Building a Shared Vision of Atlantic Cod Population Structure and New England Fisheries

Thursday, June 6, 2019
University of New Hampshire

Summary of Discussion and Recommendations

The Atlantic cod stock structure working group (ACSSWG) was formed by NOAA Fisheries in 2018 to advance the following objectives:

- Determine the most appropriate representation of Atlantic Cod stock structure for use in regional stock assessments based on currently available information. "Most appropriate" means having the greatest scientific support and accurately capturing the available data and assessment model frameworks. This determination will not include the running of assessment models.
- Identify high priority research that would contribute significantly to the issue of cod stock structure.
- Broadly consider potential management actions to meet management objectives including but not limited to maintaining status quo, altering stock boundaries, spatial and temporal restrictions, and stock composition analyses.
- The following are explicitly not part of this Working Group: New benchmark assessment, reference determination, and quota setting.
- Follow a transparent process by including stakeholders in public meetings and through regular updates.

On 6 June 2019, the ACSSWG held a public symposium at the University of New Hampshire to present the preliminary findings of a 1-year interdisciplinary review of Atlantic cod stock structure, and provide an opportunity for participants to provide feedback on how these new findings relate to their on-the-water experience and observations. The symposium results will contribute information to the final report by the Atlantic Cod Stock Structure Working Group. The objectives of the symposium were:

- Present the preliminary conclusions about cod stock structure from the perspective of six disciplines:
    1) spawning and early life,
    2) genetic markers,
    3) basic life history [abundance, growth, maturity],
    4) external or internal 'natural' markers, shape, or coloration,
    5) applied markers, both conventional and technology tags, and
    6) fisherman's ecological knowledge.
- Capture insight and feedback from fishermen on what is being observed on the water to incorporate into the stock model being developed by the Working Group.
- Compare status quo and alternatives regarding biologically-supported stock structure of cod in US waters to further identify areas of common ground in the understanding of cod population structure and areas of remaining uncertainty
- Outline further steps forward for the working group and its products

This document is a brief record of the discussions at this symposium, and a complete video of the meeting is available on the symposium website. This record of discussion has been arranged by discipline, as most questions and recommendations addressed these specific subtopics.

Spawning and Early Life History

The authors considered "early life history" to include all phases of life from spawning through juvenile settlement. This portion of the Atlantic cod life cycle forms the critical link between reproductive potential and subsequent recruitment.

Most of the discussion focused on which surveys were used to inform the presentation, and the spatial coverage of those surveys. Annual ichthyoplankton cruises have been undertaken on the continental shelf of the US Atlantic coast between North Carolina and Nova Scotia since 1971, and provides insight into broad scale patterns. Ichthyoplankton surveys were undertaken in adjacent Canadian waters, but have not been repeated in nearly 20 years. The Maine inshore trawl survey was reviewed, but did not have much signal at the life stage in question; a participant noted in the most recent year survey caught about 60 juveniles in the coastal area of 512, from Mount Desert Island up to about Cutler. Fisheries and Oceans Canada undertakes annual research vessel trawl surveys that catch some young of year cod, but not larval fish.

All available survey information was reviewed and included, but two surveys were particularly useful in elucidating patterns. The Northeast Fisheries Science Center (NEFSC) survey covers randomly selected stations throughout the continental shelf from North Carolina to Nova Scotia. Each year, the NEFSC survey covers the entire study area in two seasonal cruises: the "Spring" cruise, which began in 1968, typically reaches the New England region in March-April and captures recently settled juveniles that were spawned during the late fall and early winter months; The "Fall" cruise (September-October; beginning 1963) captures juveniles that were spawned in spring and early summer months. The Massachusetts Division of Marine Fisheries (MADMF) operates Spring (May) and Fall (September) cruises, that are restricted to Massachusetts State Waters. The MADMF survey has operated every year since 1978 and encompasses juvenile settlement areas within the GOM, CC and SNE strata.

The NEFSC survey has a minimum depth of 5m. It is recognized that the shoreline is a gap. It has been assumed in this review that the shoreline juvenile distribution follows the survey distribution in waters adjacent (just offshore) of these shore areas.

There is sufficient data to assess seasonal patterns, but it is important to note that spawning occurs at different times in different places within the area of interest. The degree to which eggs and larvae drift prior to settlement, and the time it takes to travel from spawning areas to settlement locations is dependent on water temperature and currents. Larval development is temperature-dependent; larvae in colder water remain in larval stage longer than individuals in warmer water, and thus may drift farther.

Genetic Markers

Some genetic markers that exhibit differentiation among spawning fish from different locations are associated with genes for hormone receptors. There was some discussion as to whether this pattern related to time of spawning. At present this pattern is only an association, and there is no evidence currently for cause and effect. It was note that a similar pattern is observed in GoM spring spawners and spring spawners from St. Pierre Bank, off the south coast of Newfoundland. Patterns observed in neutral markers were largely consistent with patterns in adaptive markers and whole genome, but very weak

signal in comparison. The presenters thought this weak signal likely was due to recent or on-going gene flow among spawning areas.

There was some discussion of fishing patterns and timing in the southern portion of the range (statistical areas 611-623). For instance it was noted that the best cod fishing used to be in April, but now occurs in spring, leading fishers to question if this was linked to spring versus autumn spawning. Unfortunately this question cannot be explored with genetic analyses, as Working Group members do not have genetic samples from fish south of statistical areas 537/539 (e.g. Long Island area).

Other discussion points highlighted the lack of genetic evidence for spring spawners in statistical areas 521 and 526, and the presence of a unique genetic signal in southern New England (although this does not mean there is zero connectivity with other areas).

Life History

Analysis were presented on the abundance, size at age 2, and size and age at maturity based on a 48-year time series (1970-2017) from the Northeast Fisheries Science Center's bottom trawl survey.

During discussion is was clarified that age at maturity is defined by the presence of egg development to hydration of at least some eggs in the gonad. The fish abundance data was all derived from the uncalibrated NEFSC research trawl survey. The temperature field used in the analyses is the standard modelled bottom temperature provided by NOAA Fisheries.

During discussion it was noted by fishermen that they have observed that bottom temperature has a substantial effect on cod spatial distribution. One fisherman involved in sample collections noted that in 2017 fish were much larger at age than he had been seen in previous years of sampling.

Natural Markers

Analyses of multiple natural marks suggest limited connectivity as well as ecological differentiation between winter and spring spawning populations.

There was considerable discussion concerning differences in various markers between spring and winter spawning cod in the Gulf of Maine, and the recent (starting in about 2010) changes in spring/winter relative dominance suggested by patterns in these markers. One suggestion was that this trend may be due to adaptation to changing temperature. For instance, genetic analyses indicate that cold-adapted genes may becoming less common over time. The question was raised as to whether this change is a result of an ecological advantage (i.e. temperature-dependent growth) or spawning success? Fishers noted that spring spawners have been spawning deeper over time. As an example, cod spawning used to occur close to the coast, right up to the Merrimack River, but more recently spawning has been detected in depths of 50 fathoms. As a result, eggs and larvae from these spawning events may be swept offshore by coastal currents.

The concern was raised that the rolling fishery closures currently in effect could have an effect on this winter/spring spawner pattern. A recently published scientific paper has suggested that rolling closures may have set up a situation of differential mortality via fishery exploitation

Applied Markers

Regional patterns of residence and movement have been similar among tagging studies since the early 1900s. Cod in the western Gulf of Maine and the Bay of Fundy are relatively sedentary. There is some movement between the western Gulf of Maine and the Great South Channel. There is extensive movement between eastern Georges Bank and the western Scotian Shelf and between Nantucket Shoals and the Mid Atlantic Bight. Tagging studies high residence and fidelity to spawning areas in the western Gulf of Maine and the Bay of Fundy, high spawning site fidelity on eastern Georges Bank with some post-spawning dispersal, and greater dispersal from the 'Cape Cod' spawning grounds.

The question was raised as to how fishing effort may influence patterns in tag returns. Tag returns are limited by where fishing is allowed to occur, and therefore analysis was undertaken at the spatial scale of statistical reporting areas and not finer scales.

Further discussion focused on Areas 514 and 521; particularly concerning whether or not area for 521 should be considered as part of the Western Gulf of Maine. Evidence for movement of tagged fish between 514 and 521 dates back to the work of Wise (1963), but it is in the past 10 years that genetic and fine scale movement studies have more strongly supported this view.

Fishermen's Ecological Knowledge

This work provides a valuable example of how Fishermen's Ecological Knowledge (FEK) can serve as a complement to improve our understanding of cod stock structure. Fishermen's observations related to the timing and location of cod spawning on Georges Bank were aligned and well supported by the existing scientific information tabled during the workshop. The fine scale spatial resolution of spawning provided by FEK cannot be easily obtained using traditional scientific data collection approaches. The final report of the Working Group will include a full chapter dedicated to FEK.

During discussion it was noted that the rolling fishery areas closures implemented by management are much larger than the spawning areas shown in the presentation. Historical references informed the work, but the opportunity exists for a more formal comparison of historical references and current FEK of cod spawning areas. I was also noted that spawning areas identified through FEK were coherent with inferences of spawning areas drawn from the Massachusetts research trawl surveys

Summary and General Discussion of Results

The shift in relative dominance between spring and winter spawners, with far less recruitment from spring spawners that seen historically will be an issue with stock assessment and management. Does this change indicate a need to change management approaches to protect spring spawners, or this this change an environmentally-driven trend to which we have to adapt? It was noted that spring spawners are favored over winter spawners by current spatial fishery closures, but despite this they have not contributed much to overall stock recruitment. There are implications from these trends for stock and/or spawning group recovery.

Individual cod once per year, but the aggregate spawning period is protracted and can last from a few weeks to several months. Cod spawning aggregations are valuable entities for assessment; it was suggested that perhaps acoustic surveys could be used to try to enumerate aggregations. There have been several attempts to do this, but it is labor-intensive in terms of time required to locate and survey aggregations.

The question was asked as to whether the abundance of juvenile haddock could be competing with juvenile cod. This is possible, but in general the two species have different (but not completely different) diets.

Several recommendations were tabled:

- Investigate how current management actions (e.g. rolling spatial closures) may be influencing some of the patterns presented at the workshop, particularly the changes seen in winter and spring spawner abundance.
- There is value in modeling potential future changes in cod dynamics given the relationships and trends in cod spawning presented.
- Ensure continued incorporation of local ecological knowledge and coastal oceanography in study of stock structure, and try to extend the collection of fisherman's knowledge into Southern New England.

What We Think This Information is Telling Us about Alternative Models of Atlantic Cod Population Structure

Three options were tabled to initiate discussion. Option A represented a move of statistical area 521 to a new Gulf of Maine stock "unit". Option B presented an inshore–offshore boundary to stock definition. Option C included three inshore stock units and one offshore unit.

There was a fair degree of discussion concerning the Western Gulf of Maine, given the lack of spawning fish samples for genetics (however one group is investigating use of archived otoliths for genetic material). It was noted that several other data sources (e.g. applied marks) indicate some differentiation of this area from the rest of the stock area. The lack of information from statistical reporting areas 511 and 512 in GoM reflect collapses in local abundance, starting in the 1940s. Abundance still appears low based on surveys, although is little fishing effort in area at present to support or contrast the surveys.