MAINE DEPARTMENT OF MARINE RESOURCES

COASTAL FISHERY RESEARCH PRIORITIES

HERRING

(Clupea harengus)

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for

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Preface

The 2010 research priority setting workshops follow more than a decade of research since the last series of workshops were held for herring in 1997. There has been a great deal of information gathered and new insights gained over these years. Most importantly, Maine fishermen have become full partners in establishing the research questions and pursuing the answers to those questions through collaborative research. Maine has been a leader in the region for engaging fishermen, scientists, and managers in the quest for better information on which to manage its fisheries. While there has been great progress, there remain many unanswered questions and further work to be done. Through this collaborative approach to research, drawing upon Maine's creative and innovative spirit, we are optimistic that the most pressing questions will continue to be addressed in the next decade.

I. Herring Background

Atlantic herring ("herring"; *Clupea harengus*) play the central ecological role as a forage fish for marine mammals, seabirds, and many fish throughout the Mid-Atlantic and Northeast. Herring accounted for the highest commercial landings of any single species (average 35,300 metric tons per year) in Maine from 2006 to 2008 with an average annual ex-vessel value of $9.3M. Herring also serve as a critical economic component to sustaining Maine's lobster industry. From 2005 to 2008, lobster was the second most valuable fishery nationwide ($377M annual average) with Maine generating 76% of the catch. Typically, 70 to 85% of Maine's lobster bait is fresh herring.

The herring fishery consists of fixed and mobile gear fisheries in coastal waters. The fishing weir was the predominant gear of choice until the 1940s, when both weirs and stop seines were the gears of choice. Today, mobile gear fisheries, including purse seines and mid-water trawlers, comprise greater than 90 percent of Maine herring landings compared with less than 50 percent during the 1970s. A coastwide shift in landings has occurred over the past ten years from purse seiners to mid-water trawlers.

The Maine Department of Marine Resources (DMR) is responsible for monitoring the status of the Maine Atlantic herring fishery and works in cooperation with the National Marine Fisheries Service (NMFS) to assess the status of the U.S. Atlantic coast herring stock, which extends from Virginia to New Brunswick. Atlantic herring migrate across US and Canadian waters and scientists from both countries are involved in the stock assessment throughout its range through the Transboundary Resource Assessment Committee (TRAC). These assessments indicate that the entire Atlantic coast stock complex of herring is very large and under-utilized, but stock size is believed to be much larger offshore on Georges Bank than it is in the Gulf of Maine where most of the fishing takes place. Herring are not currently overfished and overfishing is not occurring. The 2009 assessment updated the 2008 biomass estimate at 652,000 metric tons (mt) with a fishing mortality of F=0.14 which is well below the established threshold. However, the herring estimates of abundance are partially derived from bottom trawl surveys and these surveys have limitations for pelagic species such as herring.

Management of Atlantic herring is shared among the State of Maine, the interstate Atlantic States Marine Fisheries Commission (ASMFC) and the federal New England Fishery Management Council (Council) through complementary management plans that set annual quotas, called a total allowable catch (TAC), for three management areas and two sub-areas. The TACs for these areas are set based on the maximum sustainable yield that allows for a sustainable harvest but leaves enough herring for fish, birds, and marine mammals. Maine's coastal herring fishery is entirely in Area 1A. Maine regulations include spawning closures and a 'days out' provision. Requiring days out of the fishery is the primary effort control measure for the inshore fishery, restricting vessels to 2,000 pounds of herring on a day out to prolong a management area's TAC.

II. Research Priority Meetings

The Maine Department of Marine Resources (DMR), in collaboration with the Gulf of Maine Research Institute and Maine Sea Grant, conducted a series of meetings in November and December 2010 to develop research priorities for scallops, herring, and lobsters. For scallops and lobsters, these meetings provided an opportunity to update the DMR Research Priorities established through a similar initiative in 2000 for five on Maine's major commercial species (soft-shell clams, lobsters, scallops, sea urchins, and shrimp; see http://www.maine.gov/dmr/research/table_of_contents.htm). The herring research priorities workshop provided an opportunity to revisit herring discussions held between 1996-1997 that resulted in *Biology and Assessment of Gulf of Maine Herring Stocks* (http://www.gma.org/herring/herring_report_1998.pdf).

Fishermen, academic scientists, government scientists, fisheries managers, and others interested in fisheries issues gathered together in a non-regulatory, open discussion about the scientific questions they had about each species. The meetings were not structured to address management questions or to decide how to use DMR research funding. Rather, the result of these meetings is a prioritized list of research questions that can be used to stimulate new research by the marine science community and to help ensure that fishery management decisions are made on the best information.

These meetings followed the formats of the 2000 initiative and a recent symposium on rockweed (http://www.maine.gov/dmr/rm/rockweed/symposium2010/index.htm). Scientists with expertise on each species were invited to give brief presentations on specific topics along with their ideas for major scientific gaps and potential research questions. The presentations were followed by a facilitated discussion that provided an opportunity for exchanging ideas and observations. These ideas formed the basis for a list of research questions. Meeting participants were asked to prioritize among the research questions at the end of the meeting in two ways; first with regard to overall priority and second with regard to the most pressing research questions.

III. Report Format

The herring meeting was divided into four segments: Bycatch Monitoring, Biological Assessment, Stock Structure, and Foraging and Ecosystem Roles. A brief overview of each presentation is given in Section IV followed by the priority research questions.

The priority research needs were generated throughout the day and are arranged below under the topic area that is most appropriate, not necessarily the segment where they were discussed. The research needs are listed in priority order within each section.

A detailed, categorized list of questions, observations, and opinions articulated during the discussion is presented in Section V.

IV. Priority Research Questions

Herring Priority 1: Stock Assessment

Paul Rago from the Northeast Fisheries Science Center provided an overview of the Gulf of Maine/Georges Bank Atlantic herring stock assessment and 2009 updates. The full Powerpoint presentation can be found at www.maine.gov/dmr/research/priorities10/herring/rago1.pdf.

Stock assessments entail an integration of measures of trend and scale that allows for the reconstruction of historical biomass and fishing mortality, the estimation of biological reference points, and provision of scientific advice on harvest policy. Results of stock assessments are a primary source of information on the dynamics of exploited fish populations. It is important to keep in mind the scale. An assessment can reflect high mortality on a small stock or low mortality on large stock and this trend needs to be considered. The stock assessment process requires data over a long period of time. For Atlantic herring, there is good information for the past 3-4 years.

Overall, herring had high landings rates prior to adoption of the federal Magnusson-Stevens Fisheries Management Act, and then stable catches throughout 1970-80's. However, there is a lack of information by foreign fleets before 1981. The NMFS winter survey (1994-2008) provides one measure of trends. However, it was primarily designed as a flatfish (summer flounder) survey, as opposed to a synoptic survey for all species. The other trend that is useful is the NMFS spring survey, which is less variable than the winter survey. The NMFS fall survey is showing an overall pattern of stock rebuilding since the mid 1980s, but with a lot of variability. NMFS also conducts an acoustic survey, which is a 10 year program designed to estimate the magnitude of the spawning stock on Georges Bank and Jefferies Ledge, but this survey was not included in previous stock assessments.

The 2009 TRAC assessment model used catch-at-age data to estimate the removal on an age specific basis. The model included the NMFS spring and fall surveys, but not the winter and acoustics surveys. Atlantic herring biomass is about 700,000 mt and fishing mortality is below the maximum sustainable yield (Fmsy). The trend over time shows some cessation of fishing and the biomass rebuilding over time. The herring recruitment pattern shows a fueling of increase in stock size and standing stock biomass (SSB). Typically, as the SSB increases, there is a higher probability of successfully recruitment.

Most stock assessments have some degree of retrospective patterns that result in either an overestimate or underestimate of stock size. Retrospective patterns are indicative of the underlying tension of survey indices. In general, the stock size for Atlantic herring is shown to be less that previously thought. The assessment estimated 5 million mt of herring, but when looked at it in retrospect, it was actually 2 million mt. This reflects a change in some underlying attribute over time, which could be an unobserved removal through discarding or natural mortality. There are few unrecorded landings for Atlantic herring so perhaps the difference is due to higher natural mortality. The original SSB was calculated at 1.2 million mt, but upon revised estimation with a retrospective pattern, it was recalculated at 600-700,000 mt. The TRAC 2009 states that overfishing is not occurring and biomass is above the reference point.

During the discussion at the workshop, several people raised the concern that the herring resource is currently assessed as a meta complex, yet the management is on subcomponents of the resource. Each stock component has its own recruitment, growth rates, and mortality rates in terms of exposure to fishing. It is unknown whether removals represent a particular stock or a mixed stock and if that is the driving trend. This affects how to reconstruct what has happened in the past over time.

Priority Research Needs:

1. *Research sub-stock issues – morphometric patterns and removal rates regarding stocks.*
2. *Address whether herring stocks should be assessed as a whole stock or sub-stocks.*
3. *Study the role of fish behavior across borders with regard to models.*

Herring Priority 2: Stock Structure

Jason Stockwell from the Gulf of Maine Research Institute (GMRI) presented information on Atlantic herring stock structure. The full Powerpoint presentation is available at www.maine.gov/dmr/research/priorities10/herring/stockwell.pdf.

The stock structure of Atlantic herring is not critical for assessment purposes, but the herring management structure makes it critical for doing time and area allocations. There are a number of methods that can be used to indentify stock structure, including genetics, otolith microstructures (daily or yearling growth rings), otolith shape analysis, body morphometrics, otolith microchemistry, parasites, as well as traditional tagging programs to make inferences of where a fish came from. When using multiple methods, it provides a more powerful view than any single method on making assumptions about stock structure.

In the western North Atlantic, there have been some studies on spawning structure of Atlantic herring and spawning grounds have been identified. There have also been fragmented studies over the past four decades suggesting some stock structure does exist, but nothing definitive. Tagging studies by Maine DMR indicate that herring are highly mobile, with one fish travelling over 1000 km within 100 days, suggesting there is mixing going on between the management areas.

There have been a few different morphometric studies conducted on herring to date. Jefferies Ledge, Georges Bank, and Bay of Fundy fish were shown to separate out, with some overlap. In 2009, a small GMRI pilot study was done in Scotts Bay, George Bank and German Bank herring showing separation based on body morphometrics. GMRI is currently examining stock structure of alewives otoliths, morphometrics microchemistry and genetics. This work could then be applied to Atlantic herring.

In the summer and fall of 2011, acoustic systems will be outfitted on ten lobster boats along the coast of Maine to conduct survey transects for one night a week, for 16 weeks. This information will provide spatial and temporal coverage and will complement the NMFS offshore survey. This will allow direct biomass estimates of the two different components (inshore and offshore) to be

calculated. A direct estimate for one year will be calculated and can be compared to the stock assessment to give more confidence in measure of stock biomass.

The current assumption is that the inshore stock comprises 18% of the total biomass, which is based on work that clearly states that it should not be used as such. The pilot data and current Atlantic herring management structure warrants a comprehensive study for spawning areas and fisheries in US and Canada. Canada is currently surveying spawning aggregations, so samples should be easy to obtain. Morphometric analysis is relatively easy to do using a camera and image analysis system, and genetic analysis could be done at Jackson Laboratory on Mount Desert Island. Samples during spawning closures in Gulf of Maine need to be collected and this is not currently being done due to restrictions on commercial fishing in these areas. All this work has to be done in an integrated way with input from stock assessment biologist to be of relevance to the process.

Priority Research Needs:

1. *Conduct a new study of current stock structure.*
2. *Develop methodology to improve or recalibrate inshore estimate of 18% of the total biomass and understand the impact this assumption has in models at different scales.*
3. *Investigate Fourier analysis for rapid data generation through automation.*
4. *Align management research questions with assessment questions – calculate spawning biomass inshore and characteristics of stocks.*
5. *Conduct DNA studies of stocks to develop a baseline and provide 'natural tags' for future analysis.*

Herring Priority 3: Bycatch Monitoring

Matt Cieri of the Maine DMR gave a presentation on the herring portside by-catch and commercial catch sampling programs. The complete Powerpoint presentation is available at www.maine.gov/dmr/research/priorities10/herring/cieri.pdf.

The catch sampling program monitors Atlantic herring as well as menhaden and mackerel, and collects age, length, weight, sexual maturity, gonad weight and gut fullness. Spawning condition is monitored and the information is used to set ASMFC closures and to develop catch-at-age matrices for the stock assessment. The bycatch sampling program is a targeted program highlighting the bycatch of all species, but river herring (alewives & bluebacks which are both species of concern) and haddock (to track the haddock cap on Georges Bank) are of particular interest. Bycatch is also monitored through an at-sea observer project funded by NMFS and run by the observer program. At-sea observers are placed on the vessels looking for bycatch and marine mammal interactions. This program was not expanded into the herring industry until 2004. One of the major challenges in this fishery is that as the catch is brought on board it can only be sub-sampled due its high volume. At-sea observers sample directed herring trips ranging from Maine to North Carolina throughout the year. Purse seine trips were not included in 2006 and 2007. Samplers can document bycatch when pumping from net into hold. They sub-sample the catch and hand-select larger fish to collect biological data.

Portside sampling was started in 2001 to sample herring catches south of Cape Cod in Area 2, and was expanded to other species such as mackerel and menhaden in 2002. It was further expanded to portside bycatch sampling in 2004 across the region. The portside program processes targeted herring trips by gear type, from Maine to New Jersey. The sampler is present when off loading to a processor from boat or truck and standard weight and measurements are collected from a subsample.

There is some difficulty in combining data from the portside and at-sea programs for analysis. Each method is statistically valid, but analysis shows little agreement when compared side by side. Portside sampling had a higher occurrence of bycatch while at-sea observers saw a higher weight of bycatch. Also, there were low levels of agreement on occurrences between trips observed by both programs by species. There was no correlation in the relationship between the paired portside and at sea observer trips estimates of weight for a given species. Trips which recorded a relatively high level of bycatch in one program did not have a relatively high bycatch when sampled by the other. Much of the discrepancy can be attributed to sample variation due to the low levels of bycatch observed. The Council Herring Plan Development Team will form a subgroup to look at the differences between both programs to determine if there is a problem with methodology of sampling.

Since 1994, there has been a need for a centralized database to link the portside program, observer program and tie in the vessel trip report (VTR) data. Prior to 2005, there was no link between VTR and observer data. Discrepancies also exist within the databases. There is a lot more that can be done in terms of "mining" the data that has been collected, but there is a lack of analytical personnel to get this done. Making the database more connected and data mining would both be helpful.

Priority Research Needs:

1. *Perform more analysis of current data that is not being used (i.e., "data mining")*
2. *Establish a single, shared database*
3. *Improve sampling methodology on vessels*

Herring Priority 4: Forage and Ecosystem Roles

Paul Rago from the Northeast Fisheries Science Center provided his thoughts on ecosystem considerations for Atlantic herring. The full Powerpoint presentation is available at www.maine.gov/dmr/research/priorities10/herring/rago2.pdf.

It is important to consider the context in which various models consider environmental information. Fisheries assessments are trying to describe the dynamics in terms of an individual species, although we know other things are important. There are different types of ecological models used in fisheries from single species models to full system models. The Aggregate Biomass model is used in the Bering Sea, where a 2 million ton cap for overall landings within that ecosystem (primarily pollock) has been established. This type of management strategy can provide the checks and balances needed in the ecosystem.

These are complex systems. Looking at all the predator groups on Atlantic herring in the Gulf of Maine region provides an idea of how much each group needs in the ecosystem. Energy Modeling and Analysis Exercise (EMAX) characterize balances across regions and provides a way to estimate what the system may do when there is a perturbation in the system, such as removing all the dogfish. It is based on diet composition, when they ate their last meal, what was eaten, the evacuation rate, etc. Many insights can be gained through these exercises. Production Potential Models look at how much carbon is fixed and how much production it can support.

When NMFS is conducting assessments, they are always working with variables that are changing. In recent years, estimates of consumption by predators are much higher than estimates of landings. M_2 is an instantaneous rate of mortality and is attributed to predation. There is significant fluctuation in these rates over time. When calculating MSY and a broader estimate, how much is being produced and transferred out to the ecosystem is considered. As predator biomass changes, the surplus production to humans is going to change (supply-demand curve).

Predation impacts on herring are often much larger than the actual herring landings. When fishing mortalities are high, there is an enhanced risk of a major stock decline. Predation mortalities (M_2) should be included in stock assessments of prey fish. Single species assessments may be too optimistic in terms of bycatch. If the fishery and predators utilize a full size spectrum of prey, then tradeoffs are probably warranted. Predation mortality should be incorporated directly into the herring stock assessment and several trial runs of different model formulations should be conducted to help in the progression of information for stock assessments.

Priority Research Needs:

1. *Conduct food and diet studies for herring and other species.*
2. *Identify life stage bottlenecks.*
3. *Analyze growth signals over time as indicators of ecosystem.*
4. *Explore environmental co-variants tied to abundance indices.*

V. Herring Observations and Questions from Discussion

Stock Assessment

- Evaluate acoustic surveys re: spawning stocks outside sample area (2Y; 1R)
- Research sub-stock issues (10Y; 10R)
    - Morphometric patterns
    - Removal rates re: stocks
- How to improve the data going into the models (1R)
- Should we assess whole stock or sub-stocks? (different questions at each level) (3Y; 3R)
- What are the drivers/factors of spatial stock presence, age mix
- Study the role of fish behavior across borders – regarding models (3R)
- Study heterogeneity of fish age as a factor (6+) in assessment (1R)
- Research on environmental impacts (1Y; 1R)
    - Review assumptions, model inputs, unexplained model variations
- Aging structure research to inform the models

Stock Structure Mixing

- Investigate Fourier analysis for rapid data generation/automation (5Y; 5R)
- Full scale samples of old otiliths
- Trace metals analysis?
- New study of current stock structure (7Y; 3R)
- Short term vs. long term research dilemma (4 years minimum)
- Can we identify one key data factor to measure cost effectively long term? (1R)
    - Perhaps spawning stock sampling resolves this issue?
    -
- Align management research questions with assessment questions; How much spawning biomass inshore and characteristics of stocks. (4Y; 5R)

- Find a way to link fine scale information to management decision making (NMFS model expanded) (1R)

- Develop methodology to improve or recalibrate inshore estimate of 18% and understand impact this assumption has in models at different scales (8Y; 2R)

- Develop similar (above) research outside Maine – stock structure inshore

- DNA studies of stocks – baseline and provide 'natural tags' for future analysis. (2Y; 3R)

By-catch Monitoring

- Address uncertainty regarding species stratification
  By:
  - Tagging study
  - MA study
  - Portside vs. at sea sampling (1Y; 1R)
  - Data analysis/mining (1Y)

- Improve sampling methods collecting on vessels (4Y; 1R)

- River herring assessment

- Establish single shared database (6Y; 7R)

- Develop common protocols for all levels of monitoring (1Y; 2R)

- Improve and utilize spatial/temporal information for multi-species analysis

- Data mining – scarcity of analysts; much data not being used (6Y; 9R)

Forage and Ecosystem Roles

- Identify life stage bottlenecks. (2Y; 5R)

- Expand ecosystem beyond predator/prey (i.e., include all elements); refine scale to meaningful size functional areas. Avoid one-size-fits-all approach. (1Y1R)

- Develop checks and balances to offset the weight of 'unknown' externalities in management decisions.

- Develop 'alert' system to identify issues in ecosystem balance [under fishing or over fished] areas; raise to management level.

- Link single species information together
- Include diet information in models
- Food and diet studies are needed for many species and herring specifically as well (7Y; 10R)
- Explore environmental co-variants tied to abundance indices (3Y; 2R)
- Evaluate oceanographic inputs and factors by evaluating and analyzing historical data sets (2R)
- Explore relationship between predatory shore birds, seals and herring abundances.
- Analysis of growth signals over time can provide indicators and important ecosystem information. (3Y; 3R)

VI. Herring Meeting Participants

Sherman Hoyt, Matt Cieri, Mary Beth Tooley, David Richardson, Jennie Bichrest, Tony Hooper, Dave Ellenton, Ben Martens, Steve Weiner, Patrice McCarron, Paul Rago, Ted Ames, Jie Cao, Sam Truesdell, Jason Stockwell, Melissa Smith, Trisha DeGraaf, Alexa Dayton, Stephen Robbins III, David Libby, Linda Mercer, Kate Burns, Laura Taylor Singer

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