colder months (Musick 1974, MacDonald *et al.* 1984, Chang *et al.* 1999) by large juveniles and adults. Tyler (1971) reported that catches peaked during summer and identified White Hake (some were likely Red Hake; see Markle *et al.* 1982) as a periodic species abundant only in summer in Passamaquoddy Bay. *Urophycis* had mostly vacated Passamaquoddy Bay by late December when it was relatively rare in the catches (Tyler 1971). White Hake vacate the shallow waters of the southern Gulf of St. Lawrence in autumn and early winter as water temperature declines and as the area becomes iced over beginning in January (Dickie and Trites 1983, Clay and Hurlbut 1989; Clay 1991). They overwinter in the 2-5°C (Dickie and Trites 1983) deeper water of the Cabot Strait where they mix with White Hake from other populations. When spring returns and ice breakup is under way, they migrate back into waters of the southern Gulf where they spawn beginning in June. There is little interannual change in distribution in southern Newfoundland.

Interspecific Interactions

White Hake was identified as a dominant member of the ‘Deep Assemblage’ found on the Grand Bank of Newfoundland at depths below 200 m where it occurred with Redfish (*Sebastes* spp.), Atlantic Cod (*Gadus morhua*), Atlantic Halibut (*Hippoglossus hippoglossus*), Thorny Skate (*Amblyraja radiata*), and American Plaice (*H. platessoides*), among others (Gomes *et al.* 1992). It was placed in the ‘South-Temperate Bank/Slope Assemblage’ (Mahon *et al.* 1998) based on visual examination of distributional plots where it occurred with Red Hake, Goosefish (*Lophius americanus*), Silver Hake (*Merluccius bilinearis*), Spiny Dogfish (*Squalus acanthias*), Pollock (*Pollachius virens*), Cusk (*Brosme brosme*) and many other species on the Scotian Shelf.

Both juvenile and adult White Hake feed mostly on crustaceans and fish. In general, the proportion of crustaceans decreases and proportion of fish increases in the diet with increasing body size (Chang *et al.* 1999). Additional information about diets can be found in Petrov (1973), Langton and Bowman (1980), and Bowman (1981).

Chang *et al.* (1999) report that eggs and demersal juveniles are taken by larger White Hake, although this was not quantified. Predators of pelagic juvenile White Hake include Atlantic puffin (*Fraterula arctica*) and Arctic Tern (*Sterna paradisaea*) (Fahay and Able 1989). White Hake are recorded from the stomachs of Atlantic Cod and White Hake (Langton and Bowman 1980). In the Gulf of St. Lawrence White Hake can account for a significant proportion of the diet of Grey Seals (*Halichoerus grypus*) *and* Harp Seals (*Pagophilus groenlandicus*) depending on year and where samples were collected (Hammill and Stenson 2002). Hammill and Stenson (2002) estimated that up to 1,900 tonnes of White Hake may have been taken by Grey Seals in 2001.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

White Hake are well sampled in the annual bottom trawl surveys conducted by the four Atlantic Regions of DFO and the results of these surveys provide the basis for this section of the report. The following four surveys provide the best spatial and temporal coverage of White Hake: The Southern Gulf of St. Lawrence September survey (SGSL, NAFO Div. 4T), the Scotian Shelf July survey (SS, NAFO Div. 4VWX), the Northern Gulf of St. Lawrence August survey (NGSL, NAFO Div. 3Pn4RS), and the spring survey of the Grand Banks off Southern Newfoundland (SN, NAFO Div. 3LNOPs). Several other surveys have been conducted including Sentinel Surveys in the Gulf of St. Lawrence and Scotian Shelf, seasonal (spring and fall) surveys of the Scotian Shelf, a winter survey in the northern Gulf of St. Lawrence and Cabot Strait, and a fall survey off Newfoundland and Labrador. These surveys are of shorter duration and cover less White Hake habitat than the four principal surveys, and their results are consistent with those presented below.

These surveys were designed to monitor the status of groundfish species and the marine environment off eastern Canada (Chadwick *et al.* 2005). Their design and sampling protocols were maintained as consistently as possible over time to facilitate interpreting trends, though changes in vessels and sampling gear have occurred. A brief description of each survey is provided below. All of the indices are presented here in units of population numbers. These are derived by extrapolating the local density estimated in units of numbers per square km swept by the trawl to the total surveyed area. These are minimum population estimates because not all fish in the path of the trawl are caught. Several factors affect the efficiency of the survey (e.g. fish behaviour and the topography of the seafloor), and therefore the ratio of the population estimate to the actual population abundance (i.e. catchability). Because of this, the indices should be treated as relative as opposed to absolute.

The southern Gulf of St. Lawrence survey has been conducted since 1971. It was initially conducted by the *E.E. Prince* (1971-1985) using a Yankee 36 trawl and fishing during daylight hours only. The larger *Lady Hammond* took over the survey for the period 1985-1991. Fishing was conducted during a 24-hour period using a Western IIA trawl. This trawl design and hours of operation were used on all subsequent surveys. The *Alfred Needler* was used in 1992-2002, the *Wilfred Templeman* in 2003, the *Alfred Needler* and *Teleost* in 2004 and 2005, and the *Teleost* from 2006 to present (Swain *et al.* 2012). The results of comparative fishing experiments were used to adjust the survey results to account for differences between gear, vessel and hours of operation (Benoît and Swain 2003 a and b, Benoît 2006).

The Scotian Shelf survey has been conducted since 1970 (Simon and Cook 2011). From 1970 to 1981, it was conducted by the *A.T. Cameron* using a Yankee 36 trawl. In 1982, the *A.T. Cameron* was replaced by the *Lady Hammond* using the Western IIA as the new standard trawl. In 1983, the *Lady Hammond* was replaced by the *Alfred Needler* using the Western IIA trawl. In 2004, the *Alfred Needler* was replaced by the *Teleost* due to a fire on the *Alfred Needler*. The 2005 survey was conducted by both the *Teleost* and the *Alfred Needler* to investigate differences in catchability between the two vessels but this has not been investigated for White Hake. In 2006, the survey was conducted by the *Alfred Needler*. In 2007, the survey reverted back to the *Teleost* and in 2008, the sister ship of the *Alfred Needler*, the *Wilfred Templeman,* conducted the survey. Since 2009, the survey has been conducted by the *Alfred Needler*. A comparative fishing experiment was conducted between the A.T. Cameron and Lady Hammond but no correction factors were recommended for White Hake (Fanning 1985).

The northern Gulf of St. Lawrence surveys have been conducted in August since 1984 (Gauthier 2011). For the period 1984-1990, the survey was conducted by the *Lady Hammond* using a Western IIA trawl. From 1990-2003 and 2005 the survey was conducted by the *Alfred Needler* equipped with a URI 81'/114' shrimp trawl. Since 2004 the survey has been done with the *Teleost* using a Campelen shrimp trawl. Comparative fishing experiments were conducted in 1990 between the former two vessels and in 2004 and 2005 with the latter two. Bourdages *et al.* (2007) reported a length-dependent difference in catchability between the *Alfred Needler* and *Teleost*, and Gauthier (2011), using similar methods found a length-dependent difference between the *Lady Hammond* and *Alfred Needler* for the 1990 comparison. These estimated differences in catchability were included in this report.

The southern Newfoundland area has been surveyed since 1971. However, NAFO Div. 3O was not covered in 1972 and 1974, Div. 3LNO were not covered in 1983, and Subdiv. 3Ps was not covered in 2006 (Simpson *et al.* 2012). Three trawls were used in these surveys. A Yankee 41.5 was used from 1971-1982. An Engel 145 trawl was used from 1983-1995, and a Campelen shrimp trawl was used from 1996-2011. Four research vessels were used, *A.T. Cameron (1971-1982), Wilfred Templeman* and its sister ship *Alfred Needler* (1985-2000), and *Teleost* (2001-2011). While comparative fishing experiments were conducted between the various vessel and trawl combinations, there were no results available for White Hake. For the purpose of this report, it was assumed that there was no difference in catchability between the Yankee and Engel trawls. However, it is clear that the Campelen trawl is much more efficient that the other two gears (Warren 1997) and as a result the time series was split when the Campelen trawl was introduced.

The survey indices were split by length to represent immature and mature individuals. Fish less than 45 cm were assumed to be immature in the SG, SS, and NG surveys (Gauthier 2011, Simon and Cook 2011, Swain *et al.* 2012), while a length of 54 cm was used for the SN survey (Simpson *et al.* 2012). Trends in mature abundance were estimated using a log-linear regression of ln abundance vs. year. The percent change in abundance over the time period of the regression (t) was estimated as Change (%) = 100 (exp(β t) – 1) where β is the regression slope from the log-linear regression. Where possible, the time series spanned 3 previous generations (27 years). Regressions were also estimated for the previous 2 and 1 generation periods for comparison purposes.

The index of area of occupancy (A) was estimated for each survey year using the design weighted area of occupancy (DWAO), a statistic based on the stratified random survey design (based on Perry and Smith 1994).

$$A = \sum_{j=1}^{J} \sum_{i=1}^{n_j} \frac{a_j}{n_j} I_{ij}$$

where J is the number of strata sampled, n_j is the number of tows in stratum j, a_j is the area of stratum j, and I_{ij} =1 if the catch in set i in stratum j is greater than 0, and 0 otherwise.

Abundance, Fluctuations and Trends

<u>Southern Gulf of St. Lawrence (DU1)</u>

The Southern Gulf of St. Lawrence trawl survey covers the period 1971-2012. Results for the period 1971-2010 were taken from Swain *et al.* (2012). The two most recent years were provided by D. Swain (DFO Gulf Region, pers. comm. 2013). Two inshore strata were added to the SGSL trawl survey in 1984 (strata 401 and 403), thus increasing the spatial coverage of the survey. As a result, the subsequent population estimates would be biased upward relative to the area initially covered. The survey estimates for the initial strata (415-439) and for all strata are presented for comparison purposes. Few additional White Hake were captured in the new strata (Figure 5) and for consistency and to present the longest time series possible, the main analyses are done on the results for the initial strata. The survey results are presented in Table A1.

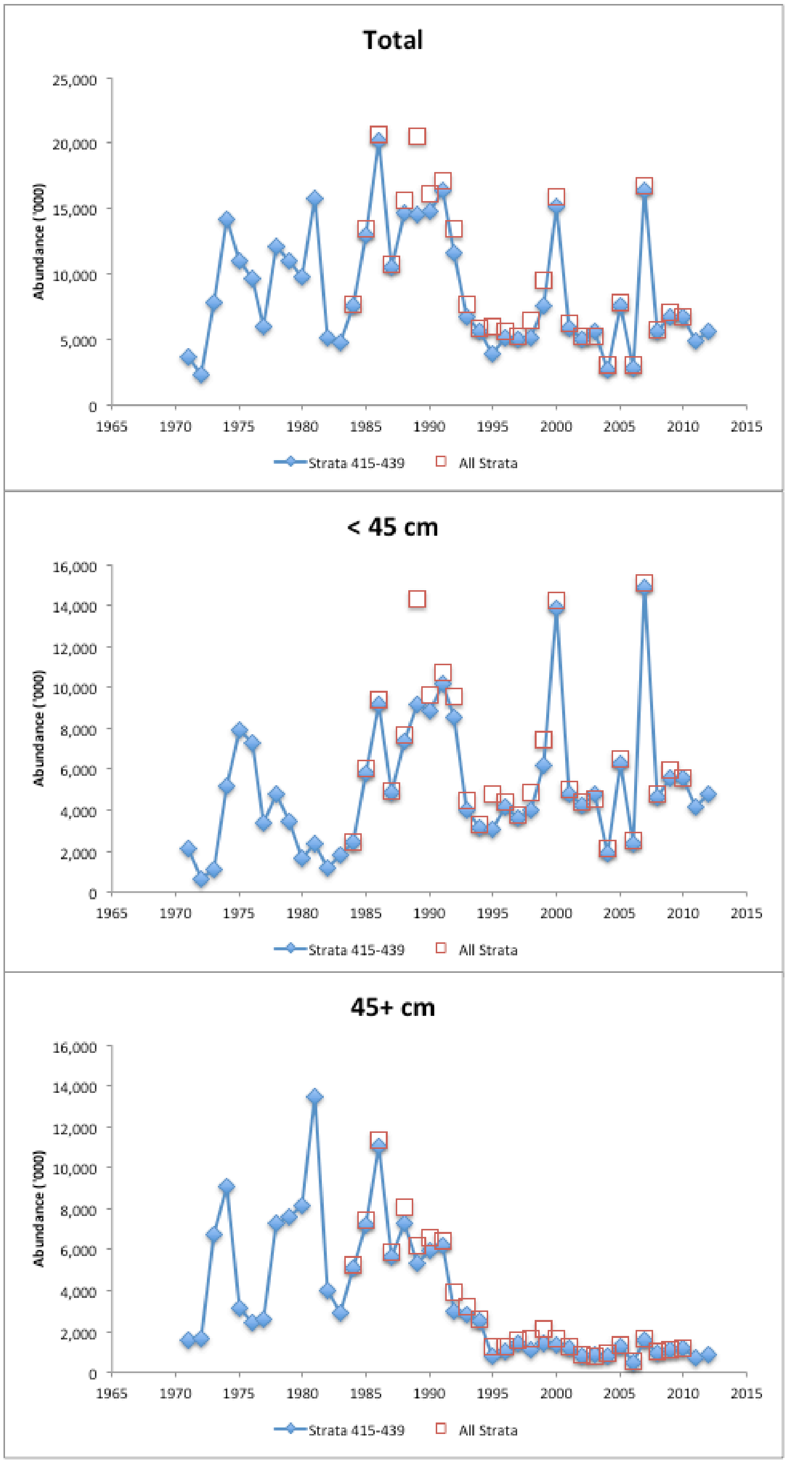

Figure 5. Abundance estimates of White Hake in the Southern Gulf of St. Lawrence (DU1), from the September bottom trawl survey for all (Total), immature (<45 cm) and mature (45+ cm) size categories. The open symbols are for all strata surveyed (including the two inshore strata that were added in 1984), and the closed symbols are for the original strata.

The estimated total abundance of White Hake initially varied around 7.8 million. This increased to a peak of around 15 million in the late 1980s, and then declined rapidly and stabilized around 5.7 million for the period of 1993-2012 (Figure 5). There were two peak estimates in 2000 and 2007 and these were the result of a large abundance of juvenile fish. However, either these points were anomalous or survival past year one was very low, since this high abundance did not persist.

The abundance of juvenile White Hake was estimated for the size class of < 45 cm total length. Juvenile abundance initially increased from about 1.3 million at the beginning of the time series to a local peak in 1975 of about 8 million. This was followed by a decline to about 1.8 million in 1983 and then an increase to 10 million in 1990. Abundance then declined and stabilized around 4.3 million for the period 1993-2012. As noted above, there were two large estimates of juvenile abundance in 2000 and 2007.

The abundance of mature fish was estimated for the size class of 45 cm and longer. The survey estimates of abundance in the initial portion of the time series (1971-1984) were highly variable but indicated an increasing trend from about 4 million initially to about 7 million in the mid-1980s. This was followed by a rapid decline over the next 2 generations to a relatively stable abundance of around 1 million individuals in the years after 2003.

The change in adult abundance over the most recent 3, 2, and 1 generation for White Hake was estimated using a log linear regression of the trawl survey results (Figure A1). For the last 3 generations (1985-2012), the estimated slope was statistically significant (-0.090 yr^{-1}, $p<0.0001$, Table 2). The estimated change was a decline of 91%. The estimated slope for the last 2 generations (1994-2012) was smaller and not significant (-0.024 yr^{-1}, $p=0.1012$). Using this slope estimate, the estimated change was a decline of 35%. Over the most recent generation (2003-2012) there was no trend (0.008 yr^{-1}, $p=0.8340$).

Table 2. Summary of log-linear regressions of trawl survey abundance indices of mature White Hake in Canada. The four surveys are the Southern Gulf of St. Lawrence (SGSL) September, the Scotian Shelf (SS) July, the Northern Gulf of St. Lawrence (NGSL) August and the Southern Newfoundland (SN) spring. Fish from SGSL are in DU1 and fish in the other three surveys are in DU2. The column Gen. indicates the number of generations over which the regression was calculated, "all" indicates the entire time series was used. The estimated slope, intercept, probability value (P value), R^2, the number of observations (N obs) and the number of years spanned by the analysis (Span) for each analysis is indicated. The estimated change in abundance is given in the last column. Note that for the 2 cases where the entire time series was used to estimate the slope, the estimated change in abundance was still calculated for the last 3 generations or 27 years.

Survey	Gen.	Slope	Intercept	P value	R^2	N obs	Span	Change
SGSL	3	-0.090	186.41	0.0000	0.713	28	27	-91%
SGSL	2	-0.024	54.83	0.1012	0.150	19	18	-35%
SGSL	1	0.008	-9.11	0.8340	0.006	10	9	7%
SGSL	all	-0.053	112.48	0.0000	0.503	42	41	-76%
SS	3	-0.053	115.28	0.0002	0.421	28	27	-76%
SS	2	-0.019	46.76	0.4322	0.037	19	18	-29%
SS	1	0.083	-158.05	0.1954	0.200	10	9	111%
SS	all	-0.019	47.92	0.0164	0.136	42	41	-41%
NGSL	2.7	-0.066	139.47	0.0002	0.467	25	24	-80%
NGSL	2	-0.003	13.77	0.8181	0.003	19	18	-6%
NGSL	1	-0.020	47.74	0.5148	0.055	10	9	-17%
SN	1.7	-0.002	12.23	0.9355	0.001	15	15	-3%
SN	1	-0.108	224.31	0.0016	0.781	9	9	-62%

The IUCN guidelines for applying criterion A allow that if a population's abundance oscillates over a time period longer than a generation, fitting a time series longer than 3 generations may give a more representative estimate of the long-term population reduction (section 4.5.1 of IUCN 2013). The guideline goes on to state that regardless of the length of the fitted time series, the change in population size should still be estimated for a period of the most recent 3 generations.

Given that there was an initial increase in abundance followed by a rapid decline, this may be considered an oscillation under the IUCN guidelines. Consequently, and for comparative purposes, the entire time series of estimates was also used to calculate the change in abundance. The log-linear regression over the entire time series of 41 years (4.5 generations) produced a statistically significant slope estimate (-0.053 yr^{-1}, $p<0.0001$, Table 2). The estimated change was a decline of 76% over a period of 3 generations.

The area of occupancy (DWAO) was initially between 15,000 – 20,000 km^2. This increased to about 25,000 km^2 in the early 1980s then declined rapidly to less than 15,000 km^2 in the mid-1990s (Figure 9 in Swain *et al.* 2012). The decline continued, but at a slower rate, to about 10,000 km^2 by 2010.

<u>Scotian Shelf (part of DU2)</u>

The Scotian Shelf trawl survey covers 1970-2011. The results were provided by J. Simon (DFO Maritimes Region, pers. comm. 2013) and are presented in Table A2.

The estimated total abundance of White Hake initially varied around 25 million in the 1970s. This increased to a peak of around 62 million in the mid-1980s. Since then the estimates have generally declined to average 21 million from 2006-2011 (Figure 6).

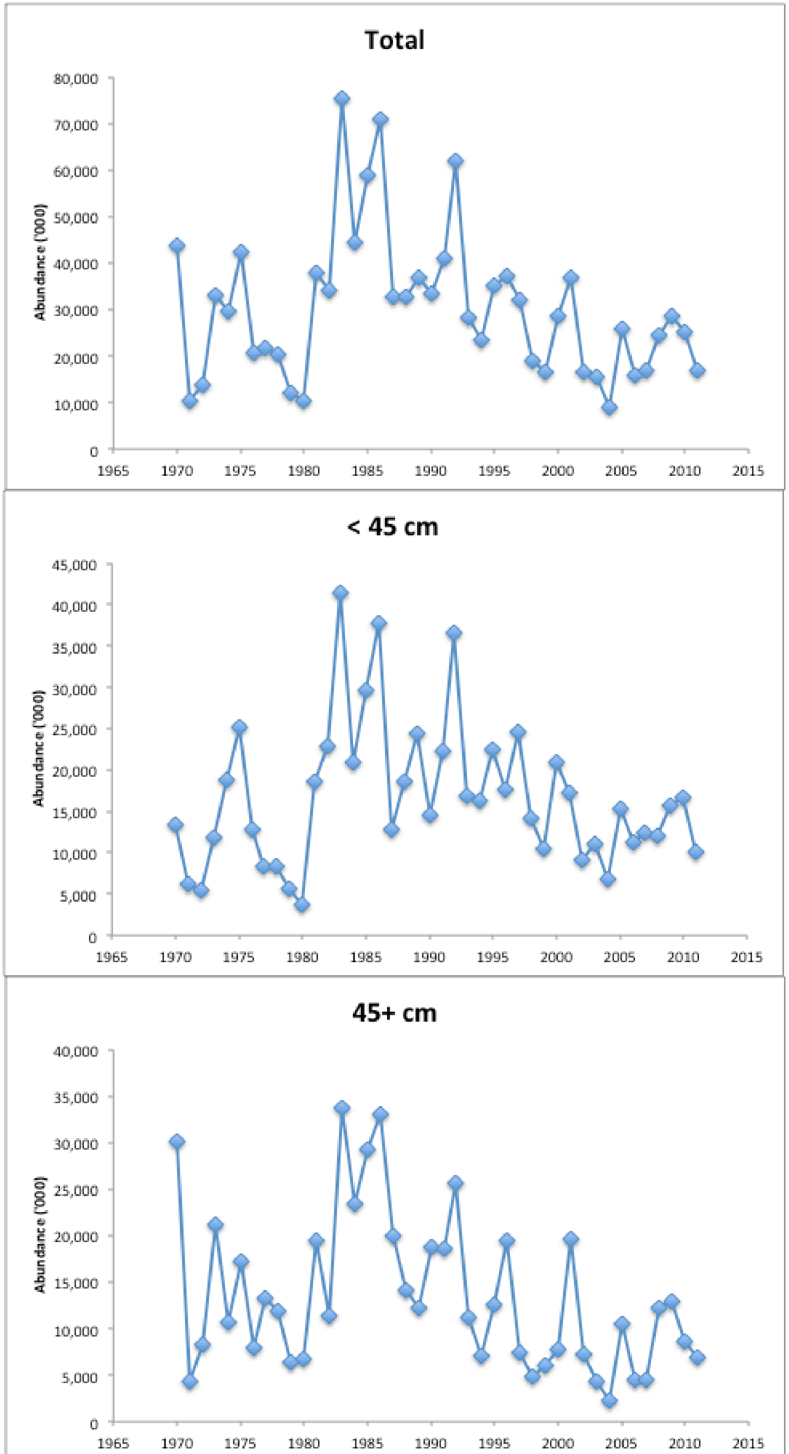

Figure 6. Abundance estimates of White Hake from the Scotian Shelf July bottom trawl survey for all (Total), immature (<45 cm) and mature (45+ cm) size categories. These fish are part of DU2.

The abundance of juvenile White Hake was estimated for the size class of <45 cm total length. Juvenile abundance initially averaged 12 million in the 1970s. This was followed by an increase to 32 million in the mid-1980s. Juvenile abundance has declined since then to an average of 13 million in 2006-2011.

The abundance of mature individuals was estimated for the size class of 45 cm and longer. Initially the estimates fluctuated and declined from around 15 million to a minimum of 6 million in 1980. This was followed by an increase to a maximum of 30 million in the mid-1980s. Since then the adult abundance has declined to an average of 8.3 million between 2006-2011.

The change in adult abundance over the most recent 3, 2, and 1 generation for White Hake was estimated using a log linear regression of the trawl survey results (Figure A1). For the last 3 generations (1984-2011), the estimated slope was statistically significant (-0.053 yr^{-1}, p=0.0002, Table 2). The estimated change was a decline of 76%. The estimated slope for the last 2 generations (1993-2011) was smaller and not significant (-0.019 yr^{-1}, p=0.432). Using this slope estimate, the estimated change was a decline of 29%. Over the most recent generation (2002-2011) the estimated slope was positive and not significant (0.083 yr^{-1}, p=0.195) and the estimated change was an increase of 111%.

Given that the overall time series from 1970 to the present may indicate the population has oscillated, the entire time series of 41 years was also used to estimate the annual rate of change. The slope of the log linear regression was statistically significant (-0.019, p=0.0164) and the estimated change over 3 generations was a decline of 41%.

The area of occupancy (DWAO) varied without trend over the survey and averaged approximately 70,000 km^2 (Figure 46 in Simon and Cook 2011).

Northern Gulf of St. Lawrence (part of DU2)

The Northern Gulf of St. Lawrence trawl survey covers 1985-2011. The results were provided by J. Gauthier (DFO Québec Region, pers. comm. 2013). Estimates of total abundance were available for the entire time series (Table A3). Estimates by size class were available from 1987 to the present.

The estimated total abundance of White Hake initially declined from around 11 million in the mid-1980s to around 2 million individuals in the mid-1990s (Figure 7). Estimates have been relatively stable since then. The trend in juvenile abundance (< 45 cm total length) was similar. The estimates declined from 6.4 million in 1987 to 1 million in 2004. Subsequent estimates have been relatively stable with a local peak of around 2.9 million in 2000. The estimated adult (>= 45 cm) abundance initially declined from 6.4 million in 1987 to a minimum of 0.5 million in 1994. Since then, the adult abundance estimates have averaged 0.9 million.

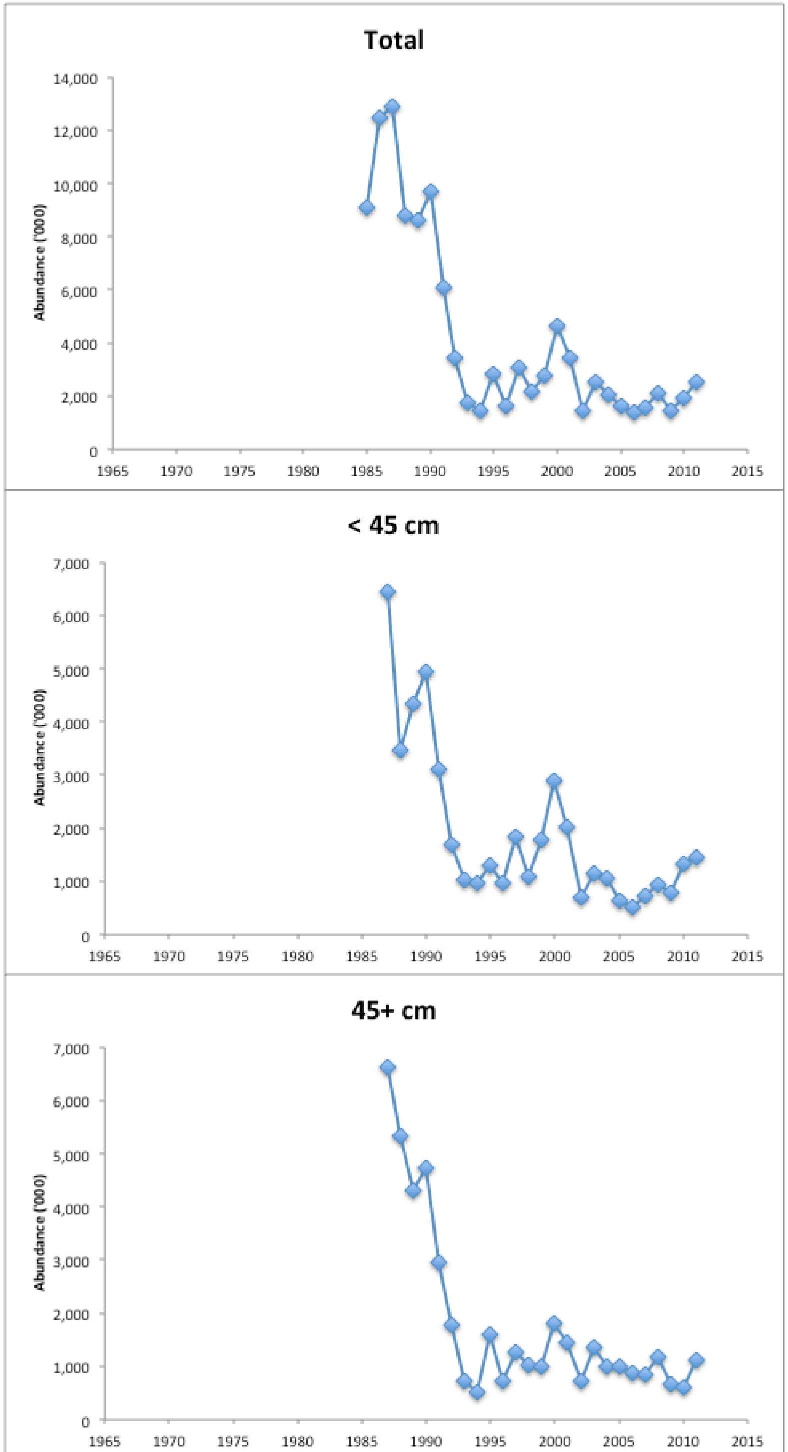

Figure 7. Abundance estimates of White Hake from the northern Gulf of St. Lawrence August bottom trawl survey for all (Total), immature (<45 cm) and mature (45+ cm) size categories. These fish are part of DU2.

The change in adult abundance over the most recent 2.7, 2, and 1 generation for White Hake was estimated using a log linear regression of the trawl survey results (Figure A1). For the last 2.7 generations (1987-2011), the estimated slope was statistically significant (-0.066 yr^{-1}, p=0.0002, Table 2). The estimated change was a decline of 80%. The estimated slope for the last 2 generations (1993-2011) was smaller and not significant (-0.003 yr^{-1}, p=0.8181). Using this slope estimate, the estimated change was a decline of 6%. Over the most recent generation (2002-2011) the estimated slope was not significant (-0.020 yr^{-1}, p=0.515) and the estimated change was a decline of 17%.

The area of occupancy (DWAO) was initially about 50,000 km^2 when the survey began in 1985. It declined to 25,000 km^2 in the early 1990s, increased to 40,000 km^2 in 2000, declined again to 25,000 km^2 in 2005, and increased again to 40,000 km^2 in 2011 (Figure 12 in Gauthier 2011).

Southern Grand Banks and St. Pierre Bank (part of DU2)

The Newfoundland spring survey provides the best temporal and spatial coverage of the Southern Grand Banks and St. Pierre Bank. Results for the total abundance for the period 1971-2011 were taken from Simpson *et al.* (2012) and the results for size (maturity) group and for 2011 were provided by M. Simpson (DFO Newfoundland Region, pers. comm. 2013) (Table A4). The trawl survey began in 1971 but the first available estimate of abundance was in 1973. Three different trawls were used for this survey, a Yankee 41.5 from 1971-1982, and Engel from 1983-1995, and a Campelen from 1996-2011. There were no comparative fishing studies done for White Hake for these gear changes. However, the Campelen trawl is much more efficient at catching bottom dwelling fish like White Hake than either the Yankee or Engel trawl (Warren 1997). This is evident in the increase in the total population estimate for White Hake when the gear change occurred in 1996. The average abundance estimate for the three years following the gear change was 4 times greater than the average for the 3 years before the gear change (Table A4). Total abundance estimates were available for the period 1973-2011, with the exception of 1974, 1983, and 2006. Estimates by size category have been available since 1996, following the change to the Campelen gear.

The average total abundance estimate for White Hake from 1973-1995, the last year before the Campelen trawl was introduced, was close to 4 million individuals (Figure 8). There was a downward trend in the estimates between 1987 and 1995. As noted above, there was a large increase in the estimates when the Campelen gear was introduced and the average estimate from 1996-1998 was 11.3 million. There was a very large peak in total abundance between 1999 and 2001 where the maximum estimate was 120 million. Total abundance then declined to around 9 million by 2010. The large increase in total abundance was due to large catches of juveniles (< 54 cm total length). In fact, the abundance of juveniles dominated the total abundance index in the period after 1996. For adults (greater than 54 cm), there was an increase in abundance estimates from about 2 million in 1996 to a maximum of 7 million in 2004. This was followed by a decline to about 2.5 million by 2011.

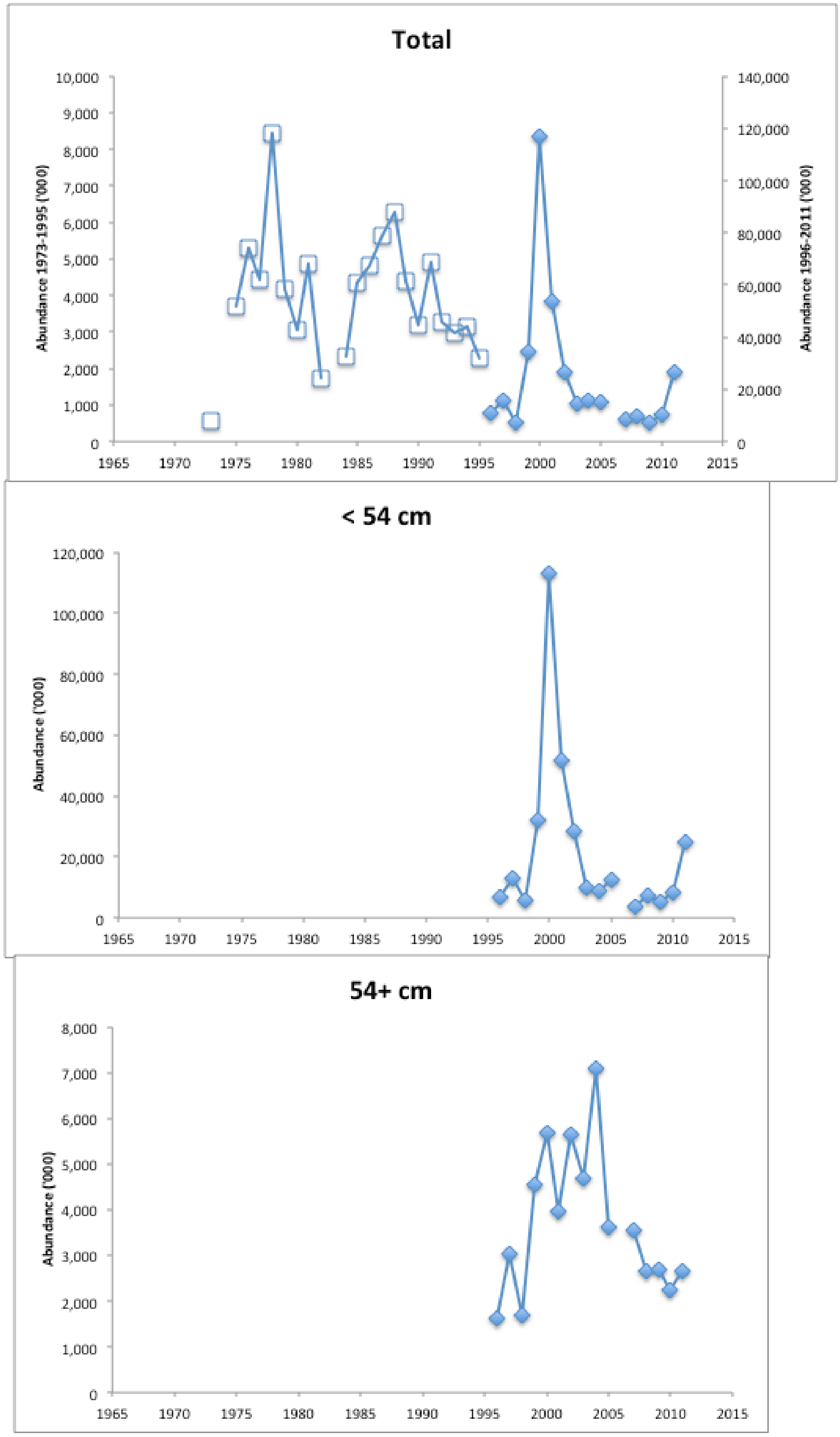

Figure 8. Abundance estimates of White Hake from the Southern Newfoundland spring bottom trawl survey for all (Total), immature (<54 cm) and mature (54+ cm) size categories. The graph for total abundance is plotted with 2 scales to accommodate the much larger estimates obtained since the trawl gear was changed in 1996. The open symbols apply to the left-hand scale, and the closed symbols apply to the right-hand scale when the Campelen trawl was used. These fish are part of DU2.

The change in adult abundance over the most recent 1.7 and 1 generation was estimated using a log linear regression of the trawl survey results (Figure A1). For the last 1.7 generations (1996-2011), the estimated slope was not statistically significant (-0.002 yr^{-1}, p=0.9355, Table 2). Over the most recent generation (2002-2011) the estimated slope was significant (-0.108 yr^{-1}, p=0.0016) and the estimated change was a decline of 62%.

The area of occupancy (DWAO) declined in the first years of the survey to reach a minimum in 1991 of just over 1,000 km^2. Since then the index has increased to around 6,000 km^2 in 2011 (Figure 7 in Simpson *et al.* 2012).

Summary of Trend Analysis

The estimated decline of adult abundance in the southern Gulf of St. Lawrence (DU1) over the most recent 3 generations was 91%. Most of this decline occurred in the first two generations and there was essentially no change in adult abundance over the most recent generation. The index of area of occupancy (DWAO) declined over the most recent 3 generations to reach a minimum of 10,000 km^2 in recent years.

Determining a change in mature abundance of White Hake in DU2 is complicated because there are 3 spatially non-overlapping trawl survey time series, there are differences in the catchability of the three surveys, and the time series are of various lengths. This is further complicated because the survey of the southern Newfoundland area did not separate mature and immature individuals before 1996, and this survey also had a gear change that resulted in a considerable increase in catchability. Nevertheless, if one compares the estimates of total abundance of the species in the period 1985-1989 when comparable fishing gears were used in the three areas, the highest average total abundance was on the Scotian Shelf (46 million), followed by the northern Gulf (10 million), and then southern Newfoundland (5 million). The estimated change in mature abundance in the Scotian Shelf area over the past 3 generations was a decline of 76% (11 million survivors) and the change in the northern Gulf was a decline of 80% (2 million survivors). The survey time series for mature individuals in the southern Newfoundland area covers only the most recent 1.7 generations and the trend over that period was stable (5 million survivors). If we accept the survey estimates as representing the relative abundance of White Hake among the three areas at the beginning of the 3-generation period (total mature abundance 61 million), and the estimated changes in mature abundance as described above (18 million survivors), this indicates the mature abundance declined by approximately 70%. If the entire time series of survey results for the Scotian Shelf area is used to estimate the annual rate of change of that portion of the DU, then the decline in the Scotian Shelf area is 41%, and the corresponding estimated decline of the entire DU is 44% (extrapolating back from their shorter time series). Most of this decline occurred over the first generation and the mature numbers appear to have been stable for the last 2 generations. The index of area of occupancy (DWAO) for this DU is approximately 116,000 km^2 with little trend over the last 3 generations.

If White Hake are assessed as a single wildlife species in Canada, a similar approach to determining the change in adult abundance could be used. The average total abundance in the southern Gulf area in 1985-1990 was 15 million. Using the respective estimates of relative abundance and change in abundance in the 4 areas, the estimated change in adult abundance in Canada is a decline of 74% over the last 3 generations. Most of this decline occurred in the first generation and adult abundance has been relatively stable in the most recent 2 generations. The index of area of occupancy (DWAO) over the Canadian range is approximately 126,000 km^2 and there has been a slight decline over the past 3 generations, mainly in the SGSL.

Rescue Effect

The US population clearly overlaps with DU2 and there is evidence that fish move across the border. However, the most recent assessment of White Hake in US waters indicates the stock is currently overfished and at low abundance (Butterworth *et al.* 2008). Thus, the current potential of rescue is limited. DU1 is discrete and isolated from non-Canadian populations of White Hake and rescue is not possible.

THREATS AND LIMITING FACTORS

Historically fishing, either directed or as bycatch, has been the largest single source of mortality, and in many regions this continues to be the case. Bundy and Simon (2005) state: “White Hake is caught as bycatch in longline, gillnet and otter trawl fisheries targeting Halibut, Redfish, Atlantic Cod, Pollock, Haddock and other groundfish. Any changes in these fisheries will have consequences for mortality on White Hake”. White Hake is a soft-fleshed species that is not as firm and as robust as other cod-like fishes such as Atlantic Cod, Haddock and Pollock. This makes it more susceptible to bruising and mortality when caught as bycatch and returned to the ocean. An additional (and much greater) source of mortality is due to expansion of the gas bladder when brought quickly to the surface from deep water.

<u>DU1 - Southern Gulf of St. Lawrence</u>

Currently, the main threat to White Hake in the southern Gulf of St. Lawrence is the exceedingly high level of non-fishing mortality (M) experienced by fish in the 1-3 and 4+ age groups (Swain *et al.* 2012). Levels of fishing mortality that appeared sustainable in the 1970s and early 1980s became unsustainable when M increased from 18% yr^{-1} in the 1970s and early 1980s to 73 - 78 % yr^{-1} in the late 1980s. Following the closure of the directed fishery in 1995, catches have been greatly reduced (Figure 9A) and fishing mortality declined to nearly zero. The lack of recovery since the closure of the fishery 15 years ago is entirely due to high M. Only the exceptionally high recruitment rate observed since the late 1990s has prevented the stock from declining further.

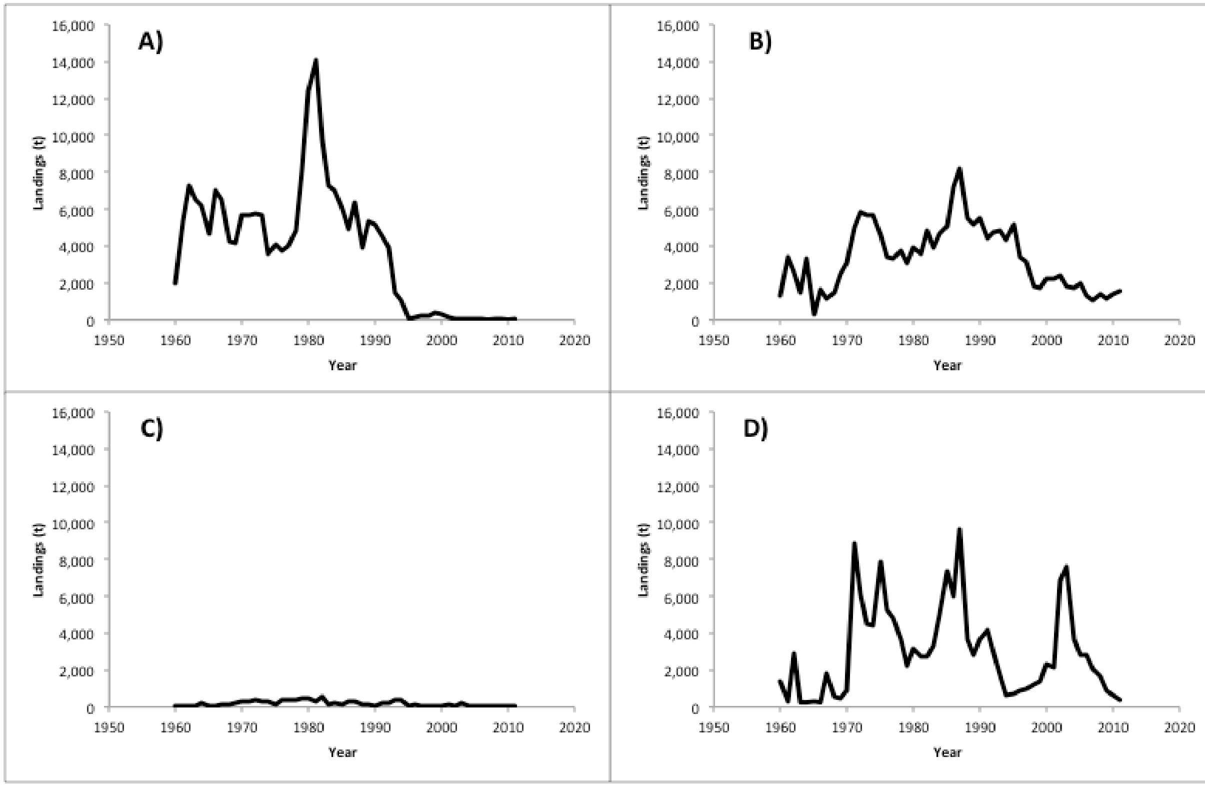

Figure 9. Reported landings of White Hake for A) the southern Gulf of St. Lawrence (NAFO Div. 4T), B) the Scotian Shelf (NAFO Div. 4VWX), C) the Northern Gulf of St. Lawrence (NAFO Div. 3Pn4RS), and D) Southern Newfoundland (NAFO Div. 2J3KLNOPs). The data were obtained from the NAFO STATLANT 21A database (www.nafo.int).

Benoît *et al.* (2011) examined possible causes of the elevated non-fishing mortality of White Hake in the southern Gulf. Factors that they considered included unreported catch, poor fish condition, life-history change, and predation by Grey Seals and other predators. The factor most strongly supported by the available evidence, albeit indirect, was predation by the increasing Grey Seal population. The dramatic shift in the distribution of White Hake to offshore areas in September is consistent with this conclusion. The inshore areas occupied by White Hake, in particular the Northumberland Strait and the area between Miramichi Bay and PEI, are heavily used by foraging Grey Seals in summer, and the recent shifts in hake distribution represents shifts from areas of high to lower risk of predation by Grey Seals. The winter distributions of both Grey Seals and White Hake off the northern coast of Cape Breton Island also overlap.

Benoît *et al.* (2011) also analyzed the extinction risk of White Hake in the southern Gulf of St. Lawrence. Stochastic age-based projections were undertaken using the estimated population size in 2009 as a starting point, two empirical stock-recruitment relationships, recent estimates of non-fishing mortality, and other related demographic parameters related to growth and maturation rates. Two stock-recruitment relationships, the Ricker and the Beverton/Holt, are commonly used in fish population simulations. When the Ricker relationship was used, there was an estimated 50% probability of extinction by 2018 and a 100% probability of extinction by 2040. The Beverton/Holt relationship predicted higher levels of recruitment. Under this scenario there was an estimated 50% probability of extinction by 2035 and a 100% probability by 2070. In order for the population to stabilize, there would have to be a reduction in M of approximately 70%. Two other simulations used alternative functional relationships for predation by Grey Seals on White Hake, namely the Holling Type II and Type III relationships. The results of these simulations bracketed those where M was assumed to be constant into the future. An assumption of the Type II relationship resulted in the population going extinct more quickly because it predicted predation mortality would increase as the White Hake population declined. Assuming the Type III relationship resulted in the population stabilizing at a lower abundance. This is because the Type III relationship allows for prey switching and a reduction in predation mortality at low abundance. Benôit *et al.* were not able to determine which of these relationships applied for White Hake.

<u>DU2 - Atlantic and Northern Gulf of St. Lawrence</u>

Overfishing may have led to the large decline in White Hake abundance on the Scotian Shelf from the mid-1980s to the end of the 1990s. The species is taken mainly as bycatch in fisheries for other groundfish species such as Atlantic Cod, Haddock, and Pollock (Simon and Cook 2011). Reported annual landings of White Hake from this area were highest in 1986 and 1987 (around 8,000 t yr^{-1}), and remained relatively high (around 5,000 t yr^{-1}) into the mid-1990s (Figure 9B). Catch restrictions were introduced in 1996, initially only for the fixed gear fleet. Catch limits were expanded in 1999 to include all gear types, and landings since then have been at or below 2100 t annually. This may explain the recent stability in the abundance of White Hake in this area. Little is known about other sources of mortality for the species in this area.

Overfishing is not considered to be a threat to White Hake in the northern Gulf of St. Lawrence, where there has never been a major directed fishery for the species. Reported landings increased from 46 t in 1960, peaking at 454 t in 1982 (Figure 9C). Annual landings averaged 137 t in the period 1960-1993. With reduced fishing effort after the first moratorium on groundfish in 1994, annual landings averaged 11 t for the 1997-2010 period (8t in 4R and 3 t in 4S). For that period, reported landings were bycatch from Atlantic Halibut, Cod, Redfish, and Turbot fisheries (Gauthier 2011). There is a bycatch limit of 10% for White Hake in these directed fisheries. Little is known about other sources of mortality for the species in this area and it is difficult to explain the large reduction in adult abundance that occurred in the late 1980s and early 1990s.

Fishing is also the only known source of human-caused mortality for White Hake in Newfoundland. Annual landings peaked in three periods, the mid-1970s, the late 1980s, and the mid-2000s. Each peak was around 8,000 t annually (Figure 9D). Recent landings have been less than 1000 t. White Hake in NAFO Divisions 3NO came under quota regulation in September 2004, when the NAFO Fisheries Commission established a Total Allowable Catch (TAC) of 8500 mt for 2005-2007 (Simpson *et al.* 2012). This allocation was between Canada (2500 mt), the EU (5000 mt), Russia (500 mt), and remaining NAFO member countries (500 mt). This TAC was maintained at 8500 mt for 2008-20010, reduced to 6,000 t in 2011 and again to 1,000 t in 2012. These reduced TACs were never taken. There is no annual TAC in NAFO Div. 3P. Nevertheless, given the recent low landings and the stability of the number of mature individuals in this area, it appears that threats to White Hake in this area are low.

PROTECTION, STATUS, AND RANKS

The southern Gulf of St. Lawrence fishery for White Hake has been protected by a fishing moratorium since 1995. Catches of White Hake are regulated by catch caps on the Scotian Shelf. NAFO has imposed TACs on White Hake in NAFO Div. 3NO. There is no directed fishery for White Hake in the northern Gulf of St. Lawrence and bycatch is limited to 10% of the directed species catch in other fisheries. There is no annual TAC for White Hake in NAFO Subdiv. 3Ps.

White Hake has not been assessed by the IUCN.

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Dr. Cote received a B.Sc. in Biology from Wilfrid Laurier University (1996) and a Ph.D. in Biology from the University of Waterloo (2000). He has 17 years of experience studying imperilled marine and anadromous fish populations. He was an aquatic ecologist with Parks Canada (Terra Nova National Park) from 2000-2012. He holds an adjunct faculty position at Memorial University of Newfoundland and has authored 18 primary and 8 secondary publications.

Alan Sinclair received a BSc (1976) and MES (1986) from Dalhousie University and worked as a technician, biologist and research scientist with DFO for 33 years (1976-2009). He was a member of the COSEWIC Marine Fishes Species Specialist Subcommittee (SSC) from 2007-2009 and has been a co-chair of the SSC from 2010-2013.

Appendix A. Annual abundance indices from DFO bottom trawl surveys.

Table A1: Minimum population abundance estimates (thousand) for White Hake in the Southern Gulf of St. Lawrence bottom trawl survey. The estimates are split by size to indicate immature (<45 cm) and mature (45+ cm) fish. Values for 1971-2010 from Swain *et al.* 2012, results for 2011 and 2012 were obtained from D. Swain, DFO Gulf Region, pers. comm.

	Strata 415-439			All Strata		
Year	<45 cm	45+ cm	Total	<45	45+	Total
1971	2,137	1,585	3,722			
1972	662	1,642	2,304			
1973	1,086	6,749	7,834			
1974	5,132	9,079	14,211			
1975	7,879	3,108	10,987			
1976	7,244	2,430	9,674			
1977	3,387	2,556	5,944			
1978	4,803	7,303	12,106			
1979	3,425	7,595	11,020			
1980	1,626	8,180	9,805			
1981	2,380	13,428	15,808			
1982	1,163	4,024	5,187			
1983	1,799	2,927	4,727			
1984	2,462	5,070	7,532	2,462	5,238	7,700
1985	5,809	7,213	13,022	6,035	7,470	13,505
1986	9,147	11,054	20,201	9,359	11,321	20,680
1987	4,848	5,677	10,525	4,905	5,856	10,760
1988	7,350	7,289	14,639	7,644	8,059	15,703
1989	9,194	5,336	14,531	14,325	6,219	20,544
1990	8,850	5,975	14,825	9,605	6,552	16,156
1991	10,186	6,159	16,346	10,760	6,388	17,148
1992	8,571	3,005	11,576	9,562	3,880	13,442
1993	3,992	2,784	6,776	4,488	3,246	7,734

	Strata 415-439			All Strata		
Year	<45 cm	45+ cm	Total	<45	45+	Total
1994	3,145	2,535	5,680	3,275	2,583	5,858
1995	3,078	799	3,877	4,740	1,223	5,963
1996	4,123	1,007	5,130	4,373	1,231	5,604
1997	3,594	1,440	5,034	3,728	1,571	5,299
1998	4,011	1,120	5,130	4,821	1,615	6,436
1999	6,156	1,381	7,537	7,464	2,080	9,543
2000	13,873	1,324	15,197	14,255	1,622	15,877
2001	4,770	1,154	5,924	5,044	1,252	6,296
2002	4,215	816	5,031	4,395	872	5,267
2003	4,797	856	5,653	4,536	775	5,311
2004	1,910	776	2,686	2,153	921	3,074
2005	6,287	1,277	7,564	6,512	1,321	7,833
2006	2,358	511	2,869	2,477	539	3,015
2007	14,887	1,533	16,420	15,107	1,672	16,779
2008	4,648	976	5,623	4,785	986	5,771
2009	5,592	1,118	6,710	5,955	1,138	7,093
2010	5,523	1,181	6,704	5,540	1,182	6,722
2011	4,163	744	4,907			
2012	4,783	865	5,648			

Table A2: Minimum population abundance estimates (thousand) for White Hake in the Scotian Shelf bottom trawl survey. The estimates are split by size to indicate immature (<45 cm) and mature (45+ cm) fish. Values were obtained from J. Simon, DFO Maritimes Region, pers. comm.

Year	<45 cm	45+ cm	Total
1970	13,392	30,199	43,591
1971	6,137	4,317	10,454
1972	5,391	8,349	13,740
1973	11,741	21,245	32,986

Year	<45 cm	45+ cm	Total
1974	18,817	10,662	29,479
1975	25,133	17,260	42,393
1976	12,811	7,927	20,737
1977	8,281	13,339	21,619
1978	8,292	11,892	20,184
1979	5,622	6,332	11,954
1980	3,666	6,807	10,472
1981	18,565	19,385	37,950
1982	22,913	11,300	34,213
1983	41,524	33,761	75,285
1984	20,864	23,408	44,271
1985	29,682	29,187	58,869
1986	37,778	33,118	70,895
1987	12,855	19,961	32,816
1988	18,635	14,203	32,838
1989	24,448	12,267	36,715
1990	14,492	18,788	33,281
1991	22,221	18,610	40,832
1992	36,506	25,592	62,098
1993	16,916	11,270	28,186
1994	16,310	7,160	23,470
1995	22,419	12,552	34,972
1996	17,573	19,506	37,079
1997	24,508	7,368	31,876
1998	14,228	4,837	19,065
1999	10,560	6,112	16,672
2000	20,941	7,721	28,662
2001	17,198	19,646	36,844
2002	9,141	7,260	16,401

Year	<45 cm	45+ cm	Total
2003	11,132	4,318	15,450
2004	6,856	2,179	9,035
2005	15,332	10,576	25,909
2006	11,295	4,487	15,782
2007	12,404	4,417	16,821
2008	12,116	12,267	24,384
2009	15,650	12,885	28,534
2010	16,663	8,672	25,335
2011	10,182	6,884	17,066

Table A3: Minimum population abundance estimates (thousand) for White Hake in the northern Gulf of St. Lawrence August bottom trawl survey. The estimates are split by size to indicate immature (<45 cm) and mature (45+ cm) fish. Values were obtained from J. Gauthier, DFO Québec Region, pers. comm.

Year	< 45 cm	45+ cm	Total
1985			9,120
1986			12,451
1987	6,445	6,632	12,874
1988	3,458	5,324	8,781
1989	4,326	4,310	8,637
1990	4,955	4,723	9,683
1991	3,115	2,950	6,064
1992	1,677	1,787	3,464
1993	1,027	730	1,757
1994	958	511	1,466
1995	1,286	1,587	2,864
1996	971	731	1,660
1997	1,841	1,264	3,105
1998	1,097	1,041	2,148
1999	1,773	992	2,755
2000	2,880	1,820	4,675
2001	2,015	1,443	3,458
2002	707	725	1,438

Year	< 45 cm	45+ cm	Total
2003	1,147	1,361	2,508
2004	1,072	989	2,061
2005	623	1,003	1,626
2006	501	872	1,374
2007	722	861	1,583
2008	928	1,192	2,120
2009	792	670	1,462
2010	1,316	593	1,909
2011	1,451	1,116	2,567

Table A4: Minimum population abundance estimates (thousand) for White Hake in the Southern Newfoundland spring bottom trawl survey. The estimates are split by size to indicate immature (<54 cm) and mature (54+ cm) fish. Results for the total abundance for the period 1971-2011 were taken from Simpson *et al.* 2012 and the results for size (maturity) group and for 2011 were provided by M. Simpson (DFO Newfoundland Region, pers. comm. 2013)

Year	<54 cm	54+ cm	Total
1971			
1972			
1973			585
1974			
1975			3,726
1976			5,301
1977			4,444
1978			8,420
1979			4,177
1980			3,068
1981			4,865
1982			1,740
1983			
1984			2,321
1985			4,369
1986			4,830
1987			5,647
1988			6,286

Year	<54 cm	54+ cm	Total
1989			4,382
1990			3,177
1991			4,918
1992			3,273
1993			2,971
1994			3,160
1995			2,293
1996	6,925	1,619	11,146
1997	13,150	3,041	15,510
1998	5,647	1,701	7,093
1999	31,856	4,550	34,693
2000	113,250	5,669	116,819
2001	51,553	3,960	53,693
2002	28,622	5,653	26,537
2003	10,099	4,669	14,330
2004	8,833	7,076	15,507
2005	12,364	3,606	15,307
2006			
2007	3,936	3,549	8,802
2008	7,498	2,664	9,703
2009	4,981	2,671	7,548
2010	8,562	2,249	10,400
2011	24,708	2,654	26,820

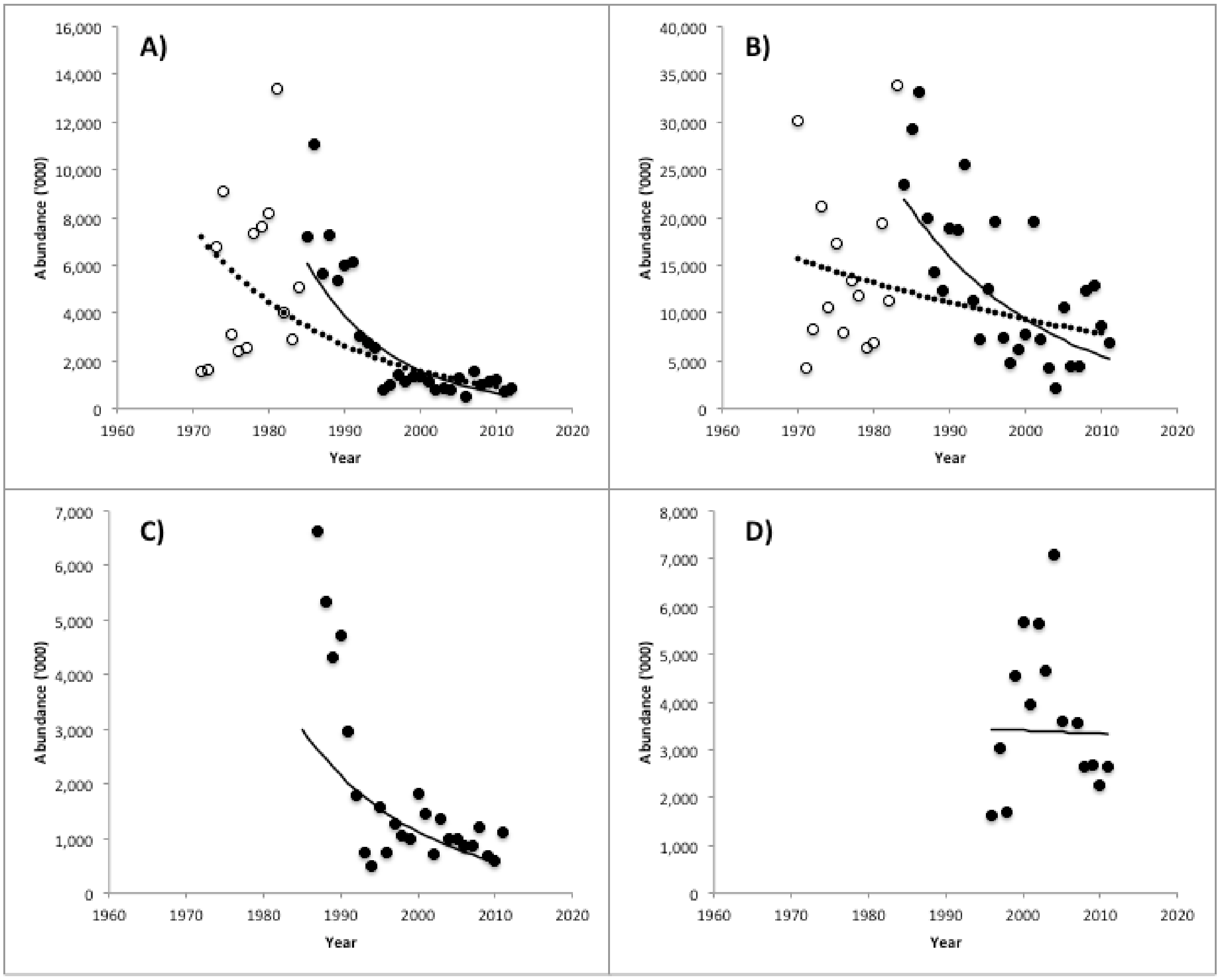

Figure A1: Log linear regressions of mature population numbers vs. year for bottom trawl survey results for A) the southern Gulf of St. Lawrence, B) the Scotian Shelf, C) the Northern Gulf of St. Lawrence, and D) Southern Newfoundland. The closed markers indicate the data for the last 3 generations (27 years) and the solid line is the fit to these data. The dashed lines in panels A and B are the fits for the entire time series.