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Northeast Multispecies Fishery Management Plan Resource Guide: Yellowtail Flounder (Limanda ferruginea)

Bibliography

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Background & Scope

The Northeast Multispecies Fishery Management Plan 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 Yellowtail flounder, 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 Yellowtail flounder. The research in this area is a compilation of basic facts including diet, lifespan and habitat as well as current research on Yellowtail flounder Biology.

Section II – Ecology

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

Section III – Fishery

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

Section IV – Management

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

Sources Reviewed

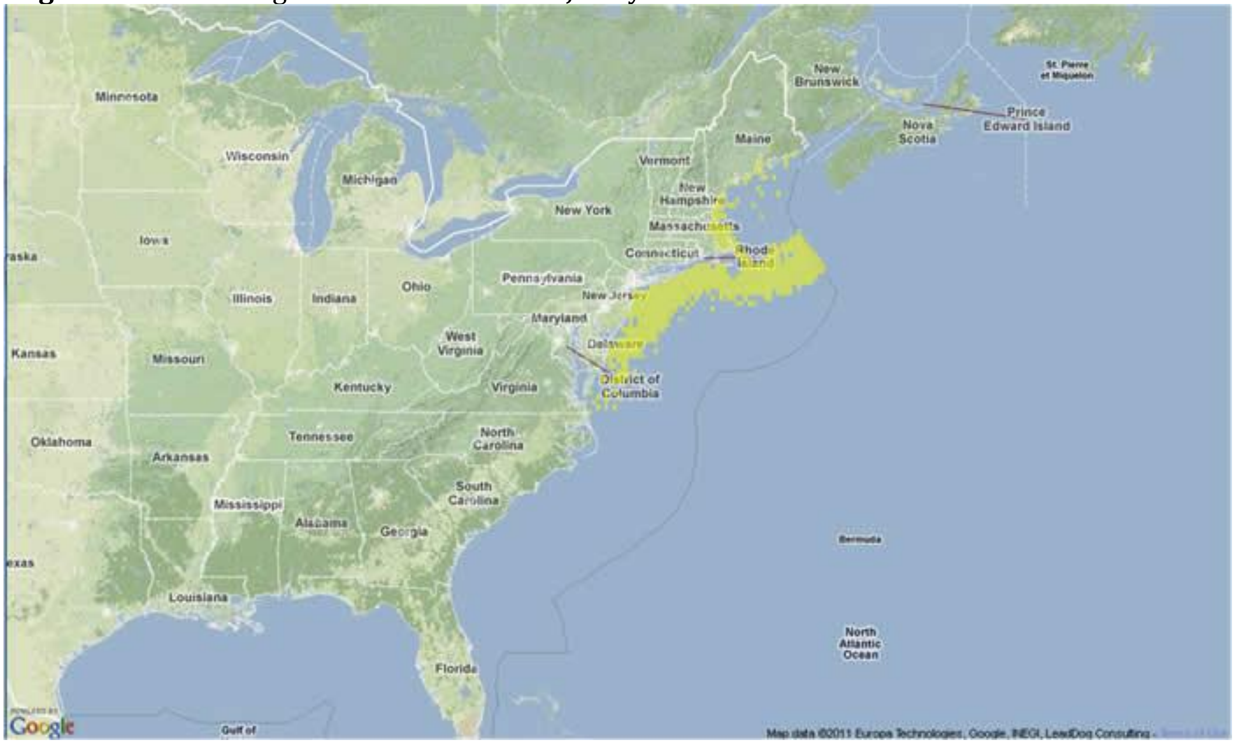
In addition to web searches the following databases were searched to identify relevant literature: Clarivate Analytics' Web of Science Science Citation Index Expanded, ProQuest Science and Technology, JSTOR, and Lexis Advance. Only English language materials were included. Priority was given to publications focusing on wild populations in the Atlantic region and relevant yellowtail aquaculture research was included.

Section I: Biology

Image from http://www.fishwatch.gov/profiles/yellowtail-flounder

Also known as: Flounder; Rusty dab

Region: U.S. wild-caught from Maine to New Jersey.



http://www.fishwatch.gov/profiles/yellowtail-flounder

Habitat: Yellowtail flounder are relatively sedentary. They live on sandy bottoms in waters between 130 and 230 feet deep

Size: Yellowtail flounder grow faster than most flatfish, up to 22 inches and 2.2 pounds.

Physical Description: Yellowtail flounder is a thin-bodied, right-eyed flounder. They are wide – nearly half as broad as they are long – with an oval body. They have a small mouth and an arched lateral line. Their upper side, including the fins, is brownish or olive, tinged with red and marked with large, irregular rusty red spots. True to their name, their tail fin and the edges of the two long fins are yellow. The underside is white, except for the caudal peduncle (the area between the body and the tail), which is yellowish.

Lifespan: They can live up to 17 years, although most don't live past age 7. They also mature earlier than most flatfish. Almost all females are able to reproduce by the time they reach age 3.

Reproduction: They spawn during the spring and summer. Females deposit their eggs on the ocean floor. After the eggs are fertilized, they float to the surface and the larvae drift in surface waters for about 2 months. When yellowtail flounder are first hatched, their eyes are symmetrical, with an eye on each side of their head. As the fish grows, it flattens out and the left eye slowly moves over to the right side of its head. After this metamorphosis, the juvenile settles to the ocean bottom.

Diet: Juvenile yellowtail flounder mostly eat worms. Adults feed on crustaceans and worms.

Predators: Spiny dogfish, skate, and a number of fish such as cod, hakes, flounder, and monkfish.

Source: NOAA. (10/24/2017). FishWatch U.S. seafood facts: Yellowtail flounder. Retrieved from http://www.fishwatch.gov/profiles/yellowtail-flounder

Avery, T. S., Boyce, D., & Brown, J. A. (2004). Mortality of yellowtail flounder, Limanda ferruginea (Storer), eggs: effects of temperature and hormone-induced ovulation. *Aquaculture*, *230*(1), 297-311. https://doi.org/10.1016/j.aquaculture.2003.09.028

Yellowtail flounder, Limanda ferruginea (Storer, 1839), is a highly marketable fish species that used to be a significant groundfish in the northwest Atlantic region. The potential of yellowtail flounder for mass rearing has recently been investigated, but studies into aspects of mortality during early ontogeny are lacking. We investigated the impact of spawning inducement on mortality of eggs from fertilization until hatch, and the effects of rearing temperature on mortality and hatching time in this multiple batch spawning flounder. An ash-free dry mass (AFDM) technique for determining mortality was employed. This technique reduced rearing tank disturbances and provided quantitative mortality estimates. We found (1) that spontaneously ovulated (SO) mean egg mass (AFDM 24.84F0.73 Ag) was significantly higher than mean egg mass from induced ovulation (IO) (AFDM 20.09F0.54 Ag); (2) that mortality of SO eggs was lower than IO eggs (p = 0.028), (3) that SO eggs reached a relatively constant (maximum) mortality by about day 3 and IO eggs by about day 5; (4) that there was no significant difference in mortality between eggs incubated at 10 jC and those incubated at 4 jC (p = 0.320); and (5) that time to 100% hatch took significantly longer for eggs incubated at 4 jC (256.0F73.5 h) than those incubated at 10 jC (77.9F11.6 h) (p = 0.003). There was considerable variation in egg mortality among batches and females; nevertheless, general trends indicate that GnRHa-induction of ovulation tends to decrease egg quality. In addition, the AFDM technique was an easily employed and accurate method of determining mortality. We recommend that unless coordination of spawning is important to a particular rearing protocol, induced ovulation should not be employed.

Dwyer, K. S., Brown, J. A., Parrish, C., & Lall, S. P. (2002). Feeding frequency affects food consumption, feeding pattern and growth of juvenile yellowtail flounder (Limanda ferruginea). *Aquaculture*, *213*(1), 279-292. https://doi.org/10.1016/S0044-8486(02)00224-7

Feeding experiments were carried out on juvenile yellowtail flounder (*Limanda ferruginea*) (6.8±0.2 g), a candidate for cold-water aquaculture in eastern North America. At about 7 °C, feeding frequency was shown to have a significant ($P<0.05$) effect on food consumption and growth, with fish fed to apparent satiation in two or four daily meals consuming more food and growing better than fish fed less often (once daily and two meals every other day). Fish fed two meals every other day ate significantly more ($P<0.05$) in the morning (8.4±0.4 mg) than in the afternoon (6.0±0.2 mg), whereas there were no differences in meal sizes between feedings for other groups. Behavioral observations revealed that fish fed fewer meals per day ingested more pellets per feeding (1.1±0.1 vs. 0.7±0.1 pellet/min), showed more activity and foraged more often throughout the day than fish fed four times daily or twice daily (3.5±0.3 vs. 2.1±0.2 behavior/min). Low incidences of aggression indicated that yellowtail flounder probably do not form feeding hierarchies; however fish fed twice daily showed a significant increase in the coefficient of variation (CV) for body weight over the course of the experiment ($P<0.05$). Fish fed twice daily gained significantly more weight ($P<0.05$) and had the lowest FCR (0.89), thus it is recommended that fish at this stage of grow-out be fed twice per day.

Manning, A. J., Burton, M. P., & Crim, L. W. (2004). Reproductive evaluation of triploid yellowtail flounder, Limanda ferruginea (Storer). *Aquaculture*, *242*(1), 625-640. https://doi.org/10.1016/j.aquaculture.2004.06.012

The reproductive effects of induced triploidy were assessed in 3-year-old yellowtail flounder. Diploids of this small flatfish show a propensity for early sexual maturation in culture. Triploidy was effective in reducing gonadal development in yellowtail flounder, but permitted physiological maturation in both sexes. Triploid males sampled during the regular spawning period in captivity had small testes and variable plasma androgen levels ($n=7$; age, 34 months). A limited production of spermatozoa and evidence of spermatogenetic dysfunction were noted histologically. Spermatozoa from triploids exhibited poor or no motility and further demonstrated reduced fertility in fertilization trials with eggs from diploid females. Most larvae resulting from fertilization trials were abnormal and nonviable; however, some triploid males produced a few larvae of normal appearance which may indicate long-term viability. Females sampled at 37 and 40 months of age had small ovaries with varying numbers of oocytes, previtellogenic to vitellogenic, that were developing amid oogonial tissue (oog). Evidence of prior summer ovulatory activity was found in 2 of the 17 females. A high proportion of the remaining 3-year-old females had vitellogenic oocytes and was likely to become fully mature by 4 years of age. Plasma estradiol-17β (E_2) levels were low in triploid females despite the fact that ovarian tissue from pubertal triploids can demonstrate a strong steroidogenic response to gonadotropic stimulation in vitro. The production of triploids will help to reduce the energetic costs of reproduction in the yellowtail flounder.

Manning, A. J., Burton, M. P., & Crim, L. W. (2008). The timing of puberty in cultured female yellowtail flounder, Limanda ferruginea (Storer): oogenesis and sex steroid production in vivo and in vitro. *Aquaculture*, *279*(1), 188-196. https://doi.org/10.1016/j.aquaculture.2008.03.059

This study examines puberty in female yellowtail flounder, correlating macroscopic, histological and endocrine parameters at the gonadal level. Short-term ovarian tissue incubations were used to study estradiol-17β production in relation to oogenic stage. Examining 2 year classes of young flounder demonstrated that cultured females retain phenotypic plasticity in reproductive age with pubertal onset occurring in one-year, two-year and three-year-olds. Immature ovaries were steroidogenic and capable of responding to gonadotropic stimulation. Endocrine puberty in females was detected by a peak in estradiol-17β production during the cortical alveolar oocyte stage prior to any ovarian evidence of vitellogenesis. Puberty, once initiated, proceeded to ovulation within 8 to 12 months; vitellogenic oocyte development followed the group synchronous pattern. Estradiol-17β was clearly the dominant of the two measured plasma hormones during pubertal onset and throughout vitellogenesis. Plasma testosterone was consistently detectable at low levels by mid-to late-vitellogenesis. Ovaries showed the highest sensitivity to gonadotropic stimulation *in vitro* during late-vitellogenesis. Variable plasma levels in both estradiol-17β and testosterone occurred in preovulatory and ovulating females during the captive spawning period. Together the results show that yellowtail flounder can mature at a young age and small size when culture conditions permit. In addition, the early sensitivity to gonadotropin by the immature ovaries may be an important physiological determinant for the timing of puberty in this species.

Puvanendran, V., Boyce, D. L., & Brown, J. A. (2003). Food ration requirements of 0+ yellowtail flounder Limanda ferruginea (Storer) juveniles. *Aquaculture*, *220*(1), 459-475. https://doi.org/10.1016/S0044-8486(02)00620-8

Several studies have shown that food ration can affect the growth of cultured fish. Determining the optimal food ration would help to achieve better growth and also provide direct economic benefits due to reduced food wastage, which would lead to commercial success. Therefore, we studied the effects of ration levels on growth performance of 0^+ juvenile yellowtail flounder to determine the optimal food ration. Two experiments were conducted; the first experiment as a preliminary using ration levels of 1%, 2%, 4%, 6% body weight per day (% bw day^{-1}) held at 7.0 °C with a stocking density of 0.95 kg m^{-2} (∼45% bottom coverage). Results of this preliminary experiment indicated that fish fed with 1% bw day^{-1} had significantly lower growth (weight, length, body depth and specific growth rates (SGR)) than those fed with 2%, 4% and 6% ration. However, fish fed with rations of 1% and 2% showed significantly lower gross food conversion ratios (GFCR) than fish fed with 4% and 6% rations. Survival was not significantly affected by different ration levels. Based on these preliminary results, we used ration levels of 1%, 1.5%, 2% and 3% for the main experiment. Fish were held at 10 °C with a stocking density of 1.45 kg m^{-2} (∼34% bottom coverage). Results indicated that fish fed with 1%, 1.5% and 2% bw day^{-1} had significantly lower growth than fish fed with 3% bw day^{-1}. GFCR was significantly different for all four rations. It was lower for 1% than 1.5%, 2% and 3% rations. Survival was not significantly different between any treatments. We discuss our results with emphasis on growth and economics (i.e., feed wastage) and stress the need to balance both components in a commercial operation.

Section II: Ecology

Benoit, H. P., & Pepin, P. (1999). Interaction of rearing temperature and maternal influence on egg development rates and larval size at hatch in yellowtail flounder. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*(5), 785-794. https://doi.org/10.1139/f98-213

We assessed the extent to which temperature interacts with maternal contributions to egg size to affect development time and size of yellowtail flounder (*Pleuronectes ferrugineus*) larvae at hatch. Maternal effects contributed significantly to differences in egg sizes produced by four females. Eggs from each female were incubated at five temperatures. Development time was most significantly affected by temperature, and female effects were minimal. However, the variance in development time within a population was significantly affected by an interaction between female and temperature effects. Average length at hatch varied significantly among temperatures and females, as did the variance in hatching length within a population. Variance in hatching length explained by maternal effects peaked at intermediate temperatures (-38% explained variance at 7°C), while variance explained by covariation with development time increased linearly with temperature, explaining -40% variance at 13°C. Overall, the nonadditive interaction between maternal contributions and the environment suggests that female effects must be considered over the entire range of environmental conditions experienced by their progeny. In addition, our results support the idea that it is inappropriate to quantify female effects among eggs and extrapolate these differences to larvae.

Brodie, W. B., Walsh, S. J., & Atkinson, D. B. (1998). The effect of stock abundance on range contraction of yellowtail flounder on the Grand Bank of Newfoundland in the Northwest Atlantic from 1975 to 1995. *J. Sea Res*, *39*, 139-152. https://doi.org/10.1016/S1385-1101(97)00056-7

Research vessel surveys showed that yellowtail flounder (*Pleuronectes ferruginea*) on the Grand Bank, off Newfoundland in the Northwest Atlantic, declined in abundance between the 1970s and the mid 1990s. The northern limit of distribution decreased substantially in the late 1980s and early 1990s, coincident with large declines in population abundance and a decrease in bottom water temperatures. This range contraction continued into the mid 1990s, despite a stabilization of the population size and a reversal of the cooling trend. In 1995, this species was rarely found on the northern Grand Bank. The area west of the Southeast Shoal on the southern Grand Bank had relatively high densities of yellowtail flounder throughout the period studied. The area occupied by the stock was positively correlated with stock abundance from surveys, but not with bottom temperatures from these same surveys. We conclude that the contraction in the area of distribution for this stock to the preferred habitat around the Southeast Shoal is primarily a function of low stock size, which resulted from increased fishing activity in the mid to late 1980s.

Cadrin, S. X. (2010). Interdisciplinary analysis of yellowtail flounder stock structure off New England. Reviews in Fisheries Science, 18(3), 281-299. https://doi.org/10.1080/10641262.2010.506251

An interdisciplinary study considering geographic patterns of abundance, geographic variation, and movement suggests that yellowtail flounder, Limanda ferruginea, on the principal U.S. fishing grounds should be managed as three separate stocks despite apparent homogeneity of genetic variation. Divergent patterns of abundance and biomass over time suggest two harvest stocks of yellowtail flounder with a boundary on southwest Georges Bank. Geographic patterns of growth and maturity indicate two phenotypic stocks of yellowtail flounder, with a boundary on northern Georges Bank. Yellowtail flounder resources off the U.S. may be a single genetic stock, but significant variation in life history attributes and different patterns of abundance over time suggest that yellowtail flounder off the northeastern U.S. should be managed as three stocks: Cape Cod-Gulf of Maine, Georges Bank, and southern New England-Mid Atlantic.

Cowen, L., Walsh, S. J., Schwarz, C. J., Cadigan, N., & Morgan, J. (2009). Estimating exploitation rates of migrating yellowtail flounder (Limanda ferruginea) using multistate mark–recapture methods incorporating tag loss and variable reporting rates. *Canadian Journal of Fisheries and Aquatic Sciences*, *66*(8), 1245-1255. https://doi.org/10.1139/F09-082

Multistate mark–recapture models can be used to model migration through stratification of the study area into states (location). However, the incorporation of both tag loss and reporting rates is new to the multistate paradigm. We develop a migration model for fish that incorporates tag loss and reporting rates but has as its primary purpose the modelling of exploitation and natural mortality rates. This model is applied to a 2000–2004 yellowtail flounder (Limanda ferruginea) tagging study on the Grand Bank of Newfoundland, Canada. We found that exploitation rates varied over both location and years, ranging from 0.000 to 0.047. Migration into the centre of the Grand Bank (state 2) was three times higher than migration out. The estimate of the instantaneous annual natural mortality rate was 0.256, which is equivalent to an annual survival rate of 0.880. We describe how these mortality estimates will be quite valuable in specifying an assessment model for this stock.

Hare, J. A., Morrison, W. E., Nelson, M. W., Stachura, M. M., Teeters, E. J., Griffis, R. B., ... & Chute, A. S. (2016). A vulnerability assessment of fish and invertebrates to climate change on the Northeast US Continental Shelf. *PloS one*, *11*(2) e0146756. https://doi.org/10.1371/journal.pone.0146756

The results from this assessment can be compared with detailed studies examining past changes in fish and invertebrate species and projecting future changes. Population productivity of both the Southern New England Yellowtail Flounder and Winter Flounder stocks has decreased and these decreases have been attributed to changes in the environment. In this climate vulnerability assessment, Yellowtail Flounder was ranked as having a low vulnerability to change in population productivity. The important accomplishment of this assessment is to frame climate vulnerability for a majority of managed fish and invertebrate species in the ecosystem and for a number of unmanaged, but ecologically or commercially important species in the ecosystem.

Huntsberger, C. J., Hamlin, J. R., Smolowitz, R. J., & Smolowitz, R. M. (2017). Prevalence and description of Ichthyophonus sp. in yellowtail flounder (Limanda ferruginea) from a seasonal survey on Georges Bank. *Fisheries Research*, *194*, 60-67. https://doi.org/10.1016/j.fishres.2017.05.012

Ichthyophonus sp. is a ubiquitous parasite infecting numerous fish species. *Ichthyophonus* sp. infection of yellowtail flounder (*Limanda ferruginea*) was first identified in Canadian waters in 1968. Between 2012 and 2014, fifteen seasonal survey cruises by Coonamessett Farm Foundation, randomly sampled a total of 1325 fish for at-sea examination at fixed stations on the U.S. Georges

Bank sea scallop fishing grounds. A subsample of yellowtail flounders were examined internally on board the ship and animals with visible lesions were collected, processed, and examined histologically. Infected fish were concentrated in eastern Georges Bank with only two of the 32 infections collected from western Georges Bank. Both macroscopic and histological evaluation of tissues showed that 81.3% of the animals infected with *Ichthyophonus* sp. were severely infected.

Hyun, S. Y., Cadrin, S. X., & Roman, S. (2014). Fixed and mixed effect models for fishery data on depth distribution of Georges Bank yellowtail flounder. *Fisheries research*, *157*, 180-186. https://doi.org/10.1016/j.fishres.2014.04.010

Fishermen reported that Georges Bank yellowtail flounder (*Limanda ferruginea*) migrated to deeper waters during 2000–2004 and 2006–2010. To test this hypothesis, we analyzed fishery data from otter trawl vessels targeting a mixed groundfish complex over the 10 year period, using a statistical linear model with catch-per-unit-effort weighted depth as the response variable, and abiotic (e.g., bottom water temperature) and biotic (e.g., skate and dogfish catch) data as predictor variables. We considered mixed as well as fixed effect models to account for dependence or correlation in catches among hauls within a trip. Yellowtail flounder shifted to deeper waters during the 10 years. Bottom water temperature had a greater influence on the movement than the distribution of skate or dogfish. Optimal water temperature was about 6.8 °C from the fixed effect model and about 7.1 °C from the mixed effect model. Skate distribution affected yellowtail flounder depth more than dogfish distribution. The mixed effect model was more parsimonious than the fixed effect model, although the latter fitted the data better and performed better under cross validation.

Klein, E. S., Smith, S. L., & Kritzer, J. P. (2017). Effects of climate change on four New England groundfish species. *Reviews in Fish Biology and Fisheries*, *27*(2), 317-338. https://doi.org/10.1007/s11160-016-9444-z

We reviewed research on effects of changes in temperature, salinity, dissolved oxygen, pH, and ocean currents on pelagic life stages, post-settlement life stages, and reproduction of four species in the New England groundfish fishery: Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), winter flounder (*Pseudopleuronectes americanus*), and yellowtail flounder (*Limanda ferruginea*).

McElroy, W. D., Wuenschel, M. J., Towle, E. K., & McBride, R. S. (2016). Spatial and annual variation in fecundity and oocyte atresia of yellowtail flounder, Limanda ferruginea, in US waters. *Journal of Sea Research*, *107*, 76-89. https://doi.org/10.1016/j.seares.2015.06.015

Potential annual fecundity (PAF) was estimated over three years (2010–2012) for yellowtail flounder with individuals from the three stocks off the northeast U.S. coast. Down-regulation of PAF, the resorption of oocytes during development, was evident as the vitellogenic cohort advanced, so we directly measured atresia of vitellogenic oocytes using stereological techniques. PAF models including relative fish condition, stock area, year, and oocyte diameter of the leading cohort explained more variation than models with just size alone based on Akaike information criteria. In a given year, Gulf of Maine females had lower PAF at size than southern New England females. Interannual differences were evident: PAF of both stocks was higher in 2010 and lower in 2012, with 2011 showing less synchronization between these stocks. Differences in size at age and relative condition suggested that energy available for somatic and reproductive growth was lower in some years in the Gulf of Maine and Georges Bank, especially in 2011. Georges Bank PAF and condition were intermediate to the other stocks or more similar to the Gulf of Maine, varying annually. A latitudinal gradient in PAF is evident based on our results and relative to earlier studies that included Canadian stocks. The magnitude of down-regulation was variable across stocks and typically 3–25% of PAF. This can be accounted for in fecundity estimates, by the seasonal schedule of sampling and use of an oocyte diameter term in the fecundity model. Theoretical models of atresia patterns suggested variable rates over the later portion of clutch development. The timing of down-regulation varied among years, and its intensity was influenced by female relative condition. Fecundity was related to fish size, but was also affected by fish condition and oocyte diameter (a proxy for time until spawning), and spatial and temporal effects. A longer time series of PAF may identify environmental drivers that modulate annual stock reproductive potential.

Morgan, M. J., & Rideout, R. M. (2008). The impact of intrapopulation variability in reproductive traits on population reproductive potential of Grand Bank American plaice (Hippoglossoides platessoides) and yellowtail flounder (Limanda ferruginea). *Journal of Sea Research*, *59*(3), 186-197. https://doi.org/10.1016/j.seares.2007.12.001

In geographically extensive fish populations the potential exists for reproductive traits to vary over the population's range but the impact that such intrapopulation variability has on overall population reproductive potential has not been formally assessed. Here intrapopulation spatial variability in size at maturity and fecundity are demonstrated for Grand Bank American plaice (Hippoglossoides platessoides) and yellowtail flounder (Limanda ferruginea). Recognition of intrapopulation variability in these reproductive traits coupled with spatial variability in abundance resulted in an increase in estimated population total egg production (TEP) by as much as 1014 eggs for American plaice and 1015 eggs for yellowtail flounder as compared to assessment of TEP for the population as a whole. Results highlight the need to explore variability in life history traits not only between but, also within populations and emphasize the need for sufficient spatial coverage during sampling in order to assess the reproductive potential of fish populations.

Pereira, J. J., Schultz, E. T., & Auster, P. J. (2012). Geospatial analysis of habitat use in yellowtail flounder Limanda ferruginea on Georges Bank. *Marine Ecology Progress Series*, *468*, 279-290. http://doi.org/10.3354/meps10035

Three theories of habitat use proposed for marine fishes—the constant density model, the proportional density model, and the basin model—make contrasting predictions of how the geographical range, local density, and fitness change as population size changes. We tested model predictions with survey data on yellowtail flounder *Limanda ferruginea* from the Georges Bank region, where abundance changed by a factor of 4 over a decade. Surveys took place in spring and fall, and data on individual length, mass, sex, and reproductive status were available. Analysis of spatial pattern revealed that the overall area occupied by flounder increased by a factor of 2 when abundance was high, and local density increased predominantly in high quality habitat that had been closed to commercial fishing. Condition, which served as a proxy for fitness, was lower in females when abundance was high. Geospatial analysis revealed mesoscale variability in condition, over 10s to >100 km, except in the spring season during low abundance periods. Spatial autocorrelation explained as much as 25% of the variability in condition, indicating that site dependence was a factor in explaining the spatial distribution that we observed. These results are most supportive of both the constant density model and the basin model. This approach detected an important population center for yellowtail flounder and determined its extent using only measures of abundance, location, and condition of individual fish, data commonly collected during routine fishery assessment surveys. Here we demonstrate that analyses linking population responses to variation in such measures at local spatial scales can have significant implications for identifying areas of important fish habitat and suggest greater use of geospatial approaches in conservation and management of exploited species.

Simpson, M. R., & Walsh, S. J. (2004). Changes in the spatial structure of Grand Bank yellowtail flounder: testing MacCall's basin hypothesis. *Journal of Sea Research*, *51*(3), 199-210. https://doi.org/10.1016/j.seares.2003.08.007

MacCall's basin model postulates that the geographic range of marine fish will co-vary with population density as a function of habitat selection. Therefore the geographic range of a stock will increase with increasing abundance, while the opposite is true of declining stocks. In this paper we investigated range contraction, and expansion, in the distribution of yellowtail flounder on the Grand Banks in relation to sediment type, temperature and depth. Yellowtail flounder were mainly distributed on gravely sand, sand-shell hash, rock-sandy sediments and to a lesser extent on rocky bottoms. As well, yellowtail flounder are highly associated with shallow, warmer waters more frequently than expected based on its occurrence in the environment. Employing a generalized additive model (GAM), we modelled the spatial distribution of yellowtail flounder in association with the environmental variables. The GAM provided a reasonable fit to the spatial distribution of yellowtail (58% overall). During periods of lower abundance, the fit of the spatial model increased, demonstrating the importance of depth and temperature in influencing the distribution of this species. We concluded that the observed range contraction of yellowtail flounder at low population levels represents selection for preferred habitats, whereas during periods of stock increase, the range of yellowtail flounder expands into less favorable habitats in support of MacCall's basin hypothesis.

Walsh, S. J., Simpson, M., & Morgan, M. J. (2004). Continental shelf nurseries and recruitment variability in American plaice and yellowtail flounder on the Grand Bank: insights into stock resiliency. *Journal of Sea Research*, *51*(3), 271-286. https://doi.org/10.1016/j.seares.2003.10.003

In 1994, a directed fishing moratorium was declared for Grand Bank American plaice (*Hippoglossoides platessoides*) and yellowtail flounder (*Limanda ferruginea*) stocks because both stocks showed severe declines in abundance from heavy exploitation during the mid-1980s and early 1990s. Four years later, the fishery for yellowtail re-opened while the plaice stock has shown little recovery and the moratorium is still in effect. To assess the possible causes of the differences in recovery between species, we examined the spatial structure and environmental characteristics of the continental shelf nursery habitats of plaice and yellowtail, and their relationship to recruitment variability and overall population size. Depth plays a major influential role determining the spatial pattern and the abundance of juveniles of both species and in the case of plaice the spatial structure of the adult population also determines the amount of nursery area utilized by juveniles. Recruitment variability was higher in plaice than in yellowtail. We found year class synchrony in both species indicating that common environmental conditions and/or biological processes are affecting recruitment in a similar manner. Density-dependent regulation appears to be more severe in yellowtail and this should contribute to a more stable population when compared to plaice. These results are discussed in terms of resiliency of both stocks to over-exploitation.

Section III: Fisheries

Historical

The fishing industry of New England has, for over 400 years, been identified both economically and culturally with groundfishing. A mixture of bottom-dwelling fishes including cod, haddock, redfish, and flounders constitute the groundfish resource. Once, great fleets of vessels sailed from Gloucester and Boston to the eastern- most reaches of North America -- the Grand Banks of Newfoundland. Source: Murawski, S. A. (mid-1990s). Brief history of the groundfishing industry of New England. Retrieved from https://www.nefsc.noaa.gov/history/stories/groundfish/grndfsh1.html

Bigelow, H.B., Schroeder, W.C. (1953). Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service. 53, 1-4. Retrieved from http://fishbull.noaa.gov/53-1/intro.pdf

Historical handbook for the identification of the fishes in the Gulf of Maine. Discusses the historical literature dealing with the fishes of the Gulf of Maine beginning with Captain John Smith's commentary in 1616 and includes citations for articles beginning in 1850. Information about the local distribution and abundance of fishes were gleaned from the U.S. Fish and Wildlife Service, the fishery statistics published by the Fisheries Branch, U. S. Fish and Wildlife Service (formerly the U. S. Bureau of Fisheries), by the Dominion of Canada, and by the Commonwealth of Massachusetts and superintendents of the Woods Role, Gloucester, and Boothbay hatcheries.

Bigelow, H.B., Schroeder, W.C. (1953). Fishes of the Gulf of Maine. "Yellowtail flounder." Fishery Bulletin of the Fish and Wildlife Service. 53, 271–275. Retrieved from the Gulf of Maine Research Institute http://www.gma.org/fogm/Limanda_ferruginea.htm

The section focused on yellowtail flounder includes a description, color, size, habitats, general range, occurrence in the Gulf of Maine and the importance of yellowtail flounder. "The yellowtail is one of the most valuable of the flatfishes caught within the Gulf of Maine. It compares favorably in quality with the summer flounder and the winter flounder, but because its body is thinner it brings a lower price to the fishermen. Thus in 1947 the average price, as landed in New Bedford, was about 8 to 9 cents a pound for yellowtails; winter flounders, about 9 to 10 cents a pound; and summer flounders, about 17 to 18 cents a pound. All the yellowtails that are brought in find a ready sale and they make up a large part of the fillet of sole sold to consumers. In 1947 our Gulf yielded between 15 and 16 million pounds of them. But yellowtails live rather too deep to be of any interest to anglers."

Lange, A. M., & Palmer, J. E. (1985). *USA Historical Catch Data, 1904-82, for Major Georges Bank Fisheries*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center. Retreived from https://www.st.nmfs.noaa.gov/tm/nec/nec039.pdf

United States historical catch data for major finfish and invertebrate species taken in the Georges Bank area during 1904 to 1982 are presented. Schemes used to prorate catch data to Georges Bank, in years when catch was not reported specifically for that area, are described.

Mercaldo-Allen R, Dawson MA, Kuropat CA, Kapareiko D. (2003). Variability in blood chemistry of yellow flounder, *Limanda ferruginea*, with regard to sex, season, and geographic location. NOAA Tech Memo NMFS NE 108; 20 p. Retrieved from https://www.nefsc.noaa.gov/publications/tm/tm180/tm180.pdf

Yellowtail flounder, Limanda ferruginea, were collected from six locations along coastal New England (i.e., Cape Cod Bay, Georges Bank, Massachusetts Bay, mouth of the Merrimack River, Mud Patch (south of Martha's Vineyard), and New York Bight), and were monitored for blood chemistry and hematology. Plasma osmolality, sodium, potassium, calcium, hemoglobin, hematocrit, and mean corpuscular hemoglobin concentration (MCHC) were measured. Osmolality and sodium concentrations were frequently reduced during spring. Potassium was generally elevated during spring and/or summer, and reduced during fall and/or winter. Calcium was usually highest during fall. The hematological indices of hematocrit, hemoglobin, and MCHC showed an overall elevation during winter as compared to fall. Fish from the inshore locations of Cape Cod Bay, Massachusetts Bay, Merrimack River, Mud Patch, and New York Bight differed significantly from fish from the offshore reference location of Georges Bank for particular blood parameters during certain seasons. These data provide a baseline range for blood constituents of yellowtail flounder over an annual cycle and at key locations in the Northeast U.S. Shelf Ecosystem. These results present evidence of possible anthropogenic effects on the blood chemistry and hematology of yellowtail flounder collected from inshore areas. Variability in blood chemistry appears to be regulated by seasonally-induced physiological and/or environmental factors, and influenced by sex and capture location. This information may prove to be useful in monitoring the health of field-collected yellowtail flounder and in assessing the condition of aquacultured fish of this species.

Pennington, M. (1985). *Some statistical techniques for estimating abundance indices from trawl surveys*. Northwest Atlantic Fisheries Organization. Retrieved from https://www.nefsc.noaa.gov/publications/series/whlrd/whlrd8510.pdf

Methods are presented for estimating an index of relative abundance from trawl survey catch per tow data. The estimated variance of the index takes into account the within survey variability in catch and possible yearly changes in catchability. Applying the techniques to a series of surveys for yellowtail flounder (Limanda ferruginea) off the northeast coast of the United States yields an abundance index with a variance which is 40 % lower than the variance of the original survey index for the current value and 57% lower for values not near the ends of the survey series.

Modern

There are three stocks of yellowtail flounder in U.S. waters, the Gulf of Maine/Cape Cod, Georges Bank, and Southern New England/Mid-Atlantic stocks. NOAA Fisheries and the New England Fishery Management Council manage Gulf of Maine and Southern New England/Mid-Atlantic yellowtail flounder; NOAA Fisheries and the New England Fishery Management Council collaborate with Canada to jointly manage Georges Bank yellowtail flounder, because the stock spans the international boundary. Yellowtail flounder, along with other groundfish in New England waters, are managed under the Northeast Multispecies Fishery Management Plan.

Brodie, W. B., Walsh, S. J., and Maddock Parsons, D. (2010). An evaluation of the collapse and recovery of the yellowtail flounder (Limanda ferruginea) stock on the Grand Bank. *ICES Journal of Marine Science, 67*: 1887–1895. https://doi.org/10.1093/icesjms/fsq121

In 1994, the biomass of yellowtail flounder on the Grand Bank had declined to 20% of the biomass associated with the maximum sustainable yield (B(msy)) because of overfishing in the 1980s, and the Northwest Atlantic Fisheries Organization (NAFO) declared a moratorium on fishing of this stock (and several others in the area). After 4 years of moratorium, the biomass had quadrupled, the fishery was reopened, and the biomass is now well above B(msy). Based on advice developed within a precautionary approach framework, total allowable catches were set corresponding to a fishing of <= 0.67 x F(msy). When the fishery was reopened in 1998, several measures to reduce the fishing mortality and ensure continued recovery were introduced. We review and evaluate the science and the management strategies developed during the decline, collapse, and recovery, noting that yellowtail flounder is the only groundfish stock on the Grand Bank that has fully recovered after its collapse. Key management measures included the elimination of fishing by non-NAFO vessels, protection of strong year classes, and keeping the fishing mortality below 0.67 x F(msy). Although overfishing is viewed as causing the stock decline, productivity was strongly affected by climatic conditions during the collapse and recovery. Changes in water temperature coincided with major changes in the catch and fishing mortality.

Cadrin, S. X., & King, J. (2003). Stock assessment of yellowtail flounder in the Cape Cod-Gulf of Maine area. *NEFSC Ref. Doc*, 03-03.Retrieved from https://www.nefsc.noaa.gov/publications/crd/crd0303/0303.pdf

Cape Cod yellowtail flounder were previously assessed as a unit stock, but are now combined with those in the Gulf of Maine. The Cape Cod–Gulf of Maine stock is overfished and overfishing is occurring. Current fishing mortality is high (2001 Fages 3-4=0.75) and much greater than the proposed FMSY proxy (F40%MSP=0.17). Spawning stock biomass declined in the early 1990s, and began increasing in 1998 to 3,200 mt in 2001, but is much less than the proposed SSBMSY proxy (12,600 mt SSB). With the exception of the strong 1987 yearclass, recruitment has been relatively stable, but early indications suggest that the 2000 cohort is extremely low. The age structure of the stock is truncated in comparison to MSY conditions.

Goethel, D. R., Legault, C. M., & Cadrin, S. X. (2014). Testing the performance of a spatially explicit tag-integrated stock assessment model of yellowtail flounder (Limanda ferruginea) through simulation analysis. *Canadian journal of fisheries and aquatic sciences*, *72*(4), 582-601. https://doi.org/10.1139/cjfas-2014-0244

In any stock assessment application, the implicit assumptions regarding spatial population structure must be carefully evaluated. Tag-integrated models offer a promising approach for incorporating spatial structure and movement patterns in stock assessments, but the complexity of the framework makes implementation challenging and the appraisal of performance difficult. A flounder-like fishery was simulated to emulate the metapopulation dynamics of the three yellowtail flounder (Limanda ferruginea) stocks off New England, and the robustness of spatially explicit tag-integrated models were compared with closed population assessments. Different movement parametrizations and data uncertainty scenarios were simulated, while the ability of the tag-integrated model to estimate reporting rate and time-varying movement were also evaluated. Results indicated that the tag-integrated framework was robust for the simulated fishery across a wide range of connectivity levels and that tag reporting rates were accurately estimated. Closed population models also demonstrated limited error. Therefore, spatially explicit approaches may not always be warranted even when regional connectivity is occurring, but tag-integrated models can provide improved parameter estimates when reliable tagging data are available. Tag-integrated models also serve as valuable tools for informing spatially explicit operating models, which can then be used to evaluate the assumptions and performance of closed population models.

Legault, C. and Steve Cadrin, S. (2006). Yellowtail flounder. Status of Fishery Resources off the Northeastern US. NEFSC - Resource Evaluation and Assessment Division. Retrieved from https://www.nefsc.noaa.gov/sos/spsyn/fldrs/yellotail/archives/07_YellowtailFlounder_2006.pdf

United States fisheries for yellowtail flounder are managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan (FMP). Under this FMP, yellowtail flounder are included in a complex of 15 groundfish species managed by 2 time/area closures, gear restrictions, minimum size limits, and, since 1994, by direct effort controls including a moratorium on permits and days-at-sea restrictions. Amendment 9 established initial biomass rebuilding targets and defined control rules which specify target fishing mortality rates and corresponding rebuilding time horizons. Amendment 13 implemented formal rebuilding plans within specified time frames based on revised biomass and fishing mortality targets derived by the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002). The goal of the management program is to reduce fishing mortality to allow stocks to rebuild above minimum biomass thresholds and, attain and remain at or near target biomass levels. In addition, a formal quota sharing agreement was implemented in 2004 between Canada and the U.S. to share the harvest of yellowtail in the transboundary Georges Bank management unit. The agreement includes total allowable catch quotas for each country as well as in-season monitoring of the U.S. catch of yellowtail on Georges Bank. The information provided herein reflects the results of the most recent peer reviewed assessments for the Cape Cod-Gulf of Maine, Georges Bank, and Southern New England-Mid Atlantic yellowtail flounder stocks (NEFSC 2005, Legault et al. 2006).

Miller, T. J., Hare, J. A., & Alade, L. A. (2016). A state-space approach to incorporating environmental effects on recruitment in an age-structured assessment model with an application to southern New England yellowtail flounder. *Canadian Journal of Fisheries and Aquatic Sciences*, *73*(8), 1261-1270. https://doi.org/10.1139/cjfas-2017-0035

The state-space model framework provides a natural, probabilistic approach to stock assessment by modeling the stochastic nature of population survival and recruitment separately from sampling uncertainty inherent in observations on the population. We propose a state-space assessment model that is expanded to simultaneously treat environmental covariates as stochastic processes and estimate their effects on recruitment. We apply the model to southern New England yellowtail flounder (Limanda ferruginea) using data from the most recent benchmark assessment to evaluate evidence for effects of the mid-Atlantic cold pool and spawning stock biomass on recruitment. Based on Akaike's information criterion, both the cold pool and spawning stock biomass were important predictors of recruitment and led to annual variation in estimated biomass reference points and associated yield. We also demonstrate the effect of the stochasticity of the mid-Atlantic cold pool on short-term forecasts of the stock size, biomass reference point, and stock status.

Miller, T. J., & Legault, C. M. (2017). Statistical behavior of retrospective patterns and their effects on estimation of stock and harvest status. *Fisheries research*, *186*, 109-120. https://doi.org/10.1016/j.fishres.2016.08.002

The presence of retrospective patterns in stock assessments is problematic for determining stock and harvest status because current estimates of stock size or fishing mortality are consistently lower or higher than those when the assessment model is updated with new data. A statistical measure of evidence for retrospective patterns is needed, but a requisite method to estimate variance of retrospective patterns is lacking. We evaluated the statistical behavior of a parametric bootstrap-based variance estimator for retrospective patterns that arise due to a change in natural mortality using a simulation experiment patterned after an assessment of yellowtail flounder on Georges Bank. We also evaluated effects of retrospective patterns on accuracy of stock assessment results and adjustments to terminal stock attributes intended to correct for retrospective patterns. We focused our analyses on Mohn's p , but the boot strap approach could be used with any measure of retrospective pattern. We found that coverage for confidence intervals of Mohn's p were adequate, particularly for commonly specified percentage levels near 95%. We also found increased statistical efficiency of terminal year stock attributes that are adjusted for estimated retrospective patterns when the model structures used to simulate observations and estimate the parameters were inconsistent. Furthermore, this increase in efficiency was generally greater than the decrease in efficiency of adjusted stock attributes when models for simulated data and parameter estimation were consistent. However, the utility of adjustments for estimating stock and harvest status depended on our expectation for future productivity of the stock and using confidence interval coverage of Mohn's p to determine whether to adjust terminal stock attributes provided no greater benefit than simply always adjusting.

Stone, H. H., Gavaris, S., Legault, C. M., Neilson, J. D., & Cadrin, S. X. (2004). Collapse and recovery of the yellowtail flounder (Limanda ferruginea) fishery on Georges Bank. *Journal of Sea Research*, *51*(3), 261-270. https://doi.org/10.1016/j.seares.2003.08.004

Stock biomass of yellowtail flounder (Limanda ferruginea) on Georges Bank was depleted by over-fishing from the 1970s to the mid-1990s, but fishery restrictions have effectively increased survival, and with recent strong recruitment, biomass is rebuilding to historic levels. The decline, collapse and recovery of Georges Bank yellowtail flounder is illustrated by past and present spatial distribution and abundance data from groundfish surveys and trends in exploitation, recruitment, biomass and age composition from recent stock assessments. Evidence for the dominant influence of exploitation on the decline and reduced abundance of this stock and the effectiveness of the current management strategy towards stock rebuilding is illustrated through deterministic simulations and yield per recruit analyses.

Wood, A. D., & Cadrin, S. X. (2013). Mortality and movement of yellowtail flounder (Limanda ferruginea) tagged off New England. *Fishery Bulletin*, *111*(3), 279-287. http://doi.org/10.7755/FB.111.3.6

From 2003 to 2006, 44,882 Yellowtail Flounder (Limanda ferruginea) were captured and released with conventional disc tags in the western North Atlantic as part of a cooperative Yellowtail Flounder tagging study. From these releases, 3767 of the tags were recovered. The primary objectives of this tagging program were to evaluate the mortality and large-scale movement of Yellowtail Flounder among 3 stock areas in New England. To explore mortality, survival and recovery rate were estimated from traditional Brownie tag-recovery models fitted to the data with Program MARK. Models were examined with time and sex-dependent parameters over several temporal scales. The models with a monthly scale for both survival and recovery rate had the best overall fit and returned parameter estimates that were biologically reasonable. Estimates of survival from the tag-recovery models confirm the general magnitude of total mortality derived from age-based stock assessments but indicate that survival was greater for females than for males. In addition to calculating mortality estimates, we examined the pattern of release and recapture locations and revealed frequent movements within stock areas and less frequent movement among stock areas. The collaboration of fishermen and scientists for this study successfully resulted in independent confirmation of previously documented patterns of movement and mortality rates from conventional age-based analyses.

Section IV: Management

Northeast Fisheries Science Center. (2017). Operational Assessment of 19 Northeast Groundfish Stocks, Updated Through 2016. U.S . Department of Commerce, Northeast Fishery Science Center Reference Document. 17-17; 259 p. https://doi.org/10.7289/V5/RD-NEFSC-17-17

Previous benchmark assessments of the Atlantic yellowtail flounder stock of Cape Cod - Gulf of Maine, Georges Bank, and Southern New England-Mid Atlantic determined that stock was overfished and overfishing was occurring. This 2017 assessment updates commercial fishery catch data, research survey indices of abundance, weights at age, and the analytical VPA assessment model and reference points through 2016. Additionally, stock projections have been updated through 2020. Based on this updated assessment, the Cape Cod-Gulf of Maine yellowtail flounder stock is overfished and overfishing is occurring), the Georges Bank Yellowtail Flounder stock biomass is low and productivity is poor, and the Southern New England - Mid-Atlantic Yellowtail flounder stock is overfished and overfishing is occurring. The 2016 fully selected fishing mortality was estimated to be 1.09 which is 320% of the overfishing threshold proxy.

TRAC (Transboundary Resource Assessment Committee). (2017). Georges Bank Yellowtail Flounder. Fisheries and Oceans Canada, Ottawa and National Marine Fisheries Service, Transboundary Resource Assessment Committee Status Report 2017, Woods Hole, Massachusetts. Retrieved from https://www.nefsc.noaa.gov/saw/trac/tsr_2017_gbytail.pdf

Since 1998, the Transboundary Resources Assessment Committee (TRAC) has reviewed stock assessments and projections necessary to support management activities for shared resources across the USA Canada boundary in the Gulf of Maine-Georges Bank region.
TRAC Review Process In the interest of transparency and in order to avoid any perceived conflict of interest, in 2017 TRAC introduced a new process of review for Eastern Georges Bank Cod and Haddock and Georges Bank Yellowtail Flounder. An overview of the entire process is available at https://www.nefsc.noaa.gov/saw/trac/trac-process-overview-2017.pdf. After the presentation of each assessment by the lead authors, there was initial scientific and technical review by the invited external reviewers (referred to as external reviewers in this document), followed by scientific and technical review by the science assessment staff and a U.S.A. and Canadian resource manager (referred to as science in this document) and then review and contributions by all meeting participants, including stakeholders, external non-government organizations and the general public (referred to as the broader TRAC in this document). At the completion of each level of review, consensus was sought and there was discussion as to whether or not revisions to the initial conclusions were warranted. In the absence of consensus, the advice from the science group will be provided along with the perspective from the broader TRAC.

Northeast Fisheries Science Center. (2012). 54th Northeast Regional Stock Assessment Workshop (54th SAW) Assessment Summary Report. US Department of Commerce, Northeast Fishery Science Center Reference Document, 12-14; 40 p. https://www.nefsc.noaa.gov/publications/crd/crd1214/

The 54th SAW Assessment Summary Report contains summary and detailed technical information on two stock assessments reviewed during June 5-9, 2012 at the Stock Assessment Workshop (SAW) by the 54th Stock Assessment Review Committee (SARC-54): Atlantic herring (Clupea harengus) and Southern New England Mid-Atlantic yellowtail flounder (Pleuronectes ferrugineus). The SARC-54 consisted of 3 external, independent reviewers appointed by the Center for Independent Experts [CIE], and an external SARC chairman from the NEFMC SSC. The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' reports for SAW/SARC-54 are available at website: http://www.nefsc.noaa.gov/nefsc/saw under the heading "SARC 54 Panelist Reports".

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/dispensatory population dynamics and in the degree of stationarity in environmental control of groundfish recruitment.

Eayrs, S., Pol, M., Caporossi, S. T., & Bouchard, C. (2017). Avoidance of Atlantic cod (Gadus morhua) with a topless trawl in the New England groundfish fishery. *Fisheries Research*, *185*, 145-152. https://doi.org/10.1016/j.fishres.2016.09.014

Many New England fishermen have traditionally used the same trawl design to target a mix of groundfish, including cod, haddock (Melanogrammus aeglefinus), yellowtail flounder, and other species .Many of these species are also caught during the same tow. Consequently, a ready-made trawl design that can avoid cod and land other groundfish does not yet exist in the fishery.

Johnson, D. L., Morse, W. W., Berrien, P. L., & Vitaliano, J. J. (1999). Essential fish habitat source document: yellowtail flounder, Limanda ferruginea, life history and habitat characteristics. *NOAA Tech. Memo. NMFS-NE*, *140*, 29 p. Retrieved from https://www.nefsc.noaa.gov/nefsc/publications/tm/tm140/

The initial series of EFH species source documents were published in 1999 in the *NOAA Technical Memorandum NMFS-NE* series. Updating and review of the EFH components of the councils' Fishery Management Plans is required at least every five years by the NOAA Fisheries Service Guidelines for meeting the Sustainable Fisheries Act/EFH Final Rule. Second editions of several of these species source documents were written to provide the updated information needed to meet these requirements. The second editions provide new information on life history, geographic distribution, and habitat requirements via recent literature, research, and fishery surveys, and incorporate updated and revised maps and graphs.

Xu, H., Miller, T. J., Hameed, S., Alade, L. A., & Nye, J. A. (2018). Evaluating the utility of the Gulf Stream Index for predicting recruitment of Southern New England-Mid Atlantic yellowtail flounder. *Fisheries Oceanography*, *27*(1), 85-95. https://doi.org/10.1111/fog.12236

The justification for incorporating environmental effects into fisheries stock assessment models has been investigated and debated for a long time. Recently, a state-space age-structured assessment model which includes the stochastic change in the environmental covariate over time and its effect on recruitment was developed for Southern New England-Mid Atlantic yellowtail flounder (*Limanda ferruginea*). In this paper, we first investigated the correlations of environmental covariates with Southern New England-Mid Atlantic yellowtail flounder recruitment deviations. The covariate that was most strongly correlated with the recruitment deviations was then incorporated into the state-space model and alternative effects on the stock-recruit relationship were estimated and compared. For the model that performed best as measured by Akaike information criterion, we also compared the estimates and predictions of various population attributes and biological reference points with those from an otherwise identical model without the environmental covariate in the stock-recruit function. We found that the estimates of population parameters are similar for the two models but the predictions differed substantially. To evaluate which model provided more reliable predictions, we quantitatively compared the prediction skill of the two models by generating two series of retrospective predictions. Comparison of the retrospective prediction pattern suggested that from an average point of view, the environmentally explicit model can provide more accurate near-term recruitment predictions especially the one year ahead recruitment prediction. However, the accuracy of the near-term recruitment prediction from the environmentally explicit model was largely determined by the accuracy of the corresponding environment prediction the model provides.