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Northeast Multispecies Fishery Management Plan Resource Guide: Acadian redfish (Sebastes fasciatus)

Bibliography

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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 Acadian redfish, 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 Acadian redfish. The research in this area is a compilation of basic facts including diet, lifespan and habitat; as well as current research on Acadian redfish biology.

Section II – Ecology

Section two is intended to provide an overview of how Acadian redfish interacts with the environment. The citations in this area focus on how temperature, food resources and predation affect Acadian redfish.

Section III – Fishery

Section three is intended to provide an overview of the Acadian redfish fishery. It is divided into two sections: Modern and Historical. The Modern section contains both news articles and scientific publications about the current state of the Acadian redfish fishery. The Historical section contains resources on the peak of Acadian fisheries in the 1940s-80s.

Section IV – Management

Section four is intended to provide an overview of the management of the Acadian redfish fishery. It includes news articles and research concerning plans and policies intended to protect and restore the Acadian redfish population.

Sources Reviewed

Along with a web search for news items and other relevant materials the following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded, Nexis.com, ProQuest's Science and Technology, and JSTOR. Only English language materials were included. There was no date range specification in order to cover any relevant research, although priority was given to publication in the last twenty years focusing on wild populations in the Atlantic region.

Section I: Biology

Image from: https://www.fisheries.noaa.gov/species/acadian-redfish

Also known as: Atlantic redfish, ocean perch, Labrador redfish

Region: Acadian redfish are found in the Atlantic Ocean from the coast of Norway to Georges Bank. NOAA Fisheries and the New England Fishery Management Council manage a single stock in U.S. waters.

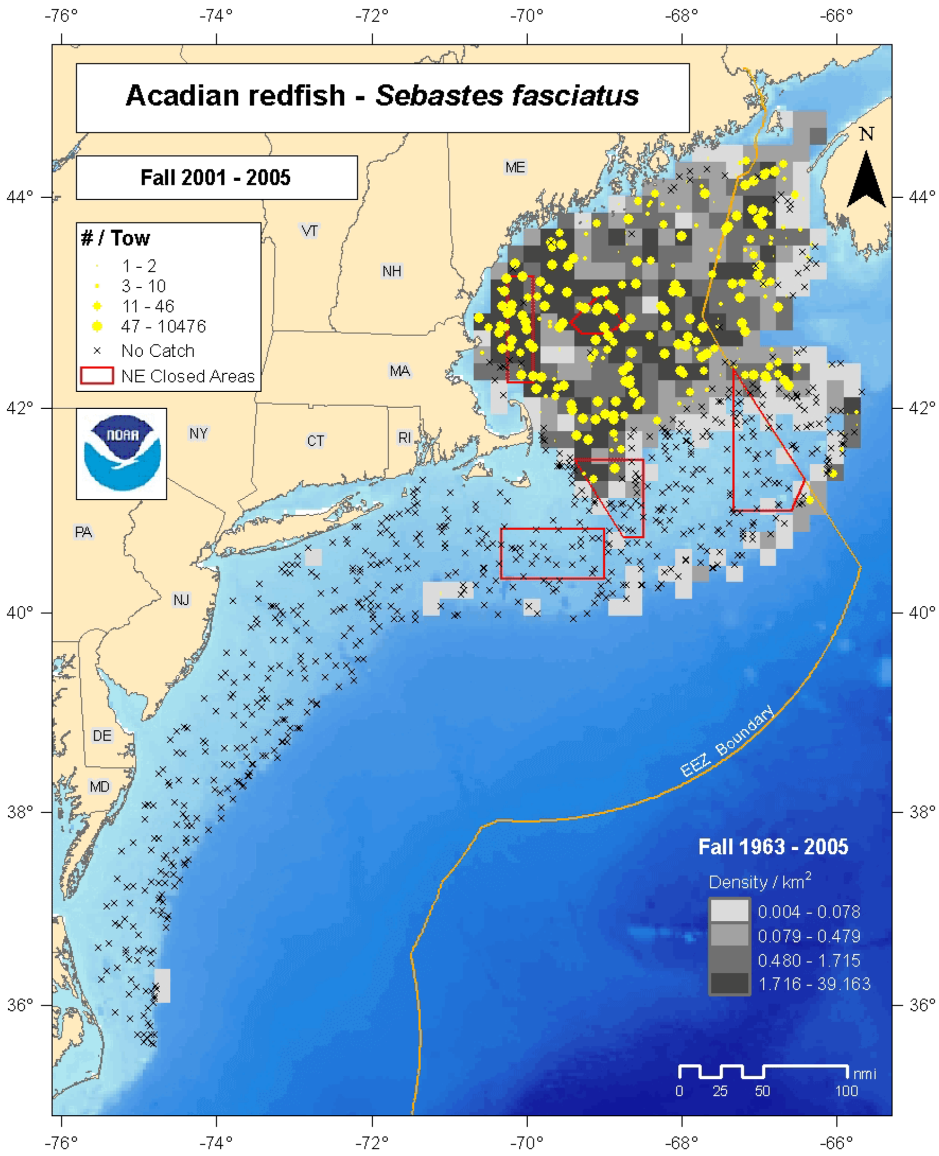
Habitat: Acadian redfish are found over rocky, mud, or clay ocean bottoms. Off New England they are most common in the deep waters of the Gulf of Maine (to depths of 975 feet). They tend to move off the bottom at night to feed and move closer to shore in the winter.
Size: Redfish can grow up to 18 to 20 inches long.

Physical description: Acadian redfish are orange to flame red, with paler underbellies. They have a flattened body that is longer than it is deep. They have large eyes and a large mouth lined with many small teeth. They have one continuous dorsal fin that runs from the nape of their neck to their caudal peduncle (where the body meets the tail) and a small tail fin. Young redfish are marked with patches of black and green pigment. They don't develop their red pigment until after they move to the ocean bottom.

Lifespan: Acadian redfish are slow-growing, long-lived fish with potential to live 50+ years. They mature at a late age (5 to 6 years) and have low reproductive rates. Redfish give birth to live young (unusual feature for fish) and newly hatched redfish can swim well at birth. Their survival rate is relatively high compared to egg-laying fish.

Diet: The diet of young redfish consists primarily of plankton and small crustaceans. Older redfish feed on larger invertebrates and small fish.

Predators: Redfish of all sizes are prey to larger piscivorous fish including goosefish, cod, pollock, and wolffish; young redfish are eaten by larger redfish and halibut.



Relative species abundance and distribution from NEFSC bottom trawl survey by time block and relative species density for the full time series.

Image from: https://www.nefsc.noaa.gov/sos/spsyn/pg/redfish/animation/fall/

Pikanowski, R.A., Morse, W.W., Berrien, P.L., Johnson, D.L., & McMillan, D.G. (1999). Essential Fish Habitat Source Document: Redfish, Sebastes spp., Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-ME-132. https://www.nefsc.noaa.gov/publications/tm/tm132/

NOAA Technical Memorandum on Acadian redfish. Redfish are a slow growing, long-lived ovoviviparous species. This document details their spawning, larval development, food habits and geographical. Acadian redfish habitats are shoal waters in the Gulf of Maine over silt, mud, or hard bottom or Scotian Shelf finer grained bottoms. It is thought that redfish may not prefer a particular bottom and use boulders and anemone for cover. Fishery exploitation began in the mid 1903s and as of the printed document was not classified as overfished.

Northeast Fisheries Science Center. (2008). Assessment of 19 Northeast Groundfish Stocks through 2007: Report of the 3rd Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 08-15; 884 p + xvii. https://www.nefsc.noaa.gov/publications/crd/crd0815/crd0815.pdf

Assessment of 19 groundfish managed under the Northeast Multispecies Fishery Management Plan. Acadian redfish is classified as not overfished and not experiencing overfishing in 2007. Data gathered on redfish assessment is displayed.

Sullivan, K. M., Duclos, K. L., Parker, S. J., & Berlinsky, D. L. (2017). Growth and Maturation of Acadian Redfish in the Gulf of Maine. *North American Journal of Fisheries Management, 37*(1), 41-49. https://doi.org/10.1080/02755947.2016.1238425

Acadian Redfish Sebastes fasciatus were captured by otter trawl from inshore and offshore sites in the Gulf of Maine. Fish weights and lengths were recorded, sagittal annuli were counted for age determination, and ovarian histology was conducted to develop ogives for length and age at maturity for females. Maximum observed ages of males and females were 25 and 37 years, respectively, but very few males greater than 21 years and females greater than 25 years of age were observed. Growth functions were significantly different between males and females, and similar growth rates (k) but higher maximum length (L-infinity) and lower t(0) values were observed in females. Mature female Acadian Redfish ranged in length and age from 17 to 39 cm and from 4 to 37 years, respectively, attaining 100% maturity at similar to 26 cm and similar to 10 years. Median length at maturity (L-50) was 21.7 cm and median age at maturity (A(50)) was 6.6 years. Smaller, immature fish were primarily sampled from inshore locations. The results of this study were very similar to previous data from a depleted Acadian Redfish population in the Gulf of Maine from 1975 to 1980, suggesting that these population parameters have not changed despite population recovery.

Campana, S. E., Valentin, A. E., MacLellan, S. E., & Groot, J. B. (2016). Image-enhanced burnt otoliths, bomb radiocarbon and the growth dynamics of redfish (Sebastes mentella and S. fasciatus) off the eastern coast of Canada. *Marine and Freshwater Research, 67*(7), 925-936. https://doi.org/10.1071/mf15002

Many past attempts to age deep-water redfish (Sebastes mentella) and Acadian redfish (S. fasciatus) in the north-west Atlantic have been stymied by inappropriate ageing methods, the absence of age validation and the failure to differentiate among species. Herein we report substantial improvements in methods for ageing Sebastes spp. by linking the established 'crack and burn' method to modern sectioning and image-enhancement protocols. Bomb radiocarbon assays of the otolith core and monitoring of year-class progression confirmed the accuracy of the resulting age determinations to an age of 46 years. The use of microsatellite DNA to confirm species identity eliminated past confusion caused by species mixtures. Age determinations of 1252 redfish from the eastern coast of Canada demonstrated the presence of significant differences in growth rate and longevity both between the two redfish species and among populations and stocks, with a maximum observed longevity of 70 years. Even within species and stocks, an individual fish with a fork length of 38 cm could be anywhere between 15 and 50 years of age, highlighting a near cessation of somatic growth after sexual maturation. In keeping with other deep-water species, sustainable management will require more attention to the low productivity expected of redfish stocks, rather than the high initial biomass that can support short-term but high catch rates.

Saborido-Rey, F., Garabana, D., & Cervino, S. (2004). Age and growth of redfish (Sebastes marinus, S-mentella, and S-fasciatus) on the Flemish Cap (Northwest Atlantic). *Ices Journal of Marine Science, 61*(2), 231-242. https://doi.org/10.1016/j.icesjms.2003.11.003

Age determination of redfish is difficult. In this paper, the ages of Sebastes mentella on the Flemish Cap are validated by following year classes from 1991 to 2000. The criteria used for S. mentella are consistent and coherent. The growth of different year classes is described and compared, and density-dependence is demonstrated to influence the growth rate of the strong 1990 year class, growth of that year class being the slowest of those followed. The slow rate of growth prevented that year class from maturing at the anticipated age. Growth is also compared between sexes, of S. mentella, S. marinus, and S. fasciatus, revealing that females grow faster than males. Finally, growth rate is compared among species. S. marinus grows fastest and S. mentella slowest, although the influence of density-dependent growth in S. mentella needs to be taken into consideration.

Ralph K. Mayo, Jon K.T. Brodziak, Michele Thompson, Jay M. Burnett, a., & Cadrin, S. X. (2002). Biological Characteristics, Population Dynamics, and Current Status of Redfish, Sebastes fasciatus Storer, in the Gulf of Maine - Georges Bank Region. Northeast Fisheries Science Center Reference Document 02-05. https://www.nefsc.noaa.gov/publications/crd/crd0205/0205.pdf

The status of the Gulf of Maine/Georges Bank redfish (Sebastes fasciatus) stock through 2000 is reviewed, and the current status of the stock is compared on a relative basis to revised estimates MSY-based reference points. The 2001 assessment is based on several sources of information including: the age composition of USA commercial landings, Northeast Fisheries Science Center (NEFSC) spring and autumn research vessel survey data, and standardized USA commercial fishing effort data. This assessment updates the analyses presented in the 1993 assessment of the Gulf of Maine/Georges Bank redfish stock as well as that prepared in 2000 by the Northern Demersal Working Group.

Roques, S., Duchesne, P., & Bernatchez, L. (1999). Potential of microsatellites for individual assignment: the North Atlantic redfish (genus Sebastes) species complex as a case study. *Molecular Ecology, 8*(10), 1703-1717. https://doi.org/10.1046/j.1365-294x.1999.00759.x

We used the four redfish taxa (genus Sebastes) from the North Atlantic to evaluate the potential of multilocus genotype information obtained from microsatellites in assigning individuals at two different levels of group divergence. We first tested the hypothesis that microsatellites can diagnostically discriminate individual redfish from different groups. Second, we compared two different methods to quantify the effect of number of loci and likelihood stringency levels on the power of microsatellites for redfish group membership. The potential of microsatellites to discriminate individuals from different taxa was illustrated by a shared allele distance tree in which four major clusters corresponding to each taxa were defined. Concomitant with this strong discrimination, microsatellites also proved to be powerful in reclassifying specimens to the taxon of origin, using either an empirical or simulated method of estimating assignment success. By testing for the effect of both the number of loci and the level of stringency on the assignment success, we found that 95% of all specimens were still correctly reclassified with only four loci at the most commonly used criterion of log0. In contrast, the results obtained at the population level within taxa highlighted several problems of assignment that may occur at low levels of divergence. Namely, a drastic decrease of success with increasing stringency illustrated the lack of power of our set of loci. Strong discrepancy was observed between results obtained from the empirical and simulated methods. Finally, the highest assignment success was obtained when reducing the number of loci used, an observation previously reported in studies of human populations.

Section II: Ecology

Baillon, S., Hamel, J.-F., Wareham, V. E., & Mercier, A. (2012). Deep cold-water corals as nurseries for fish larvae. *Frontiers in Ecology and the Environment, 10*(7), 351-356. https://doi:10.1890/120022

As a consequence of the decline of numerous commercial fish populations, an ecosystem-based approach to fisheries management, which includes the protection of essential fish habitat (EFH), has emerged. Cold-water coral (CWC) sites are recognized as biodiversity hotspots, but numerous examples of CWC destruction and degradation as a result of anthropogenic activities are well documented. However, although functional connections between CWCs and fish stocks are suspected, based on correlative evidence, proof of any close or direct relationship identifying CWCs as EFH is still lacking. Here, we provide evidence of the utilization of CWCs by fish larvae, mainly those of redfish (Sebastes spp). In multiyear surveys, fish larvae were consistently found closely associated with five species of sea pen (Octocorallia: Pennatulacea) in April and May. Prevalence and/or yields of fish larvae varied with coral host species, depth, location, and colony size. Evidence of the role of CWCs in the early life history of some fish species provides the strongest argument yet for the categorization of CWCs as EFH in the design of management programs.

Devine, J. A., & Haedrich, R. L. (2011). The role of environmental conditions and exploitation in determining dynamics of redfish (Sebastes species) in the Northwest Atlantic. *Fisheries Oceanography, 20*(1), 66-81. https://doi.org/10.1111/j.1365-2419.2010.00566.x

The six stocks of redfish (Sebastes spp.) in the Northwest Atlantic have been fished for the past 60 years, during which time they have also experienced considerable variability in environmental conditions. Despite their close proximity and with life-history features characteristic of many deep-sea fishes (long-lived, slow-growing, late-maturing, relatively low fecundity), each redfish stock has displayed quite different dynamics. Some have been able to support apparently sustainable fisheries, whereas others have been forced to close. The causes of such differences are unclear. We used dynamic factor analysis to determine the relative impacts of exploitation (days fishing for redfish, days fishing for shrimp, days fished by all fisheries, catch in the redfish fishery, total redfish catch) and environment (North Atlantic Oscillation, surface temperature, salinity, shallow, middle, and deep bottom temperatures) on trends of abundance in each stock over the years 1960-2004. The results showed that a mix of exploitation and environmental variability, with various and different lag times, accounted for observed trends. The Gulf of St. Lawrence stock was affected most by exploitation. Flemish Cap and northern Newfoundland-Labrador stocks were mostly affected by environmental factors with longer time lags than more southerly stocks. We conclude that management of redfish must take into account individual responses to exploitation and environment over the time periods during which such factors operate, often decades or more, as opposed to the usual practice of reviewing only dynamics of the past few years. Deep-sea populations cannot be managed on the same scales as shelf fisheries.

Campana, S. E., Valentin, A., Sevigny, D. M., & Power, D. (2007). Tracking seasonal migrations of redfish (Sebastes spp.) in and around the Gulf of St. Lawrence using otolith elemental fingerprints. *Canadian Journal of Fisheries and Aquatic Sciences*, *64*(1), 6-18. https://doi.org/10.1139/f06-162

Large concentrations of beaked redfish (Sebastes mentella and Sebastes fasciatus) overwinter in the Cabot Strait and the approaches of the Gulf of St. Lawrence each year. Synoptic research vessel surveys indicate that redfish are distributed more widely in the summer than in the winter, particularly within the Gulf. Significant differences in the trace element composition of the otolith ("otolith elemental fingerprint") were observed among summer aggregations, indicating that the aggregations maintained some degree of separation while in the Gulf. Sebastes mentella and S. fasciatus were readily distinguished based on otolith elemental fingerprints. Using the elemental fingerprints of the summer samples as a natural tag, we found that S. mentella tended to move out of the Gulf in the winter. Aggregations of S. mentella found in the east during the summer were not found in our winter collections. The elemental fingerprints of S. mentella from the Saguenay Fjord were clearly distinct from redfish further east in the Gulf of St. Lawrence, indicating that this group had been separated from other redfish for much of their life. The implications of our findings extend not only to the fisheries management of redfish, but also to the extent of movement expected of deep-water fish species.

Auster, P. J. (2005). Are deep-water corals important habitats for fishes? Berlin: Springer-Verlag Berlin. *Cold-Water Corals and Ecosystems*, 747-760. https://doi.org/10.1007/3-540-27673-4_39

High densities of fishes in aggregations of deep-water corals (e.g., of the genera Primnoa, Paragorgia, Paramuricea) do not necessarily indicate that corals are important habitats in terms of population processes. Frequency dependent distribution models provide a basis for assessing the role of deep-water corals. It is necessary to understand the overall habitat-related distributions of fish species, at particular life history stages, in order to assess the particular role of corals.

Examining the landscape for ecologically equivalent habitats is one approach for assessing the importance of coral habitats. Measures of the functional equivalence of habitats are demonstrated, as an example, for sites from the Gulf of Maine on the northeast United States continental shelf. Fish census data based on surveys with a remotely operated vehicle in 2003 showed that communities in habitats dominated by dense corals and dense epifauna were functionally equivalent when compared with five other less complex habitats (e.g., boulder with sparse coral cover). Comparison of species-individual curves showed that sites with dense coral and dense epifauna habitats supported only moderate levels of fish diversity when compared with other sites. Further, density of Acadian redfish (Sebastes fasciatus) in dense coral and dense epifauna habitats, where this species was dominant, was not statistically different but was higher than an outcrop-boulder habitat with sparse epifauna (the only other site where this species was abundant). Such data suggest that coral habitats are not necessarily unique but have attributes similar to other important habitats. However, the level of their importance in the demography of fish populations and communities remains to be demonstrated. Focusing conservation efforts for deep-water corals on their perceived value to exploited species, without good demographic information on fish populations, may ultimately leave corals open to destructive fishing practices if new and contrary information emerges. Conservation efforts for corals, in the absence of explicit ties to managed fish species, might do better emphasizing the intrinsic value of corals, their slow growth, high sensitivity to disturbance, and the questionable potential for recovery.

Stransky, C., & MacLellan, S. E. (2005). Species separation and zoogeography of redfish and rockfish (genus Sebastes) by otolith shape analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, *62*(10), 2265-2276. https://doi.org/10.1139/f05-143

Interspecific otolith shape variation was investigated within the species-rich genus Sebastes (redfish, rockfish) as a tool for species separation, since morphological distinction has proven to be difficult. Otolith samples from all four North Atlantic redfish species, six commercially important rockfish species from the North Pacific, and Sebastes capensis from the South Atlantic were compared for differences in linear otolith measurements and elliptical Fourier-shape descriptors. A clear distinction between the North Atlantic and North Pacific/South Atlantic species (97% correct jackknifed classification) was achieved by univariate measurements and discriminant analysis of size-corrected Fourier descriptors. Overall species classification success was 91%, 94% within the North Pacific species and 88% within the North Atlantic samples. From the Pacific rockfish, Sebastes alutus otoliths showed the strongest affinity to the North Atlantic Sebastes. High similarity of otolith shapes of S. capensis to the North Pacific Sebastes and clear discrimination from North Atlantic species coincide with current zoogeographical and speciation theories, as well as with recently reported genetic results.

Auster, P. J., Lindholm, J., & Valentine, P. C. (2003). Variation in habitat use by juvenile Acadian redfish, Sebastes fasciatus. *Environmental Biology of Fishes, 68*(4), 381-389. https://doi.org/10.1023/B:EBFI.0000005751.30906.d5

A basic paradigm in behavioral ecology is that organisms expand their distribution as preferred sites become saturated with individuals that reduce the availability of resources (e. g., shelter, prey) on a per capita basis. Previous fish community studies at Stellwagen Bank National Marine Sanctuary have shown that juvenile Acadian redfish Sebastes fasciatus (<20 cm total length; TL) were primarily associated with boulder reefs that have deep interstices amongst the boulders; and that redfish expanded their distribution to adjacent gravel habitats when local abundance on reefs was high. Multibeam and sidescan sonar surveys in Stellwagen Basin (primarily a cohesive mud seafloor) have shown that discrete small areas of the basin floor are composed of mud draped gravel and partially buried boulders. Linear video transects using remotely operated vehicles and a video/photographic equipped grab sampler across five of these sites in 1997 showed that exposed boulders do not have crevices along their lower margins and are surrounded by dense patches of cerianthid anemones, Cerianthus borealis. These anemone patches are not present on the surrounding mud seafloor. Video image data showed that late juvenile redfish (11-20 cm TL) occurred on boulder reefs as well as in the dense cerianthid patches but not on unstructured mud habitat (without cerianthid anemones). Comparisons of boulder reef and cerianthid habitats in 1998 showed that early demersal phase (0-year) redfish (0-10 cm TL) occurred only on reefs but late juveniles occurred both on the reefs and in dense cerianthid habitats. Adult size classes (>20 cm TL) also occurred in dense cerianthid habitats. Two explanations for these distributions can be advanced. The simplest is that redfish use both boulder and cerianthid habitats on an encounter basis, regardless of habitat saturation or predation pressure. Alternatively, boulder reefs serve as recruitment habitats and cerianthid habitats serve as a conduit for redfish moving away from saturated boulder reef sites, essentially serving as elements of a 'redfish pump'.

Roques, S., Sevigny, J. M., & Bernatchez, L. (2001). Evidence for broadscale introgressive hybridization between two redfish (genus Sebastes) in the North-west Atlantic: a rare marine example. *Molecular Ecology, 10*(1), 149-165. https://doi.org/10.1046/j.1365-294X.2001.01195.x

The evolutionary importance of introgressive hybridization has long been recognized by plant evolutionists, and there is now a growing recognition for its potential role in animals as well. Detailed empirical investigations of this evolutionary process, however, are still lacking in many animal groups, particularly in the marine environment. Using integrated microsatellite DNA data (eight loci analysed over 803 individuals representing 17 sampling locations) and multivariate statistical procedures (principal component, factorial correspondence and admixture proportion analyses), we: (i) provide a detailed dissection of the dynamics of introgressive hybridization between Sebastes fasciatus and S. mentella, two economically important redfishes from the North-west Atlantic; and (ii) infer the factors potentially involved in the maintenance of the hybrid zone observed in the gulf of St. Lawrence and south of Newfoundland. This study provided one of the rare examples of extensive introgressive hybridization in the ocean, and highlighted the predominant role of this process in shaping the extent of genetic diversity, interspecific differences and population structuring among redfishes from the North-west Atlantic. The extensive (average rate of introgression = 15%) but geographically circumscribed and asymmetrical pattern of introgressive hybridization, the sympatric persistence of two reproductively isolated introgressed groups, the differential patterns of linkage disequilibrium among samples, and the maintenance of genetic integrity of both species outside the defined zone of introgression despite high potential for gene flow, all implicated selection in promoting and maintaining the observed pattern of introgression.

Sevigny, J. M., Gagne, P., de Lafontaine, Y., & Dodson, J. (2000). Identification and distribution of larvae of redfish (Sebastes fasciatus and S-mentella : Scorpaenidae) in the Gulf of St. Lawrence. Fishery Bulletin, 98(2), 375-388. https://spo.nmfs.noaa.gov/sites/default/files/13_2.pdf

Genetic variation at the liver MDH* locus was used to describe the species composition and the geographic distribution of the larvae of the two redfish species, (Sebastes mentella and S. fasciatus) in the Gulf of St. Lawrence in 1991 and 1992. In both years, redfish larvae were more abundant at the junction of the Laurentian and the Esquiman Channels than in other areas surveyed. Electrophoretic analysis of 697 larvae in 1991 and 1041 in 1992 showed that larvae of both species were present in the Gulf during the two years of the study although in very different proportion. Larvae belonging to the genotype MDH*A1A1 (S. mentella) represented at least 61% of the redfish larvae collected in the Gulf in 1991 and 77% in 1992. Strong spatial heterogeneity in the frequency of the two MDH* alleles was observed; a higher proportion of S. mentella occurred in the central and deeper part of the channels and a higher proportion of S. fasciatus in shallower zones. Larvae of the genotype MDH*A1A1 (S. mentella) were significantly larger than those of the genotype MDH*A2A2 (S. fasciatus) for both years of the study, suggesting that the extrusion times differ between the two redfish species. The sizes and geographic distributions of the heterozygous larvae (MDH*A1A2) did not differ from those of S. mentella (MDH*A1A1).

Moran, J. D. W., Arthur, J. R., & Burt, M. D. B. (1996). Parasites of sharp-beaked redfishes (Sebastes fasciatus and Sebastes mentella) collected from the Gulf of St Lawrence, Canada. Canadian *Journal of Fisheries and Aquatic Sciences, 53*(8), 1821-1826. https://doi.org/10.1139/cjfas-53-8-1821

Twenty-three parasite taxa were identified from 100 sharp-beaked redfishes (50 Sebastes fasciatus and 50 Sebastes mentella) collected in the Gulf of St. Lawrence (August 1992), including 2 Coccidia, 2 Myxosporea, 9 Digenea, 2 Cestoda, 4 Nematoda, 1 Acanthocephala, and 3 Crustacea. New host records are reported for Sebastes fasciatus (Eimeriida gen.sp., Myxidium incurvatum, Brachyphallus crenatus, Gonocerca sp., and Lafystius morhuanas) and for Sebastes mentella (Crepidostomum sp. and Neoechinorhynchus rutili). The parasite faunas of the two redfishes were comparable in species diversity, 20 taxa being identified from Sebastes fasciatus and 18 from Sebastes mentella. Prevalence of M. incurvatum and abundances of Derogenes varicus, Podocotyle reflexa, Anisakinae gen.sp. larva, Contracaecinea gen.sp. larva, Hysterothylacium aduncum larva, and Chondracanthus nodosus were greater in Sebastes fasciatus, while only Sphyrion lumpi was more abundant in Sebastes mentella. The parasitic copepods Chondracanthus nodosus and Sphyrion lumpi show potential as biological tags for the identification of redfish species.

Section III: Fisheries

History: Acadian redfish came to the attention of fisheries in the 1930s and commercially viable due to recent freezing techniques enabling widespread distribution. They remained a steady source throughout the 40s and 50s with farther afield fishing, peaking at 56,000 metric tons in 1942. Declines of redfish as a fishery began shortly after, but did not become drastic until the early 80s when the population became relatively exhausted and overall annual catch numbers did not reach over 1,000 metric tons.

Modern: Declared rebuilt in 2012**,** the Acadian redfish fishery is making a slow comeback working with sector management to responsibly and sustainably fish the target population.

Sources: Mayo, R., Col, L., Traver, M. (2006) Acadian Redfish. https://www.nefsc.noaa.gov/sos/spsyn/pg/redfish/archives/03_AcadianRedfish_2006.pdf

Duplisea, D. E. (2018). Fishermen's Historical Knowledge Leads to a Re-Evaluation of Redfish Catch. *Marine and Coastal Fisheries, 10*(1), 3-11. https://doi.org/10.1002/mcf2.10006

A series of interviews with Canadian redfish Sebastes spp. fishing industry participants active in the 1980s and 1990s was conducted to determine how fish were caught, how much was caught (reported landings, unreported landings, and discards), and the sizes of fish caught during that time. Indicators of total fish catch derived from these interviews showed that reported catch may have underestimated catch by a factor of 2 or more. The proportion of small fish landed may also have been underestimated by a factor of 150–200. The re-examination of catches from interviews with fishermen can provide a useful context for interpreting population model abundance estimates for this stock. This interpretation can have implications for present-day stock assessment and fishery advice.

"Maine Fisherman Wants To Revive Redfish Fishery." (November 27, 2012). *New England Boating.* http://newenglandboating.com/maine-fishermen-wants-to-revive-redfish-fishery/

Interview with Capt. Terry Alexander which discusses working with NOAA and sector fishing for a redfish revival.

Lindsay, J. (November 14, 2010). "Fishermen, industry swarm around Acadian redfish, hoping to revive a once-robust market", *Associated Press*. https://redfishrednet.weebly.com/rednet-in-the-news.html

News article on reviving the redfish fishery which features the redfish cooperative research project, REDNET, funded by the Northeast Fisheries Science Center Cooperative Research Program, and began as a way to address the feasibility/viability a redfish trawl fishery in the Gulf of Maine through a cooperative and integrated network approach.

Pol, M. V., Herrmann, B., Rillahan, C., & He, P. G. (2016). Impact of codend mesh sizes on selectivity and retention of Acadian redfish Sebastes fasciatus in the Gulf of Maine trawl fishery. *Fisheries Research, 184*, 54-63. https://doi.org/10.1016/j.fishres.2016.06.013

A trouser trawl was used to determine the size selectivity of three sizes of mesh opening (114, 140 and 165 mm double 5 mm twine diamond) on a commercial fishing vessel fishing off Provincetown, Massachusetts, USA. Fifty-six tows were completed in March and April 2013, catching over 42,000 kg of Acadian redfish (Sebastes fasciatus) and about 6000 kg of other species. Robust models for the mean L50s and selection ranges, and confidence intervals, were developed for all three tested codends, incorporating both within and between haul variability. L50 and selection ranges were determined for the nominal 114mm (L50:22.3 cm; SR:3.3 cm), 139 mm (L50:29.2 cm; SR:4.4 cm), and 165 mm (L50:33.6 cm; SR:5.0 cm) codends. All measures of model validity were positive. These models are fully adequate to provide guidance to managers and fishermen on size retention of redfish and appropriate codend mesh size. Additionally; simulation of fishing of the three tested codends on the observed population indicated that substantial escape of redfish through codend meshes occurs (51-96%), suggesting that investigation of escape of redfish is warranted to support a sustainable fishery. The observed population also indicates that inadequate numbers of larger redfish may be available to support a higher-priced market.

Kelly, G. F. (1964). Some Recent Redfish (Sebastes) Publications. [ICES/ICNAF Redfish Symposium]. *Copeia, 1964*(2), 460-464. https://doi.org/10.2307/1441053

Review of the ICES/ICNAF Redfish Symposium of 1959 and subsequent publications concerning the fishing, biology, and distribution of redfish across the Atlantic.

Section IV: Management

He, P., Rillahan, C., & Balzano, V. (2015). Reduced herding of flounders by floating bridles: application in Gulf of Maine Northern shrimp trawls to reduce bycatch. *Ices Journal of Marine Science, 72*(5), 1514-1524. http://dx.doi.org/10.1093/icesjms/fsu235

We hypothesized that a floating trawl bridle that does not contact the seabed would reduce the herding of fish, especially bottom dwelling flounders, and thus reduce bycatch of these fish in shrimp trawls. We further hypothesized that, due to the non-herding nature of northern shrimp (Pandalus borealis), the use of an off-bottom floating bridle would not reduce shrimp catch. These hypotheses were tested in the field by comparing a trawl with regular bottom-tendering wire bridles and the same trawl with floating synthetic bridles in the Gulf of Maine northern shrimp fishery. As expected, no statistically significant differences in catch rates and size were found for the targeted northern shrimp (146.3 plus or minus 10.58 kg h super(-1) control vs. 140.8 plus or minus 9.35 kg h super(-1), p = 0.13). Total finfish bycatch was reduced by 14.9%, and the difference was statistically different (p = 0.01). The most important reduction was the catch of juvenile American plaice (Hippoglossoides platessoides) with a significant reduction of 20.0% (p = 0.01). For witch flounder (Glyptocephalus cynoglossus), a reduction of 19.3% was found, but it was not statistically significant (p = 0.14). The reduction of Acadian redfish (Sebastes fasciatus) (by 28.0%, p = 0.02) was also statistically different. Catch of targeted silver hake (Merluccius bilinearis) was reduced by 10.8%, but the difference was only marginally significant (p = 0.07). An analysis of length frequencies for the targeted shrimp and major bycatch species revealed no size-related selection between the gears with regular bridles and floating bridles. The reductions in flounder bycatch indicate reduced herding of benthic species when the bridles are kept off bottom. This easy modification may be readily adopted in the northern shrimp fisheries in the North Atlantic, and can also possibly be applied in other shrimp and prawn fisheries with further experimentation.

Simpson, A. (2015). Monterey Bay Aquarium Seafood Watch: Acadian Redfish Northwest Atlantic US Bottom Trawl. http://www.seafoodwatch.org/seafood-recommendations/groups/redfish?q=ACADIAN%20REDFISH&t=ACADIAN%20REDFISH&type=acadian

A summary report from the Monterey Bay Aquariums Seafood Watch program on the Acadian redfish, recommending as a food fish to consumers on the basis of four categories: habitat impact, management efforts, fish status (overfished or overfishing occurring) and the impact on other species.

Pavlenko, A., & Klyuev, A. (2013). Some Aspects of Possible Consequences After Decreasing a Minimal Mesh Size of Pelagic Trawls in Redfish Fishery in Divs. 3LN of the NAFO Regulatory Area. NAFO, Dartmouth, NS, Canada. http://archive.nafo.int/open/sc/2013/scr13-020.pdf

Redfish species Sebastes mentella and Sebastes fasciatus from Divs. 3LN which are fished out by both bottom and pelagic trawls with minimal 130 mesh inside size are related to the important fishery objects in the NAFO Regulatory Area. The paper shows that due to the mismatch of the minimal (130 mm) mesh size and the average mature redfish size a greater part of catch is lost; when hauling trawl to the surface the most part of redfish escape from codend. In accordance with principles of precautionary approach, it should be considered that all the fish escaping at this stage of hauling die because of the traumas and predators, increasing the unaccounted fishing mortality by this. Approximately, the effect of selectivity as a result of using the minimal 130 mm mesh size to regulate the pelagic fishery of redfish in Div.3N is 4-5% of the increase in catch size composition in relation to the stock size composition. This effect may be considered as minor because of small modal length in the stock size composition of the redfish studied. According to the preliminary estimation, the minimal 130 mm mesh size applied to regulate fishing of Sebastes mentella and Sebastes fasciatus from Divs. 3LN is highly great for selectivity of these redfish species and a reason of their higher unaccounted fishing mortality that has an extremely negative effect on their stock status. The specific composition of catches by pelagic trawl showed that diminishing minimal mesh size during the redfish pelagic fishery had no impact on bottom fish species since they were not taken by the pelagic trawl.

Brodziak, J., Cadrin, S. X., Legault, C. M., & Murawski, S. A. (2008). Goals and strategies for rebuilding New England groundfish stocks. *Fisheries Research, 94*(3), 355-366. https://doi.org/10.1016/j.fishres.2008.03.008

Rebuilding depleted fishery resources is a worldwide problem. In the U.S., the Magnuson Stevens Fishery Conservation and Management Reauthorization Act (MSRA) of 2007 requires that "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery…". However, translating this legal mandate into tangible goals and actions presents several technical challenges, especially for resources that have been chronically over-exploited. For example, maximum sustainable yields and biomass reference points are poorly estimated for stocks that have been overfished for a long period of time and are poorly defined unless sufficient data are available from periods of low-fishing mortality rates and relatively high-stock sizes. The conundrum of how to set meaningful rebuilding goals given limited information on the population dynamics and trophic interactions of a rebuilt stock can generally be addressed through adaptive management procedures incorporating learning about density-dependent population dynamics. Monitoring changes in life history parameters and recruitment is critical for successful rebuilding strategies realizing the full yield potential of rebuilt stocks while periodic re-evaluation of rebuilding targets is also needed to address uncertainties due to density dependence, trophic interactions or environmental factors. This paper summarizes the development and implementation of goals and strategies to rebuild New England groundfish stocks over the past decade. Management is particularly challenging because the true yield and population

size potentials of these interacting stocks is unknown due to chronic overfishing throughout the modern history of the fishery, uncertainty in compensatory/depensatory population dynamics and in the degree of stationarity in environmental control of groundfish recruitment.

Moore, J. A. (1999). Deep-sea Finfish Fisheries: Lessons from History. *Fisheries, 24*(7), 16-21. https://doi:10.1577/1548-8446(1999)024<0016:DFFLFH>2.0.CO;2

Recently, the depletion and increased regulation of shallow-water fishery resources have generated greater interest in the potential of deepwater fisheries. Smaller-scale fisheries for deep-sea animals have been conducted in certain locations around the world for more than a century, but large-scale commercial deepwater fisheries are a more recent phenomenon. An examination of past and current deepwater fisheries shows what we can expect from the development of new fisheries targeting unexploited deep-sea resources. Previous deepwater fisheries exhibit a pattern of rapid development, depletion of the resource, and very slow recovery. If future deepwater fisheries are to avoid this fate, development of new fisheries will require a better understanding of the resource, its relationship to the environment, and a precautionary approach to resource management.