NCRL subject guide 2018-14
DOI:10.7289/V5/SG-NCRL-18-14

Northeast Multispecies Fishery Management Plan Resource: White hake(Urophycis tenuis)

Bibliography

Judith Salter, Librarian, NOAA Central Library

April 2018

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
NOAA Central Library – Silver Spring, Maryland

Table of Contents

Background & Scope

The Northeast Multispecies Fishery Management Plan (FMP) was implemented in 1986 to reduce fishing mortality of heavily fished groundfish stocks and to promote rebuilding to sustainable biomass levels. Thirteen species are managed through plan amendments and framework adjustments to the original plan, including: Atlantic cod, haddock, yellowtail flounder, American plaice, witch flounder (grey sole), winter flounder (black back), Acadian redfish, white hake, Pollock, windowpane flounder, ocean pout, Atlantic halibut, and the Atlantic wolffish. This bibliography focuses on white hake, and is intended as a primer and reference resource for staff of the National Marine Fisheries Service, Greater Atlantic Regional Fisheries office. It is organized into four sections: Biology (life history), Ecology (interaction with the environment), Fishery, and Management.

Section I – Biology

Section one is intended to provide an overview of the life history of white hake. The research in this area is a compilation of basic facts including habitat and reproduction as well as current research on white hake Biology.

Section II – Ecology

Section two is intended to provide an overview of how white hake interacts with the environment. The citations in this area focus on how temperature and changes in the environment can impact wild white hake.

Section III – Fishery

Section three is intended to provide an overview of the white hake fishery. It is divided into two sections: Historical and Modern. The Historical section contains resources on the early white hake fishery. The Modern section contains scientific publications about the current state of the white hake fishery.

Section IV – Management

Section four is intended to provide an overview of the management of white hake. It includes relevant research concerning plans and policies intended to assess and protect the white hake population.

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded; Elsevier's Science Direct, BioOne Complete; ProQuest Science and Technology, including AFSA; JSTOR, and Lexis Advance, in addition to web searches. Only English language materials were included. Priority was given to publications focusing on wild white hake populations in the Atlantic region with a focus on the Gulf of Maine, and research on the populations from Newfoundland to Southern New England, which is managed by the U.S. and Canadian sources.

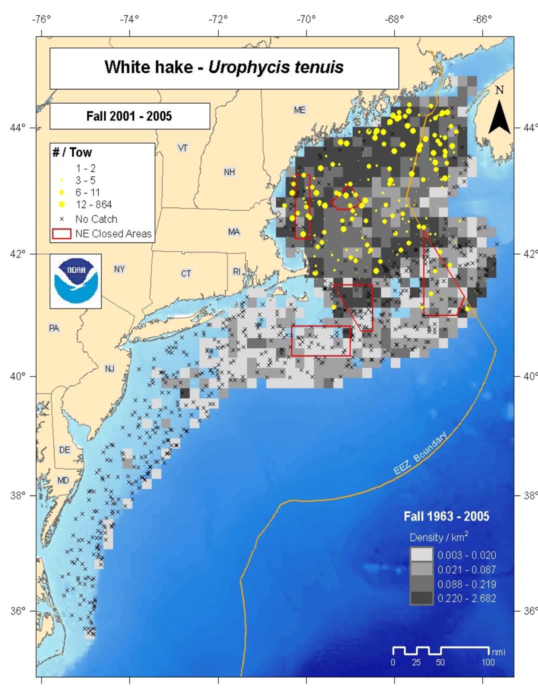
Section I: Biology

Image from:
https://www.nefsc.noaa.gov/read/popdy/studyfleet/Documents/Guide_Final_120813b.pdf

Scientific name: Urophycis tenuis

Also known as: Boston hake, black hake, mud hake, hake, ling, merluche blanche (French)

Region: White hake inhabit the continental shelf and upper continental slope waters from southern Labrador to North Carolina, with rare catches from Iceland in the north and northern Florida in the South. The white hake is primarily found in the Atlantic Ocean from Newfoundland to Southern New England. Outside Canada, the highest abundance of White Hake is in the Gulf of Maine and on Georges Bank.



https://www.nefsc.noaa.gov/sos/spsyn/og/hake/animation/fall/

Habitat: demersal gadoid species commonly taken in deeper areas of the Gulf of Maine in winter and inshore or shoal ward in summer. White hake favor soft muddy bottoms and temperatures of 5–11 ◦C (41–51.8◦F). In Canada, white hake can adjust their depth distribution to find temperatures in the range of 4-8° C. White hake in the Gulf of Maine are commonly captured over fine sediment substrates such as mud but are also reported on sand and gravel.

Behavior: Large demersal feeders with 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 in Canada white hake tend to move shoreward in summer and disperse to deeper water in winter. There is little seasonal movement for white hake off southern Newfoundland.

Size: White hake attain a maximum length of 135 cm (53 in.) and weigh up to 22 kg (48.5 lbs); females are larger than males.

Physical Description: White hake are typically grey to dark purple-brown on the dorsal area, olive-brown and bronze to golden along their sides, and white to yellow on the belly with many tiny black spots. White hake have a small head and a small single barbel at the tip of the lower jaw and its large mouth reaches to below its large eyes. two dorsal fins with short filaments that extend from first dorsal fin; elongated body with threadlike rays of short filaments extending from its pelvic fins reaching past the tips of its pectoral fins elongated body with elongated pelvic fins with a pelvic filament that does not reach the anal opening; physoclistous swim bladder; and two gill rakers on the upper elbow of first gill arch. White hake can be distinguished from red hake (Urophysis chuss) because it has smaller scales than red hake and by the number of lateral line scales and the number of gill rakers.

Lifespan: white hake attaining ages of 20+ years have been documented; average age of parents in the population, or generation time is estimated to be 9 years; the current method for determining age of white hake is to thinly section the otolith.

Diet: Demersal juveniles feed primarily on polychaetes, shrimps, and other crustaceans (Bowman 1981), but adults feed on fish, including juveniles of their own species (Langton et al. 1994) and shrimps and other crustaceans. White hake feed mostly on crustaceans and fish. Larger individuals are reported to be cannibalistic and to feed upon eggs and juveniles. In nearshore areas, white hake are also thought to predate on smaller juvenile cod.

Predators: Predators of white hake include Atlantic cod, other fish species, Atlantic puffins, Arctic terns, other seabirds and seals. White hake are consumed by seabirds; feeding studies off the coast of Maine indicated that Atlantic puffin and Arctic tern prey on pelagic juveniles that occur at the surface during the day in June-July. Smaller juveniles are eaten by adults of their own and other species. In Canada, white hake predation by grey seals is of concern as the population increased at a rate of 4.5% in Canadian waters and is likely increasing in U.S. waters as well (DFO 2014, Hayes et al. 2017).

Reproduction: White hake mature early, with 50% maturity for males and females at less than 3 years. 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. White hake eggs are most often observed in August and September on surface waters of the Gulf of Maine, Georges Bank, and southern New England. Larval distributions indicate the presence of two spawning groups in the

Gulf of Maine, Georges Bank and Scotian Shelf region, one which spawns in deep water on the continental slope in late winter and early spring, and a second which spawns on the Scotian Shelf in the summer. The northern stock of white hake spawns in late summer (August-September) in the southern Gulf of St. Lawrence and on the Scotian Shelf.

Fahay, M. P. (1987). *Larval and Juvenile Hakes (Physis-Urophycis Sp.) Examined During a Study of the White Hake, Urophycis Tenuis (Mitchill), in the Georges Bank-Gulf of Maine Area*. Sandy Hook Laboratory Report No. 87-03. https://www.nefsc.noaa.gov/publications/series/shlr/shlr87-03.pdf

This report documents material examined the epibranchial gill rakers, total caudal fin rays, and vertebrae precaudal caudal of white hake during the course of a study of the first year life history stages of the white hake, Urophycis tenuis, in the Georges Bank-Gulf of Maine area. Published biological studies of hake species in the western North Atlantic are often questioned because of the possibility of misidentification of the various species, which resemble each other strongly in all ontogenetic stages.

Fahay, M. P., & Able, K. W. (1989). White hake, Urophycis tenuis, in the Gulf of Maine: spawning seasonality, habitat use, and growth in young of the year and relationships to the Scotian Shelf population. *Canadian journal of zoology, 67(7)*, 1715-1724. https://doi.org/10.1139/z89-245

Our interpretation of the pattern of white hake spawning seasonality, habitat use, and growth of young of the year in the Gulf of Maine – Georges Bank area is based on analyses of extensive collections of early life history stages during 1984–1987 and on comparisons with studies conducted in Canadian waters. Eggs or larvae of Urophycis tenuis were not found at any time in the study area, but pelagic juveniles were abundant in May–June and size distributions indicated a shoreward migration with growth. Recruitment to nearshore areas was detected in June–July and the rate of growth for demersal juveniles was calculated to average 1.02 mm/day in the first summer. Spawning of this species during August–September on the Scotian Shelf does not appear to influence the Gulf of Maine population but, instead, appears to involve a separate stock with a different spawning schedule. It is concluded that spawning in continental slope regions south of the Scotian Shelf, Georges Bank, and southern New England during early spring results in recruitment to nearshore areas of the Gulf of Maine and southern New England. This spawning event also provides pelagic juveniles to the Scotian Shelf prior to the onset of local spawning there.

Garrison, L. P., & Link, J. S. (2000). Diets of five hake species in the northeast United States continental shelf ecosystem. *Marine Ecology Progress Series, 204*, 243-255. http://www.int-res.com/articles/meps/204/m204p243.pdf

Hakes are among the most abundant predators in continental shelf ecosystems worldwide. Fish prey consumption by hakes can be high and may be a primary source of mortality for economically important pelagic species. Hake predation plays an important role in the dynamics of both the US northeast continental shelf ecosystem and generally on a global scale. A large number (>11 000) of white hake stomachs were sampled, particularly in the medium and large size classes. The year-block gradient reflected changes primarily in the proportion of fish prey in the diets. White hake, cephalopods, and sand lance were more important in early periods while Atlantic herring and other clupeids were important in later time periods. The ontogenetic diet trends in white hake are similar to those observed in silver hake, with an increasing amount of piscivory with increasing size. Euphausiids (12.8% of diet), crangonid shrimp (15.7%), pandalid shrimp (14.2%), and unclassified shrimp (19.9%) account for the majority of small white hake diets. Medium-sized white hake had a large proportion of shrimp taxa in their diets, but unclassified fishes (25.5%) and silver hake (16.2%) were also important components. Large white hake fed almost exclusively on fish taxa, with silver hake (21.7%), clupeids (7.1%), Atlantic herring (6.5%), argentines (6.6%) and unclassified fishes (33.5%) as major prey. As abundant predators of juvenile fishes and pelagic species, the hakes have the potential to limit the recovery of overexploited stocks. As fishing pressure is reduced to rebuild stocks, it will be important to consider the role of predators on population dynamics, particularly through impacts on juvenile survivorship. Hakes are major predators in the world's oceans, and future models should be cognizant of the potential influence of hakes on the population dynamics of exploited species.

Hammill, M. O., Stenson, G. B., Swain, D. P., & Benoît, H. P. (2014). Feeding by grey seals on endangered stocks of Atlantic cod and white hake. *ICES Journal of Marine Science, 71(6)*, 1332-1341. https://doi.org/10.1093/icesjms/fsu123

High natural mortality is preventing the recovery of collapsed stocks of Atlantic cod and white hake in the southern Gulf of St Lawrence, Canada. Predation by grey seals has been proposed as an important cause of this high mortality. We determined the contribution of cod and hake to the diet of grey seals collected along the west coast of Cape Breton Island and in the Cabot Strait, an area where overwintering cod aggregate. Along the coast of Cape Breton Island, the contribution of hake and cod to the diet was 30% and 17%, respectively, by weight using stomach contents and 13% and 9%, respectively, based on intestine contents. In the Cabot Strait, when overwintering aggregations of cod were present, cod accounted for 68% (range 57–80%) of the male diet from stomachs, and 46% (range: 31–64%) of the diet determined from intestines. Among females, cod represented 14% (range: 0–34%) and 9% (range: 3–54%) of the diet from stomachs and intestines, respectively. In Cabot Strait, white hake accounted for up to 17% of the diet by weight from stomachs, and up to 6% of the diet determined from intestines. The mean length of cod consumed by seals was 28 cm (SD = 8.6) along the coast of Cape Breton Island, and 39 cm (SD = 5.7) in Cabot Strait. The mean length of hake consumed by seals was 29 cm (SD = 7.0) along the coast of Cape Breton Island, and 35 cm (SD = 5.6) in Cabot Strait. Cod and hake are more important to the diet of males than that of females. The contribution of cod to the diet of grey seals foraging in the cod overwintering area is much greater than has been reported elsewhere. In the southern Gulf of St Lawrence (sGSL, NAFO fishing zone 4T), the collapsed stock of white hake (Urophycis tenuis) has shown no sign of recovery and the collapsed stock of Atlantic cod (Gadus morhua) continues to decline despite negligible fishing mortality (Swain and Chouinard, 2008). This lack of recovery is due to elevated natural mortality of large fish (Chouinard et al., 2005; Swain and Chouinard, 2008; Swain et al., 2012a,b). Because of their continued low abundance, these stocks have been designated as 'Endangered' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC www.cosewic.gc.ca; Swain and Chouinard, 2008). While these stocks have declined, grey seals (Halichoerus grypus) have increased in abundance and it has been suggested that seal predation may be an important factor limiting their recovery (Chouinard et al., 2005; Benoît and Swain, 2008; Benoît et al., 2011).

Hurlbut, T., & Clay, D. (1998). Morphometric and meristic differences between shallow-and deep-water populations of white hake (Urophycis tenuis) in the southern Gulf of St. Lawrence. *Canadian Journal of Fisheries and Aquatic Sciences*, *55*(10), 2274-2282. https://doi.org/10.1139/f98-110

Linear discriminant function analysis of morphometric and meristic characters was used to assess the extent of differentiation between shallow- (<100 m) and deep- (>200 m) water populations of white hake (Urophycis tenuis) from the southern Gulf of St. Lawrence (NAFO Division 4T). Although meristic characters provided some evidence for stock separation, the best statistical separation was obtained with morphometric characters. Morphometric discriminant functions derived from "learning" samples were able to correctly classify 82 and 84% of the "test" samples for both females and males, respectively. A greater relative snout length in fish sampled from along the Laurentian Channel compared with those from the Northumberland Strait area was the primary discriminating character for both sexes. Our morphological evidence and previous tagging and distributional studies suggest that the populations from these two areas represent separate stocks; therefore, the traditional management unit for white hake in NAFO Division 4T may no longer be appropriate.

Northeast Fisheries Science Center. (2017). "Data." *Operational Assessment of 19 Northeast Groundfish Stocks, Updated Through 2016*. U.S. Department of Commerce, Northeast Fishery Science Center Reference Document 17-17, 4. https://doi.org/10.7289/V5/RD-NEFSC-17-17

Catch-at-age is estimated using age-length keys applied to expanded length frequency distributions. For white hake, which is landed headed, the age-length key is applied to predicted lengths based on dorsal fin to caudal fin length. Additional sources of catch for some species come from Canadian or other foreign fishing. Age structures collected by the observer program are available and should be aged to augment the survey keys. They are also available from the ASMFC shrimp survey and would allow another survey to be added to the model. Otoliths are currently being collected from the market category for heads and these should also be aged.

Roy, D., Hurlbut, T. R., & Ruzzante, D. E. (2012). Biocomplexity in a demersal exploited fish, white hake (Urophycis tenuis): depth-related structure and inadequacy of current management approaches. *Canadian Journal of Fisheries and Aquatic Sciences, 69(3),* 415-429. https://doi.org/10.1139/f2011-178

Understanding the factors generating patterns of genetic diversity is critical to implementing robust conservation and management strategies for exploited marine species. Yet, often too little is known about population structure to properly tailor management schemes. Here we report evidence of substantial population structure in white hake (Urophycis tenuis) in the Northwest Atlantic, perhaps among the highest levels of population structure exhibited by a highly exploited, widely dispersed, long-lived marine fish. We show that depth plays a role in this extensive and temporally stable structure, which does not conform to previously established fisheries management units. Three genetically distinguishable populations were identified, where all straddle several management divisions and two (Southern Gulf of St. Lawrence and Scotian Shelf) overlap in their range, coexisting within a single division. The most highly exploited population in the Southern Gulf of St. Lawrence was also the most isolated and likely the smallest (genetically effective). This work shows that conservation and management priorities must include population structure and stability in establishing effective species recovery strategies.

Valentin, A. E., Penin, X., Chanut, J. P., Power, D., & Sévigny, J. M. (2014). Combining microsatellites and geometric morphometrics for the study of redfish (Sebastes spp.) population structure in the Northwest Atlantic. *Fisheries Research*, *154*, 102-119. https://doi.org/10.1016/j.fishres.2014.02.008

Absence of panmixia has been detected in the same region for white hake (Urophycis tenuis), a long-lived (>15 years), demersal gadoid with high fecundity and a pelagic larval-juvenile phase lasting up to three months (Roy et al., 2012). Contrasting with distribution predictions from advective dispersal, two genetically distinguishable populations of white hake were identified in the GSL-LCH area (Roy et al., 2012). These populations were respectively distributed (i) along the southern slope of the Laurentian Channel located inside the GSL (i.e. area 4T-4Vn) and (ii) across a wide region from the Gulf of St. Lawrence to the Gulf of Maine, including the Scotian Shelf (areas 4RSTVnVsWX). A third population was identified on NL Grand Banks in a region comprising the southern 3PS area and Div. 3O. The structure was partially driven by geography and depth, among other unidentified factors. The present study and the study by Roy et al. (2012) suggest that genetic structuring in the GSL-LCH area occurs across smaller spatial scale than simply predicted by current patterns. These observations are consistent with the recent shifts in the general view of the biology and evolution of marine fishes. There is now increasingly recognized that population structure might occur on a limited geographical scale ranging from tens to a few hundred kilometers and that adaptive variation might be more important than anticipated (Conover et al., 2006; Hauser and Carvalho, 2008).

Section II: Ecology

Ames, E. P., & Lichter, J. (2013). Gadids and alewives: structure within complexity in the Gulf of Maine. *Fisheries Research, 141*, 70-78. https://doi.org/10.1016/j.fishres.2012.09.011

The collapse of Atlantic cod (Gadus morhua) along the northern 240 km of New England's historically productive coastal shelf has continued for nearly twenty years. Resident spawning groups and their subpopulations have disappeared and have yet to recover, causing local groundfish fisheries to collapse. Three additional gadid species, haddock (Melanogrammus aeglefinus), pollock (Pollachius virens), and white hake (Urophyscus tenuis) collapsed along the northern coastal shelf during the same period, raising concerns that their resident coastal groups were part of a metapopulation and may have also been lost. Analysis of their distribution and movements in the 1920s appeared to corroborate this. The four gadids had clusters of resident coastal groups along the coastal shelf that coexisted in the same area. Cod, white hake and pollock appeared to exhibit metapopulation characteristics, having resident and migrating components distributed along the coast in three different areas, with migrating components arriving and leaving along common migration routes fall when alewives left. The groups were centered near rivers with alewife spawning runs and disappeared from the area during the 1950s after alewives (Alosa pseudoharengus) declined locally. The results suggest that large, stable concentrations of young-of-the-year alewives were a factor in where resident and migrating gadid groups were located.

Colburn, L. L., Jepson, M., Weng, C., Seara, T., Weiss, J., & Hare, J. A. (2016). Indicators of climate change and social vulnerability in fishing dependent communities along the Eastern and Gulf Coasts of the United States. *Marine Policy, 74,* 323-333. https://doi.org/10.1016/j.marpol.2016.04.030

Changing climatic conditions are affecting the relationship between fishing communities and the marine resources they depend on. This shift will require an adaptive response on the part of policy makers and fishery managers. In the U.S., the National Oceanic and Atmospheric Administration (NOAA) established, in its fisheries agency (NOAA Fisheries), a set of social indicators of fishing community vulnerability and resilience to evaluate the impacts of changes in fishery management regimes. These indicators enhance the analytical capabilities within NOAA Fisheries for conducting fisheries social impact assessments and informing ecosystem-based fishery management. Building on the existing Community Social Vulnerability Indicators (CSVIs), new measures of climate change vulnerability are defined for the U.S. Eastern and Gulf coasts. These new indicators are used to assess the impact of sea level rise on critical commercial fishing infrastructure and the dependence of communities on species identified as vulnerable to the effects of climate change. Under the integrated vulnerability indices, white hake Urophycis tenuis climate vulnerability is listed as moderate.

Reuchlin-Hugenholtz, E., Shackell, N. L., & Hutchings, J. A. (2015). The potential for spatial distribution indices to signal thresholds in marine fish biomass. *PloS One*, *10*(3), e0120500. https://doi.org/10.1371/journal.pone.0120500

We assume that the stock areas encompass a meta-population or a series of related populations and assume minimal immigration or emigration. Spatial distribution is calculated within the same NAFO area for which the abundance metric, i.e. Spawning Stock Biomass (SSB) from DFO stock assessments, has been estimated and we correct spatial distribution metrics for differences in stratum area. SSB estimates are based on DFO stock assessment models which vary per species. The species we examine include American plaice (Hippoglossoides platessoides), cod (Gadus morhua), haddock (Melanogrammus aeglefinus), halibut (Hippoglossus hippoglossus), pollock (Pollachius virens), redfish (Sebastes spp.), silver hake (Merluccius bilinearis), white hake (Urophycis tenuis) and winter flounder (Pseudopleuronectes americanus). These species are or have been exploited commercially and have experienced large changes in SSB, increasing the likelihood of detection of a relationship between SSB and the Spatial Distribution Metric (SDM). The populations, their location, years included in each analysis, and the magnitude of SSB decline are reported. We did not apply a size threshold to the SDM, because information regarding maturity is not available for every species. Area Occupied (AO) is a measure of range. For American plaice and white hake, D90% showed a negative linear relationship with SSB; i.e. with an increase in SSB, there is a decrease in area across which 90% of the biomass is concentrated. The relationship between SSB and the Gini index was negative and linear for WSS cod, but positive and linear for American plaice and pollock, and positive and convex for white hake. According to these relationships, as WSS cod SSB increases, the population becomes more evenly distributed, whereas the American plaice, pollock and white hake populations become less evenly distributed as SSB increases. According to its convex shape, white hake experiences a relatively faster reduction of even spread as SSB increases.

Stortini, C. H., Shackell, N. L., & O'Dor, R. K. (2015). A decision-support tool to facilitate discussion of no-take boundaries for Marine Protected Areas during stakeholder consultation processes. *Journal for nature conservation*, *23*, 45-52. https://doi.org/10.1016/j.jnc.2014.07.004

More decision-support tools are needed to help stakeholders and government agencies objectively compare conservation and socio-economic trade-offs among proposed boundary options. To that end, we developed a method to identify which boundary minimizes spatial overlap of highly vulnerable species and a dominant stressor. We evaluated the vulnerability of 23 key species to bottom trawling, the most prevalent stressor in the area. We then compared the spatial overlap of the most vulnerable species and the 2002–2011 footprint of bottom trawling among boundary options. The best boundary option was identified as that which minimized spatial overlap and total area. This approach identifies boundary options which provide the greatest protection of vulnerable species from their most significant stressor, at limited socio-economic cost. It is an objective decision-support tool to help stakeholders agree on final boundaries for MPAs. The authors rated white hake (Urophycis tenuis) as a highly vulnerable species.

Section III: Fishery

The Northeast multispecies fishery is managed by the New England Fishery Management Council using a variety of management tools, including days-at-sea, special management programs, and sectors. The fishery involves numerous species of groundfish found throughout the Greater Atlantic region. The fishery is executed using primarily trawl, gillnet, and hook gear. In directed white hake fisheries, Atlantic cod, black dogfish, monkfish and other species are landed as bycatch. In turn, white hake are also caught as bycatch in gillnet, trawl and long-line fisheries directing for other species.

Implementing regulations for the groundfish in the Northeast multispecies fishery are found under *50 CFR Part 648 Subpart F—Management Measures for the NE Multispecies and Monkfish Fisheries*. Retrieved from https://www.gpo.gov/fdsys/pkg/CFR-2017-title50-vol12/xml/CFR-2017-title50-vol12-part648.xml

Committee on the Status of Endangered Wildlife in Canada (2014). *COSEWIC assessment and status report on the White Hake Urophycis tenuis in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 45 pp. http://www.registrelep-sararegistry.gc.ca/virtual_sara/files/cosewic/sr_White%20Hake_2013_e.pdf

The Atlantic and Northern Gulf of St. Lawrence population were designated as endangered in November 2013. 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. The Southern Gulf of St. Lawrence population was designated as threatened in November 2013. 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.

Historical

U.S. landings have primarily been taken in the western Gulf of Maine, both incidentally in directed fisheries for other demersal species and as an intended component in mixed-species fisheries. Since 1968, U.S. landings have accounted for approximately 90 percent of the Gulf of Maine-Georges Bank white hake catch. Canadian landings averaged 600 mt from 1977-1991, increased to 1,700 mt in 1993, but have since declined to less than 100 mt. Total landings of white hake increased from about 1,000 mt during the late 1960s to 8,300 mt in 1985 (Figure 18.2). Landings then declined to 5,100 mt in 1989, rose sharply to 9,600 mt in 1992, and have since steadily declined to levels not seen since the early 1970s. Landings of white hake subsequently increased to 4,400 mt in 2003, but declined to 3,600 mt in 2004.

Ames, E. P. (2012). White hake (Urophycis tenuis) in the Gulf of Maine: Population structure

insights from the 1920s. *Fisheries Research, 114*, 56-65. https://doi.org/10.1016/j.fishres.2011.08.007

White hake (Urophycis tenuis) provides an important fishery in the Gulf of Maine (GOM) that is currently depleted. Even though several year classes are present, there is little evidence of white hake reproduction occurring along the northern coastal shelf. Based on survey indices of early life history stages, researchers concluded that they reproduced at one of the two population centers located either from the Scotian Shelf area in eastern GOM or from the Georges Bank-Mid Atlantic Bight area. White hake have been absent from large areas of the GOM for more than 15 years and this suggests substantive changes may have occurred in their distribution since the 1920s. Various factors may have contributed to this observation, including the loss of spawning aggregations. This study examined the historical population structure of white hake in the Gulf during the 1920s, a period when stocks were more abundant. Their seasonal distribution, movement patterns and the behavior of individual population components were derived from relevant scientific literature and surveys of fishermen gathered during the period. The study identified several resident groups of white hake near the coastal shelf that displayed cyclic movement patterns to fishing grounds that have been abandoned for decades. The comparison of historical distribution patterns to recent white hake surveys revealed the loss of resident white hake groups from grounds bordering the northern GOM coastal shelf that apparently were undetected spawning components. Significance of the predator–prey linkage with alewives is discussed.

Melendy, J., McClelland, G., & Hurlbut, T. (2005). Use of parasite tags in delineating stocks of white hake (Urophycis tenuis) from the southern Gulf of St. Lawrence and Cape Breton Shelf. *Fisheries Research, 76(3)*, 392-400. https://doi.org/10.1016/j.fishres.2005.07.006

Historically, the fishery for white hake was the third or fourth most important groundfish fishery in the southern Gulf of St. Lawrence with annual landings averaging 5675 t from 1960 to 1994. This fishery has been under moratorium since 1995, following its collapse in the early 1990s, and there have been no signs of stock recovery. The indices of biomass and abundance in 2002 were the lowest on record. Use of parasites as "biological tags" has often proven advantageous over traditional mark-recapture methods for studies of fish stock structure and migration. It is especially appropriate for delicate, deep water species. This approach, aside from being less costly, avoids the trauma associated with traditional tagging. Parasite markers have frequently been used for studying structures of hake. The present study was designed to complement the meristic and morphometric studies of Hurlbut and Clay (1998) by using parasite tags to examine the stock structure of white hake in the southern Gulf of St. Lawrence. In light of possible mixing of southern Gulf and Cape Breton shelf hake over-wintering along the southern slope of the Laurentian Channel, parasite tags are also used in an effort to study the discreteness of 4T and 4Vn fish. White hake are generalists feeding on whatever is abundant (Bowman et al., 2000). During the summer and fall, white hake exhibit a geographically disjunct distribution in the southern gulf (Kohler, 1971; Hurlbut and Clay, 1998; DFO, 2004). Hence, regional differences in intermediate host abundance and frequency in hake diets would intuitively manifest themselves as geographical variations in infection parameters of passively transmitted.

Stokes, K. (2013). *Report on the 56th Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC): Benchmark stock assessments for Atlantic surfclam and White hake.* Northeast Fisheries Science Center, Woods Hole,MA. https://www.st.nmfs.noaa.gov/Assets/Quality-Assurance/documents/peer-review-reports/2013/2013_03_23%20Stokes%20SARC%2056%20white%20hake%20and%20surf%20clam%20benchmark%20assessment%20review%20report.pdf

Landings (state unclear) of white hake of the order of 17,000 mt per year are reported from 1893, with a high of almost 22,000 mt in 1898. By the 1920s annual landings had reduced to the order of 10,000 per year and by the 1950/60s to 2-3,000 mt per year. Since 1964 landings have varied considerably from a low of 1,147 mt in 1967 to over 8,000 mt in 1985 and over 9,500 mt in 1992. In more recent years, landings have fluctuated in a lower range, generally less than 2,000 mt but near 3,000 mt in 2011. Catches in US waters have primarily been from the Gulf of Maine but with Massachusetts contributing high proportions in some periods, including over 80% in 2011. The majority of catches in recent decades have been by otter trawlers. Precise definition of catch history is complicated as landings are generally not of whole fish, requiring conversion using landed lengths to whole fish lengths and weights, and a mixed landings category for red hake and white hake. There is a relatively small recreational catch.

Modern

Davis, A., Hanson, J. M., Watts, H., & MacPherson, H. (2004). Local ecological knowledge and marine fisheries research: the case of white hake (Urophycis tenuis) predation on juvenile American lobster (Homarus americanus). *Canadian Journal of Fisheries and Aquatic Sciences*, *61*(7), 1191-1201. https://doi.org/10.1139/f04-070

Southern Gulf of St. Lawrence fish harvesters voiced the concern that white hake (Urophycis tenuis) were jeopardizing the recruitment of juvenile American lobster (Homarus americanus), through predation, into the commercially exploitable population. The harvesters insisted that marine science was not documenting this situation, since sampling was being conducted in the wrong places and at the wrong times of year. This paper reports on the results arising from a 2-year collaborative and interdisciplinary research project designed to examine fish harvesters' concerns. Several social research methodologies were used to identify and interview "local knowledge experts" about where and when sampling should occur. Following harvesters' advice, white hake stomachs were sampled over a 2-year period. Contrary to harvester expectations, American lobster was not found in any of the 3080 white hake stomachs sampled. Yet, harvesters' advice did result in successful sampling from within the places recommended and at the times of year specified. The research also demonstrates an interdisciplinary and collaborative approach that generates meaningful research results while incorporating marine harvester local knowledge and addressing their concerns.

Link, J. S., & Garrison, L. P. (2002). Changes in piscivory associated with fishing induced changes to the finfish community on Georges Bank. *Fisheries Research*, *55*(1-3), 71-86. https://doi.org/10.1016/S0165-7836(01)00300-9

There are many ecologically and commercially important piscivores in the Georges Bank fish community. There has been a noticeable shift in the abundance of these predators during the last four decades which is generally attributed to fishing pressure. Although many fish persist as piscivores in this system, not only has their relative abundance changed but their size composition has also changed. Both factors influence the total magnitude of piscivory by these fish. To ascertain the cascading effects of fishing on fish predation, we examined relative abundance, total stomach contents, diet composition, consumption rates, and total food consumption of fish for several species across the time period. The proportion of the diet comprised by fish for piscivores on Georges Bank has remained remarkably consistent. However, the composition of specific fish prey has changed across the time series. We assert that a major effect of intense fishing pressure is a shift in energy flow for marine ecosystems. White hake principally ate other hakes, in particular silver hake, throughout most of the time series and herring during the late 1970s and late 1990s. White hake declined on Georges Bank in recent years (Fig. 4A). The large size class was a small component of this population. This species exhibited a classic ontogenetic shift in diet towards increased piscivory (Fig. 4B), with fish comprising more than 80% of the diet for the largest size class. Total consumption generally followed white hake abundance (Fig. 4C). The large size class comprised a disproportionate amount of the total consumption. The amount of fish consumed was a large fraction of the total consumption.

Reuchlin-Hugenholtz, E., Shackell, N. L., & Hutchings, J. A. (2016). Spatial reference points for groundfish. *ICES Journal of Marine Science, 73(10)*, 2468-2478. https://doi.org/10.1093/icesjms/fsw123

We selected six stocks of five species to identify potential spatial reference points: American plaice (AP) (Hippoglossoides platessoides), (two stocks of) Atlantic cod (Gadus morhua), redfish (Sebastes spp.), silver hake (SH) (Merluccius bilinearis), and white hake (WH) (Urophycis tenuis). These stocks each exhibit positive and concave HDA xHDA x − SSB relationships (cc is significantly lower than 1), meaning that a threshold point can be detected below which the decline in SSB per unit HDA xHDA xaccelerates (Reuchlin-Hugenholtz et al., 2015). There are two additional advantages to this selection of species: they encompass considerable phylogenetic breadth and they represent taxonomic orders (Gadiformes, Scorpaeniformes, Pleuronectiformes) that support many of the world's most commercially important demersal fisheries. According to density-dependent habitat selection theory, areas of high density can be indicative of high population productivity and have positive individual fitness consequences. White hake surplus production P in year t is estimated by (2) $P_t = SSB_{t+1} - SSB_t + C_t$, SSB_t is spawning stock biomass at time t, and C_t is catch at time t. The surplus production model was fit to the catch and biomass data, using a Schaefer model based on a logistic population growth model (Quinn and Deriso, 1999). The predicted surplus production in each year in the Schaefer model is given by: (3) $\hat{P}_t = 4m\frac{SSB_t}{K} - 4m\left(\frac{SSB_t}{K}\right)^2$, where m is the maximum sustainable yield and K is the carrying capacity or equilibrium biomass in the absence of fishing (Worm et al. 2009, modified from Quinn and Deriso 1999). The parameters m and K are estimated using maximum likelihood, whereby (4) $SSB_{MSY} = 0.5K$. For other stocks, spatial reference points can be used in concert with SSB reference points, strengthening efforts to incorporate a precautionary approach to fisheries management.

Sosebee, K. (2017). "White hake." *Operational Assessment of 19 Northeast Groundfish Stocks, Updated Through 2016*. U.S. Department of Commerce, Northeast Fishery Science Center Reference Document 17-17, 142-152. https://doi.org/10.7289/V5/RD-NEFSC-17-17

This assessment of the white hake (Urophycis tenuis) stock is an operational update of the 2015 operational assessment (NEFSC 2015) and the last benchmark assessment (NEFSC 2013). Based on the previous assessment the stock was not overfished and overfishing was not occurring. This assessment updates commercial fishery catch data, research survey indices of biomass, and the ASAP assessment model and reference points through 2016. Stock projections have been updated through 2020.

Population projections for white hake are not well determined and projected biomass from the last assessment was outside the confidence bounds of the biomass estimated in the current assessment. The rebuilding deadline for this stock was 2014 and the stock is not yet rebuilt. The 2014 catches-at-age were re-estimated for landings, discards, and both surveys. The annual spring and fall age/length keys were completed and used to estimate the catches-at-age. While stock status of white hake has not changed, the stock has not rebuilt even with a very low fishing mortality. The change in the 2014 catch-at-age by using annual age/length keys resulted in a lower SSB in 2014 before additional years were added.

State of Stock: Based on this updated assessment, the white hake (Urophycis tenuis) stock is not overfished and overfishing is not occurring according to trends in the fully selected fishing mortality of white hake between 1963 and 2016 based on the 2017 assessment. Retrospective adjustments were made to the model results. Spawning stock biomass (SSB) in 2016 was estimated to be 21,276 (mt) which is 69% of the biomass target (SSBMSY proxy = 30,948; Figure 63). The 2016 fully selected fishing mortality was estimated to be 0.066 which is 36% of the overfishing threshold proxy (FMSY proxy = 0.1839; Figure 64).

Status Recommendation: Based on this updated assessment, the panel agrees with the recommendation that the white hake stock is not overfished and overfishing is not occurring. The white hake stock shows no truncation of age structure. There may be a year class (2015 Age 1) that is above average. Also, estimates of commercial landings and discards have decreased over time.

Key Sources of Uncertainty: Catch at age information is not well characterized due to possible misidentification of species in the commercial and observer data, particularly in early years, low sampling of commercial landings in some years, and sparse discard length data, particularly in early years. Since the commercial catch is aged primarily with survey age/length keys, there is considerable augmentation required, mainly for ages 5 and older. The numbers at age and mean weights at age in the catch for these ages may therefore not be well specified. White hake may move seasonally into and out of the defined stock area. There are no commercial catch at age data prior to 1989 and the catchability of older ages in the surveys is very low. This results in a large uncertainty in starting numbers at age. Since 2003, dealers have apparently been culling extra-large fish out of the large category. However, there was no market category for landings until June 2014. The length compositions are distinct from fish characterized as large and have been identified since 2011. This may bias the age composition of the landings, particularly in 2014 when 2000 of the 5000 large samples were these extra-large fish. A pooled age/length key is used for 1963-1981 and fall 2003 (second half of commercial key).

Research Needs: The panel recommends that the age structures collected by the observer program should be aged to augment the survey keys. Ages are also available from the Atlantic States Marine Fisheries Commission (ASMFC) shrimp survey and this would allow another survey to be added to the model. Otoliths are currently being collected from the sow market category and these should also be aged. The panel also recommends considering and evaluating the addition of recreational catch and discards in a future assessment. Another recommendation is to consider market categories and how landings are aggregated in the model. Finally, the longline survey should be considered for inclusion in a future assessment.

Section IV: Management

Butterworth, D.S., Rademeyer, R.A. (2013). *Preliminary statistical catch-at-age assessments of Georges Bank/Gulf of Maine white hake*. Document submitted to NEFSC white hake assessment working group meeting, Woods Hole, January 7–11, 35 pp. https://drupalupload.uct.ac.za/maram/Documents/pub/2013/White_hake.pdf

The Statistical Catch-at-Age assessments of the Georges Bank/Gulf of Maine white hake stock from GARM III are updated to include revised data, which also now extend for a further four years. With no change in methodology, an assessment based on these data results in lower spawning biomasses in absolute terms, likely in the main as a result of estimating a lesser doming effect in the commercial selectivity-at-age. As these data used are not yet fully finalized, only a preliminary investigation into refining the assessment methodology is carried out, where this involves development of a provisional new Reference case, computation of biological reference point values, and conducting a number of sensitivity tests. The aim is to advise and assist the final assessment process, and some further tests for running given finalized data are also suggested. The primary assessments run thus far suggest that the stock is currently not overfished and that overfishing is not occurring.

Butterworth, D. S., Rademeyer, R. A., Brandão, A., Geromont, H. F., & Johnston, S. J. (2014). Does selectivity matter? A fisheries management perspective. *Fisheries Research*, *158*, 194-204. https://doi.org/10.1016/j.fishres.2014.02.004

The authors' experiences in relation to the estimation of selectivity and its impact on the formulation of management advice are summarized for 14 different resources. These include instances where advice (generally in the form of a catch limit) is based on an assessment, as well as cases where a Management Procedure is developed (applying MSE) for this purpose. Relative paucity of older fish in either or both of catches or surveys is a frequent occurrence which has a number of alternative explanations, including doming in selectivity, and estimates of many biological reference points are not robust to this uncertainty. However, when the impacts of uncertainties in estimating selectivities are considered relative to those of the other uncertainties which also influence the calculation of catch limits, the former usually (although not always) seem to be of somewhat lesser importance. For the Gulf of Maine-Georges Bank white hake (Urophycis tenuis): the conventional choice was $M = 0.2\ yr^{-1}$, the log-likelihood prefers asymptotically flat commercial selectivity, but given that choice, the assessment also exhibits a strong preference for appreciably domed survey selectivity (Butterworth and Rademeyer, 2013).

He, P., Glass, C., Annala, J., Cadrin, S., La Valley, K., & Pol, M. (2012). Biology, harvesting, management and conservation of hakes. *Fisheries Research, 114*, 1. https://doi.org/10.1016/j.fishres.2011.12.007

Hakes are an important group of fish in terms of landings from fisheries as well as ecological functions. In the Northwest Atlantic, hake fisheries have been a significant component of fisheries since the 1950s. Despite their importance, they have received relatively little attention within the scientific and management communities. Many of the species in the group are considered "data-poor" species for stock assessment and ecosystem-based management. It has been a challenge to identify robust biological and management reference points for stock rebuilding, fit hake data into traditional stock models, prevent bycatch in hake fisheries and hake bycatch in other fisheries, and even identify different hake species in the field and in the market.

Helser, T. E., & Alade, L. (2012). A retrospective of the hake stocks off the Atlantic and Pacific coasts of the United States: uncertainties and challenges facing assessment and management in a complex environment. *Fisheries Research*, *114*, 2-18. https://doi.org/10.1016/j.fishres.2011.10.001

Hake stocks off the northeast and northwest coasts of the United States and Canada have been commercially exploited since the early 1950s and have been major contributors to the historic world-wide hake catches. However, these species can be contrasted in many different ways related to specific adaptations within the unique ecosystems in which they live, the diverse and changing fisheries targeting them, and the complexity of stock assessment tools and management structures that have emerged in an attempt to provide a sound scientific basis for setting catch limits. This paper takes a retrospective and contemporary look at two species, comparing and contrasting our current state of knowledge, highlighting uncertainties and identifying the complex challenges facing assessment and management.