SSC CORRESPONDENCE

Associated Fisheries of Maine
PO Box 287, South Berwick, ME 03908 207-384-4854

January 20, 2012

RECEIVED
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NEW ENGLAND FISHERY
MANAGEMENT COUNCIL

Dr. Chris Legault, Chair
Scientific and Statistical Committee (SSC)
New England Fishery Management Council

VIA ELECTRONIC MAIL

Dear Dr. Legault:

Associated Fisheries of Maine (AFM) is keenly interested in the discussion that the SSC will have about Gulf of Maine cod on January 25, 2012. Unfortunately, I have a scheduling conflict and will not be able to attend your meeting to hear that discussion.

I am writing to request that the SSC explore/explain the working group's decision to start the Gulf of Maine cod assessment with data beginning in 1982 as opposed to 1964 when the NEFSC survey series starts. It is my understanding that fisheries scientists in most parts of the world prefer, and some international fora (IWC, CITES) require, that assessments include data from as many years as available, even when datasets for some years may not be as complete as for other years. It has been explained to me by fisheries scientists with whom I have consulted (including Dr Ray Hilborn) that including all data years in an assessment is "best practice". One reason for this, I gather, is that it allows MSY-related reference points to be better estimated; these are, of course, required under the Magnuson-Stevens Act. In particular, I would like to know if including data available from years back to 1964, which is available, might provide a more optimistic view of the current status of Gulf of Maine cod, and if the SSC would recommend that methodology be further explored.

On behalf of AFM, I want to thank the SSC in advance for their efforts to respond to the requests for review made by the New England Fishery Management Council and other interested stakeholders, as well as hopefully the question I have raised in this correspondence.

Sincerely,

M. Raymond

Maggie Raymond

91 FAIRVIEW AVE
PORSTMOUTH NH 03801

NORTHEAST HOOK FISHERMAN'S ASSOCIATION

January 18, 2012

New England Fishery Management Council
50 Water Street, Mill 2
Newburyport, MA 01950
Phone: (978) 465-0492
Fax: (978) 465-3116

SUBJECT: 53rd Northeast Regional Stock Assessment Workshop (SAW 53)/ Stock Assessment Review Committee (SARC) Meeting. 100% MORTALITY GOM COD

Dear NEFMC Council Members & SSC Members:

The NEHFA represents a small group of Commercial Fishermen with the Limited Access Handgear (HA) Permits, employing the use Rod and Reel or Hand lines to catch Cod, Haddock and Pollock along with small quantities of other regulated and non-regulated marine fish. Our group takes great pride in the fact that we use traditional fishing methods that have been used for generations. Our numbers are low as is the quantity of fish we catch. Our method of fishing has been mostly replaced by modern fishing methods. We stubbornly employ the use of Handgear because we firmly believe it is the most environmentally friendly method of commercial fishing.

We wish to provide our years of on the water cod fishing experience to hopefully correct what our group feels is a flaw in the assessment process. Specifically with regard to the Discard Mortality of GOM cod. The results of the Stock Assessment Working Group Data Meeting came to the conclusion that the discard mortality of GOM cod will be 100% for Handline (commercial and recreational). They came to this conclusion over what appeared to be much debate. We firmly believe that this number for Handline jigged cod is 100% wrong. We believe that the actual discard mortality to be around 5-10% for this gear. We provide the following reasons:

1. "Survival of Discarded Sublegal Atlantic Cod in the Northwest Atlantic Demersal Longline Fishery" North American Journal of Fisheries Management 29:985–995, 2009 is **the best available science** on this topic and should be used as a primary reference for the assessment. Figure 2 clearly shows the survival of sub legal jigged cod is at approximately 90% for the cold water temperatures usually found in the GOM. Although "dead weak or injured fish" were not included in the study the percentage of cod jigged that would fall into this category would be very small. Most cod are caught in the mouth when jigged and only a small area where the hook penetrates is where the fish would be harmed. This study backs up our experience and states "Because only healthy jigged fish were selected, the calculated survival rate is for these fish only and does not take into account those that died and were discarded. That said, **it was rare to discard jigged fish, as most of them were vigorous when captured** and before caging. Regrettably, the number of jigged fish that were discarded was not recorded".

2. The Stock Assessment Working Group reviewed various studies and hypnotized how they may be flawed. We disagree with almost all of their assumptions made to invalidate the results of the various studies available. We will address each of the assumptions below:

   a) ***Handling***: Commercial cod jig fishermen typically use J style de-hookers. The cod is quickly unhooked and released over the side in one quick motion. The cod is typically not handled since the jig is held with one hand and the de-hooker in the other. The whole process takes split seconds and no slime is removed nor does the fish ever touch the deck.

   b) ***Impacts on growth due to reduced feeding ability***: This would be insignificant concern. Cod are voracious predators and will not be deterred from feeding. Several cod tagging studies for cod caught in the GOM have shown that cod continue to grow normally after captured and released. The small wound from a fish hook would very quickly heal.

   c) ***Whether predator avoidance was compromised or predator exposure was increased at release time (birds, mammals, other fish predators):*** Cod are essentially the chief predator for most of the year in the GOM. When they are found in abundance in the spring and early summer the only predator would be the porbegal shark. Since porbegal sharks are not common, the interaction between a recently released cod and these sharks would be extremely rare. Blue sharks are another potential predator (in the summer) but like porbegal sharks the interaction would also be very rare for a recently released cod. As far as any other predators (Birds, mammals, etc.) these interactions would be de minimus. Spiny Dogfish usually appear in the GOM in July after the majority of the spring cod have moved on with the baitfish. Spiny dogfish do not normally prey on sub legal cod of the size that are typically caught by jigging. Again any interaction between spiny dogfish and sub legal cod when using Handlines would be de minimus.

   d) ***"It was noted that studies where fish were held in cages to evaluate survival could be biased either high or low. On the one hand, being held in a cage reduces exposure to predation, which would inflate estimates of survival. On the other hand, the cage could induce stress, damage to fish from contact with the cage, and even mortality due to cannibalism—all factors that could potentially increase mortality".:*** We do not believe the cages in the various studies protected the cod from predation due to the low interaction between the cod and predators as mentioned above. We do believe there could be some increased mortality when the cod are kept in cages after being caught. The fish is stressed from being caught and then placed into a cage potentially causing more stress since the fish can't seek its preferred depth or temperature to recover naturally.

3. The Stock Assessment Working Group failed to adequately consider the "Activity and distribution of cod in the Ipswich Bay spawning area" Northeast Consortium 2005. Although this study did not deal with release mortality it should be noted that the cod for the study were caught using a trawl. The fish were sedated, operated on to insert DST tags, and released. Even with the stress encountered during this study, the recapture rate was 15.5% and some cod traveled 48km with some recaptures 757 days later. I personally participated in this study and I was quite amazed with the ability for cod to recover from the process of inserting a DST tag into the belly of the fish. **By observation one can infer this process would be much more stressful on a cod then catching cod using Handlines.**

4. The Stock Assessment Working Group failed to adequately review the various tagging studies for GOM cod such as the "Northeast Regional Cod Tagging Program (NRCTP)" and other cod tagging studies that may have used handlines to tag cod. There may be a wealth of information that can be obtained by reviewing the percentage of cod tagged that were returned using handlines. It should be obvious that if a cod was tagged, traveled many miles and was recaptured years later that it is not logical to assume 100% discard mortality. **How can a successful cod tagging study be possible if they all die after being caught?**

The members of the NEHFA are asking you to fully reject the 100% discard mortality values used for commercially caught cod using handlines and I would suspect that the 100% discard mortality for recreationally caught cod is also an inappropriate value. Accepting the 100% discard mortality of hook and line caught cod flies in the face of conservation. We request that you ask the working group to go back and try again. This time it is suggested that experience handline fishermen should have a seat at the table as a member so their experience and wealth of real knowledge can utilized to hopefully to produce a GOM cod assessment that can be accepted by all. **This is a very significant issue** with the introduction of catch shares fishery Management. The implications are that the NMFS may use the 100% discard mortality and quotas may be cut in half. **It would be absolutely wrong to assume every cod that is caught by using a handline ends up dead.**

988 MILLIKEN ET AL.

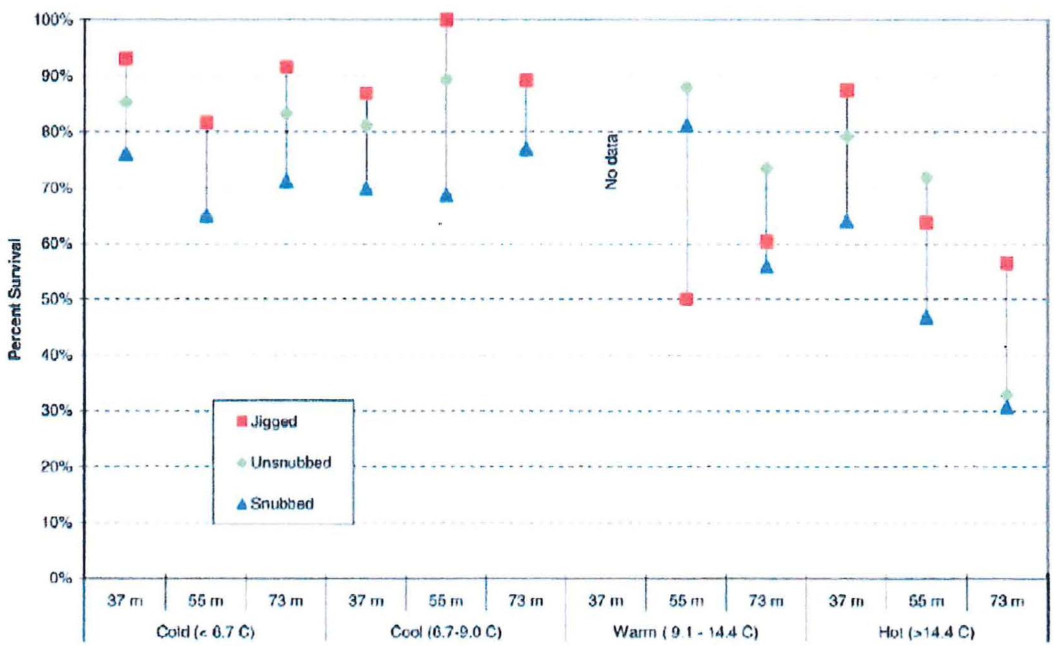


FIGURE 2.—Survival of sublegal-size Atlantic cod by depth of capture, sea surface temperature, and capture or dehooking technique.

Respectfully,

Marc Stettner

NEHFA MEMBERS: Christopher DiPilato, Paul Hoffman, Hilary Dombrowski, Scott Rice, Ed Snell, Marc Stettner

If you are a holder of a groundfish HA permit and wish to join the NEHFA, please contact the NEHFA at the address above.

Exploring Fine-scale Ecology for Groundfish in the Gulf of Maine and Georges Bank

ABSTRACTS

Genetic Insights into the Stock Structure of Atlantic Cod in US Waters, Adrienne Kovach
Collaborators: Adrienne Kovach[1*], Timothy Breton[2], & David Berlinsky[2], Isaac Wirgin[3], Lorraine Maceda[3], University of New Hampshire, Departments of Natural Resources[1] and Biological Sciences[2], Durham NH, [3]New York University School of Medicine, Dept. of Environmental Medicine, Tuxedo, NY

Marine species have long been viewed as open, panmictic populations with high connectivity, owing to their vagile, pelagic larval stages and the high migratory potential of adults. This classical view of marine species was supported by tagging studies, which demonstrated long distance migrations, and by early genetic studies that revealed high levels of gene flow, as expected for a marine environment considered to be free of dispersal barriers.

Recently, there has been a paradigm shift in the view of the population structure of marine species, articulated by a review by Hauser & Carvalho (2008). Overwhelming evidence now points toward the existence of population structure on fine geographic and temporal scales. A growing body of literature emphasizes the importance of process, such as sedentary life history strategies, spawning site fidelity, natal homing, adaptations to local environmental conditions, and ocean currents and bathymetric features promoting egg and larval retention; the effect of these processes is to limit dispersal and promote self-replenishment of local populations, leading to subdivision and potentially reproductive isolation. Additionally, evidence of multiple life history strategies within a population, such as temporally divergent spawning behaviors or inshore *vs.* offshore migration patterns, have also been linked to fine-scale population structuring in cod, herring and other marine species.

The implications of the different paradigms are significant for management. The current management models are typically based on the "old dogma" of panmictic populations, and do not consider fine-scale population structure. Stocks encompass large geographic regions with multiple oceanographic features and may be comprised of individuals with potentially different life history histories. As such, their boundaries may not have a biological basis. This may be true for cod in U.S. waters, which are currently managed according to a two stock model, consisting of (1) a Gulf of Maine stock and (2) a stock comprised of Georges Bank and areas southward, from southern New England to the mid-Atlantic coast. Evidence inconsistent with the current management model includes movement data from recent tagging studies (Tallack and Whitford 2008) and genetic data (Lage et al. 2004, Wirgin et al. 2007).

In our previous work (Wirgin et al. 2007), we found heterogeneity within the Gulf of Maine, stemming from temporally divergent inshore spawning populations. A spring spawning population in Ipswich Bay was genetically

distinct from winter-spawning cod from all other sites within the Gulf of Maine (including the same bay), Georges Bank and sites in southern New England. We also found that cod spawning on the northeast peak of Georges Bank are differentiated from populations south of Cape Cod, consistent with an earlier finding by Lage et al. (2004). Whether these differences were stable over time, or merely reflected variation among cohorts or plasticity in spawning behaviors, remained an open question.

In the current study, we expand on our previous efforts with increased and replicated sampling over time, in order to develop a model of population genetic structure of cod in US waters. *Our objectives were to 1) identify and sample all current spawning aggregates, 2) characterize the fine-scale population structure of spatially and temporally separated spawning aggregates, 3) investigate the temporal stability of the genetic structure, using replicate samples collected over a 2-5 year period, and 4) determine whether young of the year fish sampled on juvenile nurseries could be assigned definitively to their populations of origin.*

This research was truly collaborative in nature, not only with respect to contributions to the genetic analyses from both UNH and NYU, but also with respect to the sample collection. The latter involved numerous commercial fisherman, supported by the collaborative research program of the Northeast Consortium, recreational fisherman, and fisheries biologists from the Massachusetts Division of Marine Fisheries, Canadian Department of Fisheries and Oceans, and also a partnership with the University of Massachusetts-Dartmouth School for Marine Science and Technology.

During December 2005 – July 2008, 1488 adult cod were captured via otter trawl, gill net or hook and line; a fin clip was taken for genetic analysis. We targeted spawning fish from the following sites: northeast peak of Georges Bank, the inshore Gulf of Maine in Ipswich Bay, Massachusetts Bay, and Bigelow Bight, ME, the offshore Gulf of Maine at Jeffrey's Ledge and Stellwagen Bank, and south of Cape Cod from Nantucket Shoals, and Cox Ledge. At Ipswich Bay, Massachusetts Bay and Coxes Ledge, distinct spawning aggregates were identified and sampled in both the spring and winter. Additionally, adult fish not in spawning condition were sampled from Ipswich Bay, Platts Bank (offshore ME) and New York Bight. Six of the spawning aggregates were sampled in 2 subsequent years, enabling a test for stability in the structure.

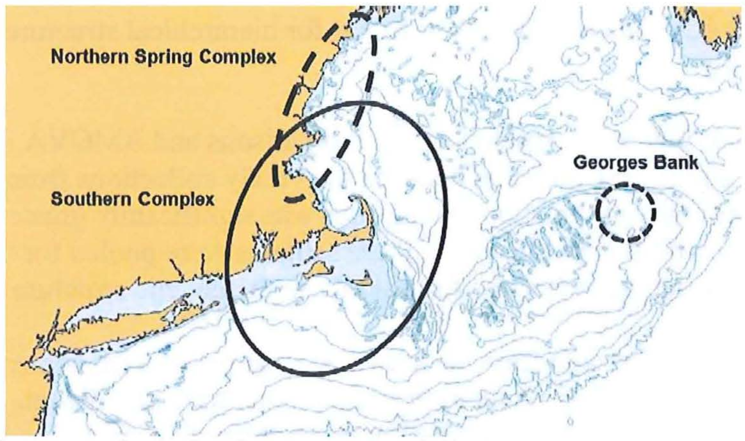
Genetic analysis of the fin clip-extracted DNA was performed using a panel of 10 microsatellite markers (*Gmo*02, *Gmo*132, Brooker et al. 1994; *Gmo*19, *Gmo*35, *Gmo*36, *Gmo*37, Miller et al. 2000; P*Gmo*32, P*Gmo*34, P*Gmo*38, and P*Gmo*58, Jakobsdóttir et al. 2006), and 6 SNPs (Pantophysin I (*Pan* I), Pogson et al. 2001, *AHR6*, *ARNT8,* Wirgin et al. 2007*, and ARNT1*, *CYP5*, and *K ras,* characterized in

this study). Several statistical population genetic methods were employed to analyze the genotypic data, including F-statistics ($F_{ST,}$ a measure of genetic variation among populations), allelic differentiation exact tests, and molecular analysis of variance (AMOVA), to test for hierarchical structure and temporal variability.

Results of pair-wise population F_{ST} comparisons and AMOVA indicated there was no significant variation between the yearly collections from the same sample locations and that variation among sites was significantly greater than annual variation within sites; therefore, these samples were pooled for further analysis. These findings are evidence for stability in the genetic structure over time.

When the pooled data from all spawning aggregates were compared by pair-wise F_{ST} analysis, 16 of 45 population comparisons were significant. The primary source of differentiation occurred between the spring spawning coastal aggregates of the inshore Gulf of Maine (Ipswich Bay, Massachusetts Bay and Bigelow Bight) and sites in the offshore Gulf of Maine, winter spawning inshore Gulf of Maine and southern New England sites (Nantucket and Cox Ledge). Additionally, Georges Bank was strongly differentiated from the southern sites. The significant F_{ST} values ($P<0.001$, following Bonferroni adjustment) ranged from 0.0071 – 0.0156, consistent with findings from other studies reporting weak, but significant differentiation for cod in European and Canadian waters (Beacham et al. 2002, Westgard & Fevolden 20007) over similar small geographic scales. Evaluation with the less conservative $p <0.01$ and the exact tests yielded 13 additional, significant comparisons for F_{ST} values in the range of 0.0017 – 0.0076, consistent with the level of fine-scale structuring documented among adjacent fjords in Norway (Jorde et al. 2007). Visualization of results with a principle coordinate analysis (PCA) demonstrated that the spring spawning inshore GOM sites clustered separately from the winter spawning inshore GOM, offshore GOM and southern sites, with Georges Bank positioned somewhat intermediately. Comparison with our data from 2003-2005 of Wirgin et al. (2007) showed consistency in the genetic composition of sites sampled in both studies, further supporting the temporal stability of the population genetic structure we identified.

The majority of the genetic variation in this study can be explained by three major groupings: a <u>northern spring coastal complex</u> that consists of spring spawners in coastal GOM, a <u>southern complex</u> that consists of winter spawners in coastal GOM and winter and spring spawners in the offshore GOM and southern New England, and the <u>northeastern Georges Bank</u> spawners (see figure). The Georges Bank population was strongly differentiated from the southern sites, and only weakly so from the inshore GOM and similar to the offshore GOM. In addition to the significant variation among the complexes, we also found significant variation within complexes ($p<0.0001$, using AMOVA, molecular analysis of variance), indicating the presence of finer scale population differentiation.



We consider several mechanisms as potentially important in generating the fine-scale genetic population structure that we observed. 1) Temporal differences in spawning may have a genetic component, rather than being plastic (Bekkevold et al. 2007); this is further supported by studies of captive populations that continue to spawn at divergent times, despite similar environmental conditions (Ottera et al. 2006). 2) The genetically divergent populations may exhibit alternate resident and migrant strategies (Robichaud & Rose 2004). Howell et al. (2008) recently showed that most spring-spawning cod in Ipswich Bay are sedentary residents. The winter spawning and offshore populations may be more migratory. 3) Spawning site fidelity may be common, but some individuals may exhibit natal homing, which facilitates reproductive isolation, while others may behave like "adopted migrants" (McQuinn 1997), whereby they follow the migratory behaviors of nearby populations to which they disperse and recruit as juveniles. 4) Environmental forces that affect the dispersal of early life stages or the migrations of adults may differ among seasons or for inshore *vs.* offshore. For example, larval dispersion models have shown that wind patterns in the GOM in the spring and summer favor local retention, while those in the winter may force larvae to drift with the currents offshore (Jim Churchill, Woods Hole Oceanographic Institute, personal communication). 5) Lastly, the genetic structure revealed by the markers today reflects a historical signal in the data set, such as postglacial population expansion; the low genetic differentiation in general may reflect a relatively recent history of Atlantic cod populations (Pampoulie et al. 2008).

The majority of the genetic differentiation in this study can be attributed to 2 highly informative markers, *Pan* I and *Gmo*132, which had much higher per locus F_{ST} values than the other markers (0.038 - 0.109 and 0.028 – 0.043 for *Pan* I and *Gmo*132, respectively, in comparison to 0.0012 for the mean of the other loci combined). These two markers have been previously shown to be under selection (Nielsen et al. 2006, Pogson 2001), in contrast to most genetic markers used in

population studies, which are presumed neutral. Results of F_{ST} outlier selection tests confirmed that these loci were under selection in our study as well. The differentiation of the major spawning groups could be explained by differing allele frequencies of the *Pan* I A allele, which was higher in the northern spring complex than the southern complex or Georges Bank, and the *Gmo*132- 117 and 135 alleles, which differed in the southern complex relative to the northern spring complex and Georges Bank.

It is suspected that *Gmo*132 is linked to a gene with unknown function ("hitch-hiking selection"; Nielsen 2006). *Pan* I is located in a gene that codes for a protein found in the membranes of microvesicles (Pogson 2001), but its relevant function in fish is unknown. *Pan* I A & B allele frequencies follow different patterns across the range of cod. Variation at *Pan* I has been correlated with numerous factors, including temperature, salinity, depth, growth and migratory behaviors. The covariates, however, differ among geographic locations; for example, while the *Pan* I A allele has been linked to warm waters in Norway (Westgard & Fevolden 2007), in Iceland it's the Pan B allele that dominates under those conditions (Pampoulie et al. 06). In our study, no consistent pattern was evident for temperature, salinity or depth in relation to the observed genetic variation, and the variation in these potential factors was small among our populations. A correlation of the *Pan* I B allele with offshore migrations or spawning has been found in populations in Norway, Iceland and Canada. This relationship is consistent for our study, in that populations with the highest *Pan* I B allele are found in the southern complex and Georges Bank, the populations that spawn offshore or are most likely to undertake offshore migrations. However, the differences in allele frequencies were small, with the frequency of the *Pan* I B allele occurring at 0.85-0.90 in the northern complex and near fixation in the southern complex and Georges Bank. A correlation with growth cannot be ruled out, as size differences have been documented for the GOM vs. other populations (Tallack & Whitlock 2008), however, to our knowledge growth data do not exist for the seasonally divergent spawning groups.

In conclusion, we found strong evidence for population genetic structure that is not consistent with the 2-stock management model. Cod in US waters are broadly structured into 3 groups: 1) a northern spring spawning coastal complex in the GOM, 2) a southern complex consisting of winter-spawning inshore GOM, offshore GOM and sites south of Cape Cod, and 3) a Georges Bank population. These groups are temporally stable and the magnitude of genetic differentiation, while not large, is sufficient to assign juveniles to their population of origin via mixture modeling. Genetically distinct groups overlap spatially in the inshore GOM, but are separated by temporal divergence in spawning behavior. We also found evidence of finer-scale structuring within the southern complex. Our results also support earlier findings that the Great South Channel may be influential in separating populations on the northeast Georges Bank from those south of Cape Cod. We suggest that several mechanisms are operating simultaneously to produce the population structure. Our finding that the majority of the differentiation is attributed to two non-neutral loci, points to the importance of local ecological adaptations. The particular selective forces shaping the adaptive divergence, however, are yet unknown and warrant further study.

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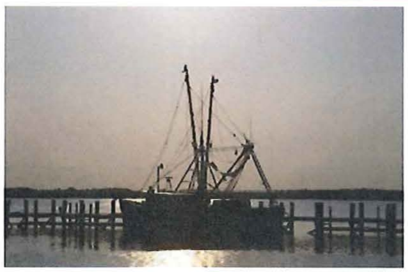
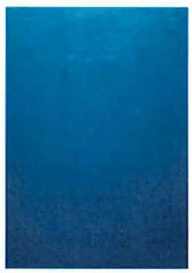
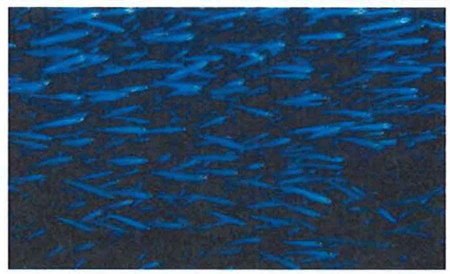
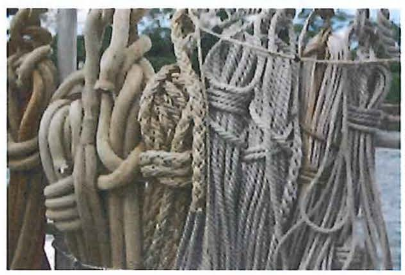
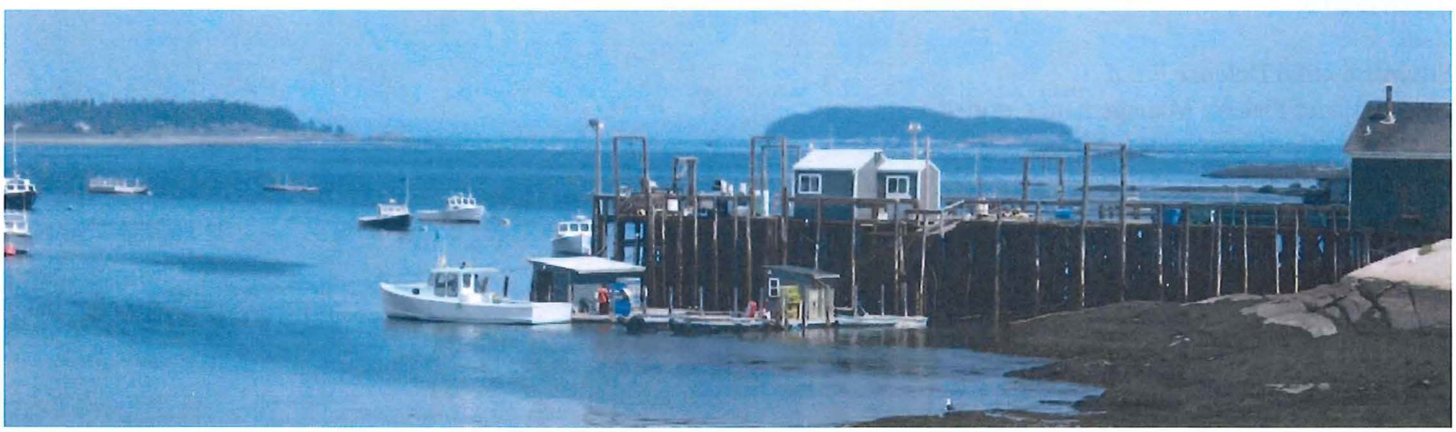
A report on the workshop:

Reconciling Spatial Scales and Stock Structures for Fisheries Science and Management







June 27-28, 2011
Sheraton Harborside Hotel
Portsmouth, N.H.

This report is a summary of the workshop "Reconciling Spatial Scales and Stock Structures for Fisheries Science and Management" held in Portsmouth, New Hampshire, on June 27-28, 2011. The workshop was convened by New Hampshire Sea Grant and the Northeast Consortium as a public forum to discuss how emerging data on fish stocks might be used to better manage fisheries. Rather than summarize each talk, poster and discussion session individually, this report organizes outcomes within the three key questions that participants focused on. This document should not, however, be considered a consensus statement of all presenters and attendees.

Organizing Committee:

Dr. Michael Armstrong, Massachusetts Division of Marine Fisheries
Dr. Steve Cadrin, University of Massachusetts
Aaron Dority, Penobscot East Resource Center
Rachel Gallant Feeney, Northeast Consortium, Workshop Co chair
Capt. David Goethel, *F/V Ellen Diane*
Dr. Jake Kritzer, Environmental Defense Fund
Dr. Kenneth J. La Valley, New Hampshire Sea Grant College Program, Workshop Co chair
Melissa Sanderson, Cape Cod Commercial Hook Fishermen's Association
Dr. Fred Serchuk, NOAA Fisheries Northeast Fisheries Science Center
Dr. Robert Steneck, University of Maine
Melissa Vasquez, NOAA Fisheries Northeast Regional Office
Dr. Jim Wilson, University of Maine

Sponsors:

Environmental Defense Fund
New England Fishery Management Council
New Hampshire Sea Grant College Program
Northeast Consortium
Penobscot East Resource Center
The Nature Conservancy
University of New Hampshire Cooperative Extension

Report Preparation:

This summary report was compiled and edited by Rachel Gallant Feeney and Dr. Ken J. La Valley in consultation with the Organizing Committee and several workshop participants. Report design and layout are by Rebecca Zeiber, New Hampshire Sea Grant.

Introduction

Photo credit: Rebecca Zeiber/NHSG

Photo credit: Rebecca Zeiber/NHSG

Capt. Paul Howard, Executive Director, New England Fishery Management Council

Marine spatial management has been an essential tool for fisheries conservation, stock rebuilding and gear conflict resolution in the Northeast. However, the National Ocean Policy, the Bureau of Energy Management, Regulation and Enforcement (BOEMRE) Task Force, and the movement towards ecosystem-based fisheries management (EBM) are driving fishery managers, scientists, fishermen and other stakeholders to better coordinate efforts and consider systems more holistically.

The National Ocean Policy, adopted July 2010, established, among other things, the National Ocean Council (NOC), regional planning bodies to coordinate ocean management, and priority objectives towards ecosystem-based management. Recently established by the governors of the five New England states, the Northeast Regional Ocean Council (NROC) will likely be charged by the NOC to develop and implement a coastal marine spatial management plan for our area. This plan is to be submitted to the NOC for certification by 2015.

The fishery management councils can add tremendous value to regional planning under the National Ocean Policy due to their 30-year history of marine resources management mandated by federal law, including use of best-available science, inclusion of public input, representation of stakeholders and, more recently, movement towards ecosystem-based fisheries management. However, the NOC has denied the requests of the regional councils to be members of the regional planning bodies, citing a need for "more thoughtful consideration and analysis." Having only a consultative role for such an important ocean use — commercial and recreational fisheries — is not adequate.

The National Ocean Policy was designed to coordinate federal activities. However, agencies are still striking out on their own. For example, the BOEMRE Task Force is looking at the spatial needs for a single ocean use — offshore wind energy. Due to the Federal Advisory Committee Act, federal entities can only receive advice from other federal entities. Therefore, the New England Fishery Management Council cannot be members of the BOEMRE Task Force. Nevertheless, the NEFMC is actively consulting with them about the areas being considered for wind development.

There are several benefits to the NEFMC to move towards EBM. First, it would simplify the current nine fishery management plans into potentially three based on ecosystem production units (Gulf of Maine, Georges Bank and Southern New England). A more comprehensive and coordinated approach to fishery interactions and ecosystem constraints on rebuilding stocks can be afforded by EBM. Smaller scale fisheries management can also enhance stewardship and the understanding and credibility of scientific data. A transition strategy and vision for this very difficult task of implementing ecosystem-based fisheries management is currently under consideration by the NEFMC, so this workshop could not have come at a more opportune time.

Overview

Fishermen and scientists are continually learning that stock boundaries of marine species are not always what was once thought. Fishery managers often face dilemmas when ecological and management boundaries do not coincide. This public workshop explored how fisheries managers can better use data on stock structure and ecological processes in achieving sustainable fishery resources. Costs and benefits of using increasingly detailed data in management were discussed. Events such as this afford opportunities to take a step back, examine the progress made to date, identify future needs as fisheries and management approaches continue to change, and determine how to best meet present and future needs.

In addition to this final report, documentation of the workshop includes the posting of presentation slides with audio recordings on the Internet, linkable from the websites of the Northeast Consortium and New Hampshire Sea Grant. Also, preparations are under way for a special issue of the journal *Fisheries Research* to feature about 12 articles on the topics submitted by the oral and poster presenters from the workshop. We aim for these to be helpful tools for the region as stakeholders seek to continually improve fishing, research and resource management.

Key Questions

Q1: *What do we know and what progress has been made?*

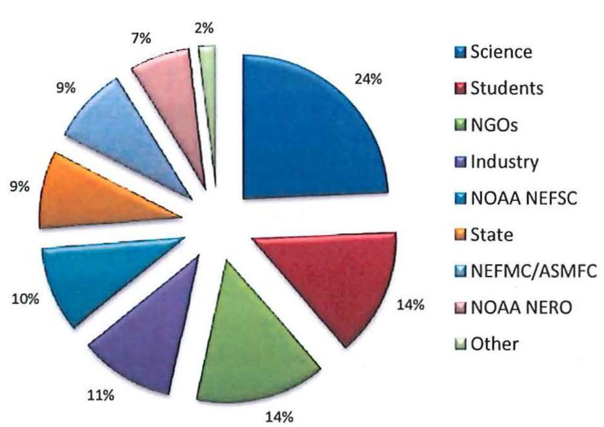
Q2: *What do we need to know and how will we get there?*

Q3: *What are the social incentives, benefits and risks of alternative management scales?*

Participants

More than 115 fisheries stakeholders attended the two-day workshop. Attendees included commercial fishermen, fishing sector managers, government and academic scientists, fishery managers, students and representatives of non-governmental organizations.

Affiliation of Workshop Attendees



Geographic Distribution of Workshop Attendees

U.S.		
	Massachusetts	46%
	Maine	28%
	New Hampshire	14%
	Rhode Island	3%
	Washington, D.C.	2%
	California	1%
	Connecticut	1%
	Maryland	1%
	Michigan	1%
	New Jersey	1%
	North Carolina	1%
Argentina		1%

Q1: What do we know and what progress has been made?

Photo credit: Rebecca Zeiber/NHSG

"The burden of proof is on the fisheries scientists for proving that changing the scale of management is warranted. There needs to be careful evaluation to identify when adding resolution will improve the assessment and sustainability of the resource."
– federal scientist

Identify evidence of spatial scale structure of populations and ecosystems and provide examples where such spatial scales have been successfully incorporated within a management context.

The assumed paradigms about the patterns of fish populations in northeast U.S. waters are changing as fisheries science matures. The spawning site fidelity of Atlantic salmon, once considered the exception, is becoming the rule as we better understand the life history parameters of more species. Stocks of several species intermix, particularly while feeding, and the Great South Channel seems to be where the boundaries of many stocks converge. Although we now see evidence of population connectivity, the challenge is to measure it quantifiably.

When the modern era of fisheries management began in the 1970s, administrations, jurisdictions and data collection systems were designed based on the prevailing theory of the day — that species' distributions were broad and homogeneous. With improvements in stock identification, there are increasing examples of mismatches between the scale of biological population structure and the management units. Assessing and managing several independent populations as a metapopulation (or the reverse) can lead to biases in stock assessment, resulting in reduced stock biomass estimates and a high probability of overexploitation. However, it is very difficult to fit fine-scale data into a system that is based on a broad theory. The resulting mismatch can lead to misperceptions of the magnitude and distribution of population productivity.

Stock unit definitions are not set through the fishery management plans, but rather they come out of the stock assessment process. The management plans in New England tend to not consider interrelationships among species other than technological (bycatch), because those relationships have been difficult to quantify in the assessment process. A few attempts have been made to use dynamic management, such as a flexible area access system adopted in 1992, but there have been difficulties in implementation, such as assimilating near real-time biological and fishery data.

Why do we manage at the scales that we do? The Magnuson-Stevens Fishery Conservation and Management Act mandates that a stock will be managed as a unit throughout its range. Just because finer-scale stock structures are emerging from the data, the whole science and management system does not necessarily need to be overhauled. Careful evaluations of the costs and benefits of incorporating new information are needed. Simulation models are a useful tool for exploring the potential consequences of having a mismatch between biological and management scales.

Fisheries management can be best described as an experiment. There is a tremendous amount that we have learned and mistakes have been made along the way, but we need to learn more. It is a collective enterprise and we have to think about how we design the experiment as carefully as possible. The following are a few case examples highlighted at the workshop of how our knowledge of the spatial structure of fish populations is being refined and how that information is (or is not) being used to more effectively manage fisheries.

Q1: Case Examples

Atlantic Cod

The solution to rebuilding depleted cod stocks in New England has been evasive, but persistent research using a broad range of approaches is beginning to shed new light on finer-scale population dynamics than were once accepted. More evidence is emerging that cod express spawning site fidelity, such that the preservation of the remaining spawning activity might be critical to the long-term productivity and sustainability of the stocks. As a result, there is heightened concern today about local extirpation of cod populations.

The "cod problem" is no more evident than in the eastern waters of the Gulf of Maine, where despite virtually no fishing for cod in about two decades, cod have yet to recover. Formerly, the inshore Gulf of Maine was a mosaic of spawning areas, but today spawning areas are concentrated in southwestern areas. The prevailing paradigm has been that cod from the Western Gulf of Maine would re-populate eastern areas, but tagging, genetics, oceanographic and other studies suggest that the eastern area is more connected with the Bay of Fundy. It may take a longer time frame to rebuild this area than was once hoped due to natural oceanographic and biological processes.

Some cod stocks are rebuilding, particularly in southern New England and Western Gulf of Maine waters. Tagging combined with genetic analyses show more connectivity of cod between these two areas than with Georges Bank. Rolling closures that were established in the late 1990s to reduce fishing mortality have incidentally protected cod spawning aggregations in several federal areas. However, recreational vessels and state waters are exempt from the rolling closures. As cod stocks rebuild, there is a resurgence of spawning areas that become very attractive areas to fish on. Massachusetts has implemented small-scale closures within state waters for spawning protection in addition to what the federal rolling closures provide. The transition to sector management for groundfish has raised discussion about relaxing the rolling closures. From a mortality point of view, this makes sense because mortality is now controlled by hard quotas, but we need to be mindful about the implications for spawning protection.

"Targeted closures to protect spawning will benefit us all. Cod and haddock need to be left alone, else the spawning is interrupted."

– fisherman

Photo credit: Rachel Feeney/NEC

"In general, fishermen think that there are more fish in the ocean than the scientific community has defined. Today, the catch per unit effort for cod and pollock in the Western Gulf of Maine is as high as they can remember. That wasn't the case 10 years ago."

– sector manager

Q1: Case Examples

"Management units should be consistent with biological processes. The spatial structure of populations affects how they respond to management and harvest."
– state biologist

"We currently have a patchwork of spatial and temporal management actions."
– manager

"There was a great long-line fishery for haddock and cod from 1980 to 2002 off of Chatham involving 40-50 boats. Today, there are only four boats. Also, the Area 1 haddock SAP [Special Access Program] let us have an experimental fishery. The first year was really good, but the next year we caught half as much, and just a few fishermen are now fishing there. I see fish come, go and change a lot. The fish move up and down the coast."
– fisherman

Herring

In general, there are greater dispersal barriers and genetic distinctions in fresh water and anadromous environments than in marine systems; such is the case for river herring and Atlantic herring. For management purposes, the total allowable catch of Atlantic herring is allocated into four management areas, roughly reflecting the inshore and offshore composition of the herring stock complex. In addition, inshore seasonal spawning closures in state waters restrict fishing activities to protect spawning herring. New management strategies under development for coast-wide river herring stocks also attempt to capture the underlying seasonal spatial distribution of the species. River herring is listed federally as a "Species of Concern," so managers must minimize bycatch of these stocks to aid in their recovery. To understand where river herring bycatch has occurred at sea in the Atlantic herring fishery, a spatial analysis of fishery-dependent data has defined smaller units than the statistical areas to manage. Bottom trawl data from NMFS surveys are being used to find other areas where river herring could be encountered. Spatial and temporal options are being developed to monitor and avoid river herring based on local abundance thresholds.

Lobster

Lobster management is anything but simple. There are seven Lobster Conservation Management Areas that are designed to maintain the culture and history of lobster management, but there are three stock units that are based on statistical areas that do not necessarily match the population dynamics. The potential for mismanagement is high with so many jurisdictional and biological boundaries crossing each other. The 2009 stock assessment concluded that there is lobster recruitment failure in southern New England, which contains part or all of six of the seven management areas. Managers are now considering a five-year moratorium on the fishery in the south. Managers have been warned about the southern stock for nearly a decade, but limited progress has occurred. Another misalignment is the offshore management area, which contains three stock units. How do you craft one set of regulations to account for the varying conditions over the range?

Striped Bass

One fishery where the biological and management units are aligned is striped bass, and it is likely no coincidence that it is a fairly successful fishery. The Atlantic States Marine Fisheries Commission formed in 1942 out of the need to better coordinate the spatial management of migratory coastal stocks. The Commission manages striped bass as one stock with individual production areas from North Carolina to the Canadian border. The bulk of the stock (75-80%) is based in the Chesapeake Bay, and there are unique harvest restrictions for the Bay because of the degree of resident fish. Striped bass is one of the most successful fishery rebuilding efforts in recent history based on catch rates and young of the year indices.

Q1: Case Examples

Rainbow Smelt

Genetic data can improve our understanding of biological structure and help converge the spatial scales of populations and management units. Anadromous fish tend to be philopatric, characterized by local larvae retention and natal homing that can lead to population structuring on scales local to rivers or estuarine retention zones. Population divergence results from lack of gene flow in philopatric systems, but can be homogenized by straying. The challenge is identifying the level of philopatry relative to straying, which varies among species, populations and geographic regions. Rainbow smelt is a "Species of Concern" in the Northeast U.S., only found from Downeast Maine to Buzzard's Bay, Mass. A recent NMFS Proactive Species Conservation Program has focused on increasing our understanding of smelt population status and structure, including genetic diversity and variation. Rainbow smelt do not spend much time in freshwater. Adults spawn just above the head of the tide and larva are swept downstream to develop in near-coastal waters. In this study of smelt from 18 rivers in the Northeast, genetic differentiation was found to be on the low end for andromous fish, potentially as a result of the short amount of time spent in natal rivers and retention zones, and on a scale larger than that of individual estuaries or bays. Five genetically distinct groups of smelt were identified, with genetic differentiation overall strongly correlated with geographic distance. Weak river-level structuring was also evident with high gene flow among adjacent rivers, suggesting widespread straying. The most genetically unique smelt were located within topographically distinct features, such as capes or enclosed bays, suggesting that geomorphic features influence larval retention. Genetically divergent populations are important to identify for proactive management as they may be more susceptible to perturbations. Understanding the factors that influence the population structure aids our ability to manage spatially appropriate population units.

Winter Flounder

Although winter flounder exhibits fine-scale population patterns, this species is managed and assessed broadly as three unit stocks: Gulf of Maine, Georges Bank and Southern New England/Mid-Atlantic. In 2008, the biomass of winter flounder in the southern New England stock was estimated to be at a record low, and the fishery in this region has been closed since 2009. Despite the closure, rebuilding has been slower than expected in many regions of Southern New England. However, results from a recent industry-based survey suggest that a large biomass of winter flounder is present in this area, indicating that winter flounder in the Great South Channel are exhibiting much greater productivity than elsewhere in the Southern New England stock. From fishermen's knowledge and historical tagging studies, we understand that the winter flounder in the Great South Channel likely represent a mix of stocks, adults that migrate in seasonally and resident spawning fish. Fishermen have advocated that winter flounder in the Great South Channel should be managed as a distinct stock. This may benefit fishermen and improve management.

"Fish have changed their migratory patterns. Yellowtail are more concentrated in deeper water. Winter flounder spawn near shore, but not in estuaries like we thought. Haddock have pulled away from shore. About 30 fathoms is the shallowest you'll see them."

– fisherman


Photo credit: Jason Goldstein UNH

"In fisheries management, identifying conservation units based on the scale of biological processes is of critical importance because spatial structure affects how populations respond to management actions."

– university scientist

Keynote Speaker

Dr. Simon Thorrold, Senior Scientist, Woods Hole Oceanographic Institution
"Population connectivity and the spatial scales of population structure in marine fishes"

The more we look, the more we find in terms of fine scale population structures. Understanding population structure is a necessary prerequisite for effective spatial management of marine fish. However, the spatial extent of an entire meta-population may be of less significance to spatial management than connectivity rates among geographically isolated sub-populations. Spatial management of marine fish populations depends on the following fundamental questions: Where did spawning occur? Where did the population grow up? Is there natal homing? We can understand connectivity intuitively, but it depends on the life history of the fish itself, and the problem is that we cannot track individuals through their full life history. The question we are beginning to address is where on the larval settlement continuum a population exists, between closed (natal homing) or open (random settlement).

Mathematically, we can create models that calculate the probability matrix of settlement, but the challenge is to test their accuracy by measuring connectivity in the field. To provide direct estimates of population connectivity, either through natal homing or larval dispersal, two studies are shedding new light on the degree of fine-scale population structure in the ocean. In the first, we used otolith geochemistry as a natural tag to retrospectively determine natal origins of spawning weakfish (*Cynoscion regalis*) collected from five major estuaries along the U.S. East Coast. There is much more population structure, as evidenced by natal homing, than was implied by any of the conventional genetic approaches. Adults spawn and larvae are retained in estuaries and embayments throughout its range from Florida to Maine. There is no genetic differentiation among adult weakfish, but isotopes from otoliths have identified natal homing areas. For managers, these results help confirm that the actions taken to protect spawning in a particular area will pay off for that same area in the long-run. Juvenile weakfish spend several months in natal estuaries, so it is not far-fetched to imagine that they can find their way back. This type of finding generates momentum for actions at local levels.

The second study examined larval dispersal of coral reef fish in Kimbe Bay, Papua New Guinea using TRAnsgenerational Isotope Labeling (TRAIL) and DNA parentage analysis. Mature females were injected with a barium solution that had a unique isotopic ratio, which was then incorporated into the eggs and thus the embryonic otoliths. This produces hundreds of thousands of tagged larvae. Fin clips have also been used for DNA parentage analysis and for identifying movement rates. Estimates of self-recruitment within a small marine reserve for both clownfish (*Amphiprion percula)* and butterflyfish (*Chaetodon vagabundus*) were similar (~50%), despite the fact that clownfish spawn demersal eggs with a pelagic larval duration of 10-14 days compared to 30-40 days for the butterflyfish. We have also tracked larvae of both species for distances up to 30 km from their natal reef, suggesting that at least some individuals do indeed disperse long distances. It was determined that the marine protected areas are large enough to sustain populations and that fish from those areas were traveling to open areas. About 60% of fish in the fishing zones are coming from the no-activity zones. This information is being used to inform and empower local stakeholders in the design and implementation of a comprehensive management strategy for the diverse coral reefs of Kimbe Bay. The fishermen are now seeing the benefits of protecting certain areas.

Taken together, these studies suggest that optimal spatial scales for most marine fish stocks are likely to be significantly smaller than those used currently in fisheries management. We still know remarkably little about fish movements, and comprehensive spatial management cannot occur without a basic understanding of movements. We also need to be aware of the limitations to data. Philopatry seems to be a defining characteristic of many marine fish. The more we use techniques to identify movements, the more homing patterns we see. The increasing evidence of homing patterns in fish populations is empowering local communities to make a difference, averting the "tragedy of the commons."

Q2: What do we need to know and how will we get there?

Identify critical information, processes, and scientific and managerial requirements needed to achieve fisheries management at appropriate ecological scales.

Alignment of fish population management with natural ecological processes may be an improvement upon traditional approaches and more appropriate within an ecosystem-based management context. However, moving from single species management — something that has been in place for several decades of evolving management plans — into more complex system governance is not a trivial proposal. Ecosystem-based management takes into account the interactions among the components of the ecosystem, which includes humans as one integral component. With limited available data and resources, how can we move in the direction of finer scale management or at least manage at more appropriate ecological scales? Do we understand the socioeconomic implications of doing so? Workshop participants were asked to identify critical information, processes, and scientific and managerial requirements needed to achieve fisheries management at appropriate ecological scales. Comments and individual perceptions were recorded and synthesized into three common themes: Fundamental Concerns, Data Requirements and Management.

Fundamental Concerns

Spatial management of marine fish populations depends on several fundamental questions: Where did spawning occur? Where did the population grow up? Is there natal homing? The problem becomes immediately clear — the science of today is unable to track the full life history of marine species. Intuitively, fisheries scientists understand that connectivity between spawning aggregations and current stock delineations are happening, but are currently unable to clearly identify these critical linkages. From these fundamental questions, common concerns were brought to light, questioning the need to manage at finer scales and if so, at what level (spawning aggregation, geographically and/or genetically separated units, etc.). What is the "point of diminishing returns" between gathering more data and taking a management action? There are trade-offs between precision with finer scale science versus meeting biological and management goals.

"We know remarkably little about fish movements, and comprehensive spatial management can't occur without a basic understanding of movements. Estimating connectivity is the biggest hurdle in spatial management."
– university scientist

"The question fisheries scientists can begin to address is where on the larval settlement continuum a population exists, between closed (natal homing) or open (random settlement)."
– university scientist

"When there is a mismatch in scale between biological and management units, a sustainable resource model is difficult to attain. We need to weigh the potential costs of changing assessment units with the costs of not doing so."
– federal scientist

Q2: What do we need to know and how will we get there?

"Genetic and isotopic techniques to identify population connectivity are expensive and time-consuming. We don't need this data on every species. We should be developing larval dispersal models on select and commercially important species."
– federal scientist

"We need to identify and protect additional spawning aggregations. The industry-based cod survey has produced several years of valuable data but has not yet been sufficiently used."
– state scientist

"We need to understand the relative contributions of spawning areas as a first step to determining the level of fine-scale management required for a given stock."
– state scientist

Data Requirements

Collaborative fisheries research has been a strong component of fisheries science in the Northwest Atlantic for more than a decade. Over this time, significant investments have been made in understanding fish movement and distribution patterns through tagging programs, fleet monitoring efforts and genetic analyses. In addition, bio-oceanographic analysis of primary productivity, larval dispersal and nutrient uptake has improved understanding of the dynamics of the Gulf of Maine ecosystem. In addition, substantial efforts have been undertaken to improve our understanding of historical spawning aggregations, fishing effort and changes in natal homing regions.

When asked "What do we need to know?" to manage at appropriate ecological scales, participants were quick to point out that rich data is available and that scientists need to re-visit and better utilize this data pool to consider finer scale systems approaches to management. However, critical "gaps" in our understanding of ecosystem processes were identified. More investment is needed to understand trophic level relationships, feeding and spawning linkages, source populations and mixing (connectivity). In addition, better tracking of commercial fishing effort on both spatial and temporal scales would improve biologists' understanding of stock movement and would greatly facilitate adaptive management approaches. Single-species management is counter to how multi-species fisheries function. Additional research to improve understanding of how fishing gear operates and how it impacts species, both individually and as a heterogeneous population, is needed.

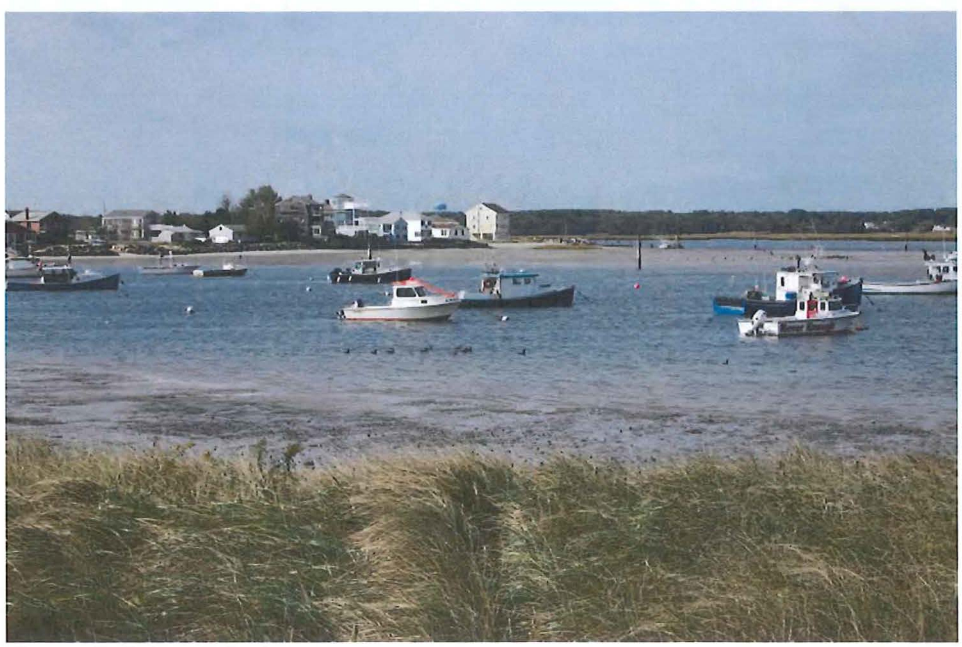


Photo credit: Rebecca Zeiber/NHSG

Q2: What do we need to know and how will we get there?

Management

Ecosystem-based management (EBM) is an innovative management approach that considers the whole ecosystem, including humans and the environment, rather than managing resources in isolation. This differs substantially from the current or traditional management system. In light of recent changes from the days-at-sea paradigm to resource allocation, fisheries scientists' understanding of stock connectivity and trophic level dynamics will be important for the sustainable management of Northwest Atlantic fisheries to move forward. In fact, the 2010 National Ocean Policy identified EBM and marine spatial planning as the primary tools for ocean resource management. In order to move towards finer-scale or ecologically appropriate controlling units, managers must have clearly articulated and evaluatable goals. What is management trying to manage — a population, a stock or a spawning component? With clarity, assessments can be tailored and reflective of a more dynamic system. Participants were concerned that, when faced with immediate concerns, management and science may ignore complex population structure in lieu of a more practical homogeneous stock assumption. Another common discussion point was the need for a more flexible management structure that would allow for adaptation to dynamic ocean processes.

Photo credit: Rebecca Zeiber/NHSG

"When the multispecies plan was adopted in the mid-1980s, it was an effort to move away from the single species management box; we do multispecies management with single-stock constraints. Those constraints aren't going away, but only increasing with finer scale information."
- management staff

"We need a clear vision and leadership from the New England Fisheries Management Council."
- fisherman

"There needs to be regular strategic evaluation of spatial management as part of biological, social and economic impact assessments."
- management staff

Keynote Speaker

Dr. Michael J. Fogarty, Research Fish Biologist, NOAA Fisheries Northeast Fisheries Science Center

"Spatial considerations for ecosystem-based fishery management on the Northeast U.S. Continental Shelf"

The National Ocean Policy (2010) puts ecosystem-based management and marine spatial planning as primary tools for ocean resource management, and the Northeast Fisheries Science Center is designing a "roadmap" toward that end. One step is to identify spatial management units based on the ecological production units of the Northeast Continental Shelf. We currently have geographically specified stock structures that remain at the heart of management plans, but there are a large number of potentially different definitions of the geographical extent of stocks. For the historical catch data, the finest spatial scale we have is 10 minute squares (~100 square miles), but these boundaries are not ecologically relevant; there is strong evidence of finer scale processes. We need to consider nested or hierarchical spatial scales that would take into account the protection of concentrations of vulnerable species (e.g., cold water corals, sea turtles, etc.).

For a more integrated approach to defining spatial management units, a number of variables need to be incorporated. The physiographic variables include bathymetry and surficial sediments. The physical oceanographic and hydrographic measurements include sea surface temperature, annual temperature span and temperature gradients. The biotic measurements include satellite-derived estimates of chlorophyll-a and primary production. Chlorophyll gradient metrics are included to capture frontal zone positions. We employed principle components and K-means cluster analyses to define spatial units, and the results showed seven major ecological production units on the shelf including: Eastern Gulf of Maine-Scotian Shelf, Western-Central Gulf of Maine, Inshore Gulf of Maine, Georges Bank-Nantucket Shoals, Intermediate Mid-Atlantic Bight, Inshore Mid-Atlantic Bight and Continental Slope (Cape Hatteras to Georges Bank).

We suggest a spatial management structure that consolidates ecological subareas so that nearshore regions are considered special zones nested within the adjacent shelf regions and have similar treatments as the continental slope regions. This leads to four major units that could form the base of management plans: Mid-Atlantic Bight, Georges Bank, Western-Central Gulf of Maine and Scotian Shelf-Eastern Gulf of Maine. A transition to place-based management strategies under the tenets of ecosystem-based fishery management will also require harmonizing the emerging perspectives on population structures with the broader context of ecological production units that may serve as potential spatial management units.

With the increasing ability to track and map where fleets are operating, we can better integrate the human and ecological aspects of the situation. We need to find common spatial frames of reference that would meet multiple objectives together, such as combining right whale exclusion zones and fishery closed areas. We need to consider how gear operates and how it impacts species, both individually and as a heterogeneous population. Single-species management runs counter to the way that the fisheries operate — on a mix of species. We need a multispecies perspective right from the start. If sectors operate as cooperatives and share information, they can help identify where choke species occur and help avoid them. We can take advantage of fishermen's wisdom to avoid problems.

Q3: What are the social incentives, benefits and risks of alternative management scales?

Given fine-scale stock structure patterns, what types of fisheries management approaches will maximize our knowledge about ecosystem structure and function? Specifically consider consequences of management units that are too large vs. those that are too small. Identify the potential impacts on access and utilization of catch allocations by the fishing community.

We are discovering a wide range of fish processes that occur at scales much smaller than the fish stock units as presently defined, and that when the spatial scale that restrains fishing exceeds the fish population scale, there can be local extirpation of population components. This leads one to ask if management needs to occur at finer scales than at present and how governance should be organized to accurately account for the structure of the ecosystem. Can fisheries management be redefined to understand the system better? Over the years, a tremendous web of governing bodies, governance processes and boundaries has been created, driven by the U.S. Constitution down to local, community norms. We are continually searching for ways to govern ourselves more efficiently and economically. The major problem that fine-scale science is raising is a governance problem.

Matching ecological and management scales can create incentives for harvesters to participate in the science and decision-making to steward local resources for both present and future use. However, managing at too fine a scale may increase the governance system complexity such that its effectiveness is reduced. The potential is great for social and economic costs to the fishing industry from changing management boundaries and scales. There needs to be a careful balance between over- and under-managing resources. Keeping data collection as simple and efficient as possible will be key to incentivizing the industry to participate. In some cases, the science does not yet justify new management paradigms. There need to be clear benefits of new governance systems that outweigh deficiencies in present governance systems. For example, lowering the fishing mortality rate may produce the desired results more efficiently than managing at a finer scale. What follows are a few examples highlighted at the workshop of the social implications of fishery scales.

Photo credit: Rachel Feeney/NEC

"When does our practical experience or our science tell us that we have to change? What is the tipping point?"
– anthropologist

"Fishermen haven't fished using their minds since 1996. The only challenge now is to avoid bycatch."
– fisherman

"Organizations are typically nested hierarchies, but there are informal structures of information flow to serve interests. When you have a degree of independence at the local level, self interest drives people to find information that solves problems. It can lead to more efficient organizations."
– university faculty

Q3: Case Examples

"Some boundaries are culturally or belief-driven and if we try to change them, we'll be banging our heads against the wall."
– state biologist

Photo credit: Rebecca Zeiber/NHSG

"We can't prosecute the TAC [total allowable catch] because of the rolling closures. The fish are only here at certain times a year. It's useless to have a TAC."
– fisherman

American Lobster

In many ways, the American lobster fishery in Maine is considered to be a collective action success. The laws, rules and norms are largely supported by the lobstermen due to the high level of participation in management. Lobster zones were established in 1996 and have the authority to limit the number of traps, the time of day that fishing can occur and entry into the fishery. The state commissioner must adopt the zone regulations unless deemed unreasonable, so the power is really within the seven elected zone councils. Lobster zones have restrained the spatial extent of fishing and slowed down fishing pressure to where the scale of fishing is similar to the scale of the population. Since 1996, landings have doubled as the resource has increased, but there has also been a 15% decline in the number of licenses.

The Atlantic States Marine Fisheries Commission is currently recommending trap reductions to help limit landings, but this is unlikely to have a significant effect unless the number of traps is severely reduced. Trap density reductions have effects at the local level, such as increasing catch per trap, less gear conflicts and edge effects. In 2008, a survey of lobstermen showed a broad concern about the number of traps and a willingness to reduce traps. There was a general belief that the resource was either stable or declining and there were concerns about the cost of bait. A proposal for trap reductions was then created, but was spectacularly shut down due to distributional concerns. At the district (sub-zone) level, the survey showed very strong agreement about reductions. Thus, scale at which agreements about reductions will occur may need to be at very local levels.

Q3: Case Examples

Atlantic Cod

Although Atlantic cod in the Gulf of Maine are managed as a single stock, recent evidence suggests the existence of at least two genetically distinct stocks and a mosaic of spawning aggregations that are temporally and spatially distinct. Many of these spawning aggregations, particularly along mid-coast and eastern Maine, have been extirpated through fishing activities. Increasing exploitation of spawning aggregations in the southern Gulf of Maine by both the recreational and commercial fleets has raised concerns over the future viability of these aggregations. A call to close these areas to protect spawning activities came from the active recreational and commercial participants in these fisheries. In response to these concerns, three small-scale spawning closures have been implemented in recent years, two in Massachusetts state waters and one in the federal waters off New Hampshire. The boundaries and timing of these closures were designed using information provided by commercial and recreational fishermen and through observations of fleet activities.

Continued rebuilding of the Gulf of Maine Atlantic cod stock(s) and the realization of future economic gains are predicated on the preservation of recruitment from existing spawning activity. Preservation of spawning diversity will likely result in greater stability of the exploited cod stocks that could reduce dramatic swings in allowable harvest, benefiting fishermen, processors and fishing communities. Spawning closures cause a significant short-term hardship for fishermen, but the understanding within the fleets is that they will result in long-term gains. The negative effects of the closures may be greater for commercial and recreational fishermen who are constrained to fishing nearshore because of vessel limitations because most of the spawning cod disperse offshore when the spawning activities cease.

Surf Clams

The surf clam assessments have consistently determined that the stock is not overfished and overfishing is not occurring, yet recruitment has been dropping since 1999. However, commercial fishing is not considered the primary cause. The warming of Atlantic waters and paralytic shellfish poisoning from pollution is constraining the surf clam fishery to Mid-Atlantic areas relative to its traditional range (Virginia to New Bedford, Mass.). These stressors heighten the importance of re-examining the scale of management. An alternative stock structure should be considered in the next assessment because variability within the stock area is increasing. The industry, scientists and managers have been cooperating to manage this fishery since well before the Magnuson-Stevens Act. This fishery began in Long Island, but has expanded throughout its range, and so the definition of community has grown with it. There are organizations that form and disappear (via radio, cell phone, texting) as they compete and cooperate with each other. This history of collaboration strengthens current efforts to preserve the resource for sustainable harvests.

Photo credit: Graham Sherwood/GMRI

"What are the management objectives? Local management? Maximum sustainable yield? And/or the National Ocean Policy?"
– lawyer

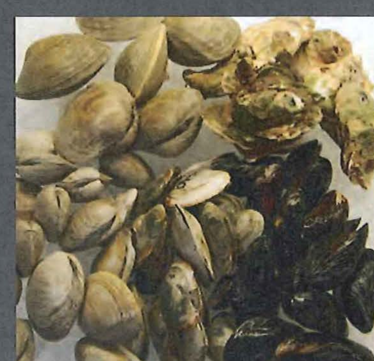


Photo credit: Rebecca Zeiber/NHSG

Q3: Case Examples

"Do federal laws need to be revised further to better facilitate ecosystem-based management?"

– lawyer

Photo credit: B. Beal/UMM

Photo credit: Rachel Feeney/NEC

Sea Scallops

Sea scallops are managed as a single stock throughout their range and occur in discrete offshore fishing grounds from Georges Bank to Cape Hatteras, N.C. The fishery is managed under an area rotation scheme, a spatially-explicit strategy that closes areas to fishing for variable lengths of time to promote scallop growth, reduce bycatch of finfish and mitigate habitat impacts. This strategy resulted in $400 million dockside revenues in 2010 from a fleet of 350 vessels. However, bycatch of yellowtail flounder in the scallop fishery has constrained scallop harvest resulting in economic losses. Recently, regulated accountability measures for yellowtail flounder bycatch in the scallop fishery have imposed time and area fishing closures that do not incorporate social and economic incentives for the fleet to avoid bycatch. In 2010, a yellowtail flounder bycatch avoidance system that uses fishery-dependent, spatially specific information in real-time to avoid bycatch hotspots was introduced. The voluntary program incorporates incentives to maximize scallop yield, maintain traditional fishing grounds and participate in self-enforcement. The spatial and temporal scales for yellowtail avoidance are designed to provide useful information to the fleet without negatively impacting normal fishing operations. Suggested movements to facilitate bycatch avoidance are on the scale of three miles or less and updates are provided daily. These fine-scale adjustments incorporate the social and economic objectives for scallop harvest, and the program has been successful, creating incentives for fishermen to share catch information. Results include reduced catch of overfished yellowtail flounder stocks and extended access to lucrative scallop grounds.

Sea Urchins

The urchin fishery in Maine is a classic boom-and-bust fishery, and its demise is largely because the scale of management has been too large. Asian markets were opened to Maine urchins in 1987, and by 1993 the urchin fishery had peaked as the second most valuable fishery in the state. Modest management began in 1992 with a license requirement, and regulations increased over time. The co-management system was created in 1996 with two zones and an advisory panel of industry members and scientists. Regulations were enacted at the state level but the relevant biological dynamics appear to occur at the scale of individual ledges. On each ledge, as urchins were removed by harvesting, kelp and other seaweeds grew and urchin predators like crabs moved in, thus extirpating them. The scale of the zones maintained an open access environment on each ledge; fishermen had no incentives to be selective or cooperate to conserve the resource. In Nova Scotia, leaseholds for urchins have been tried, but with mixed success. The resource was hit by disease, leaving little incentive for fishermen to invest in conservation practices. The zones were too big for harvesters to manage and harvest the entire area. Some ledges shifted to urchin barrens. If Maine went to a quota system to prevent overfishing, a total allowable catch would need to be set for each ledge, which would be exceedingly difficult or impossible. Leaseholds, however, may work more effectively than they did in Nova Scotia because urchins in the colder shallow waters found in Maine are less prone to disease. More research is needed to assess the feasibility of such a system for the Maine fishery. The size of individual leaseholds should be matched to the scale of harvesting to avoid overfishing.

Keynote Speaker

Dr. Ana M. Parma, Research Scientist, Centro Nacional Patagónico, Puerto Madryn, Chubut, Argentina

"Balancing scales — Opportunities and challenges in the management of spatially structured fisheries"

In artisanal, small-scale fisheries, experience shows that fisheries management approaches that rely on centralized assessments and top-down enforcement of regulations are doomed to fail because of ineffective enforcement and prohibitive costs of monitoring fish resources and landings. Command-and-control approaches can be ineffective when landing sites are spread out along the coasts, often in remote places without any port infrastructure. Furthermore, persistent gradients in regional productivity may require data at fine spatial resolution to adjust harvesting controls and reference points to local conditions. This is most evident in benthic shellfish fisheries that target stocks of sedentary organisms, for which the assumptions of conventional fisheries models do not hold. Fishermen's participation — provided the right incentives are in place — is the only feasible alternative to collect the information needed to make decisions at the appropriate spatial scale and to achieve compliance with regulations.

Territorial Use Rights in Fisheries (TURFs) offer a suitable alternative to command-and-control approaches for fisheries that target relatively sedentary species, such as benthic invertebrates or reef fish. They combine managing at the local scale, allocation of access to the resource by space rather than catch and a community-based governance structure. As such, they provide incentives for fishermen to cooperate in the management of their local resources and allow local experimentation and adjustments of harvest controls to reflect local productivity. This is exemplified by the Chilean loco (*Concholepas concholepas*) fishery, in which the implementation of TURFs stopped the "race to fish." Exclusive access to fishing grounds encouraged fishermen to protect the resources therein and to invest in local enforcement of access rights and self-imposed regulations. Overall, this helped stabilize and rebuild a fishery that had previously collapsed under open access, and for which a program of limited entry and individual quotas proved unenforceable and unable to control harvest rates.

But the design of a TURF system poses significant challenges. Resource assessment programs and management institutions need to be restructured in order to provide technical support at a diversity of nested spatial scales. In the Chilean system, each TURF needs its own procedure for setting catch quotas, so some form of local assessment needs to be conducted. How do institutions provide support at the small scale when there are hundreds of TURFs scattered along the coasts? Simple control rules driven by the results of local participatory surveys offer a practical alternative to centralized full stock assessments. Professionals working at the local level (the "barefoot ecologist" proposed by Jeremy Prince) can facilitate assessments and help organize communities. While TURFs are spatially discrete, they are not biologically, socially or economically independent. This requires standardization of monitoring indicators and regional coordination of surveys, management plans and marketing. In addition, because populations within TURFs are not isolated but are interconnected by larval dispersal, the incentives to protect local resources are not complete and a sort of "tragedy of the larval commons" can develop. Even if local resources are overharvested, larvae can enter from neighboring areas. Therefore, TURF performance improves with regional coordination.

Most critical challenges are those related to the size of TURFs and the distribution of access privileges that need to take into account not only the biology of the target resources but also the social geography and traditional practices of the fishing communities. Differences in local productivity of fishing grounds in Chile created marked contrasts in the economic viability and performance of TURFS along the coast. TURFs have to be big enough to be profitable and buffer the spatial variability of recruitment, but small enough to be enforceable.

Keynote Speaker

Are TURFS always best? No. TURFS will be unsuitable when the spatial dynamics of the fishery is variable and the spatial scale of feasible TURFs is too small to buffer the variability of local recruitment. When the fleet is dynamic, following the pulses of productivity, it is unwise to assign access rights to small stretches of coast because fishermen would be locked into territories that are too small to be viable. What are the alternatives? Where global stock assessments and enforcement of catch allocation are possible, quotas may be more suitable than territorial rights. This is the case in the tehuelche scallop (*Aequipecten tehuelchus*) fishery of Peninsula Valdes, Argentina — an artisanal diving fishery currently managed under limited entry and individual quotas assigned to permit holders. Where global stock assessments are not feasible, centralized enforcement is ineffective and fishing practices are nomadic — such as in the Chilean macha (*Mesodesma donacium*) fishery — local management with the flexibility of access at larger spatial scales may be most appropriate.

Clearly, one size does not fit all in terms of management strategies. The search for solutions to the global fishery crisis has been marked by a tendency to oversell management tools. But solutions need to be tailored to the specifics of the fishery, following some general guidelines. Management systems need to encourage responsible behavior in all sectors by clarifying access rights, ensuring transparency and accountability, and addressing enforcement problems. The latter is perhaps the most pervasive Achilles heel in small-scale fisheries. Compliance with rules needs to be encouraged by self-interest but also by strong penalties on rule violations. We need both carrot and stick approaches. The stick does not need to be just in the hand of the management authority, but in the local community as well.

Photo credit: Rebecca Zeiber/NHSG

Conclusions

When the modern era of fisheries management began in the 1970s, administrations, jurisdictions and data collection systems were designed based on the prevailing theory of the day: species' distributions were broad and homogeneous. The assumptions are changing as fisheries science matures. With improvements in stock identification, tracking and molecular genetics, there are increasing examples of mismatches between the scale of biological population structure and management units. When the spatial scale that restrains fishing exceeds the fish population scale of resident habitat, there can be local extirpation of population components (e.g., Maine urchin). It is likely no coincidence that fisheries are fairly successful where the biological and management units are well-aligned (e.g., striped bass). Evidence is growing that more and more species express spawning site fidelity (e.g., cod), such that the preservation of the remaining spawning activity might be critical to the long-term productivity and sustainability of the stocks.

Rich data sets are available that scientists need to revisit and better utilize. However, critical "gaps" remain in our understanding of ecosystem processes. Although we now see more discrete population processes and evidence of population connectivity, the challenge is to make robust quantitative measurements that track the full life history of marine species. More investment is needed in understanding trophic relationships, feeding and spawning linkages, source populations and mixing. Genetic data are improving our understanding of biological structure and helping to converge the spatial scales of populations and management units. As science continues to improve our understanding of fish population structure, managers will be faced with determining what "scale" is appropriate for a given species. This will involve more than biological considerations, but the societal and economic impacts of scale change to local, state and regional fishing communities. In some cases, the science does not yet justify new management paradigms.

The movement towards ecosystem-based fisheries management and marine spatial planning, driven in part by the 2010 National Ocean Policy, is challenging fishery managers, scientists, fishermen and other stakeholders to better coordinate efforts and consider systems more holistically. However, moving from single species management — something that has been in place for several decades of evolving management plans — into more complex system governance is not a trivial proposal. The potential for mismanagement is high with so many jurisdictional and biological boundaries crossing each other. We have a tremendous web of governance, and what we are continually searching for is a way to govern ourselves more efficiently and economically. There need to be clear benefits of new governance systems that outweigh deficiencies in present governance systems to justify change.

The workshop made clear that management units should be consistent with biological processes, and that the major problem that finer-scale science is raising is a governance problem. Ecosystem-based management is uncomfortable because the nuances are obscure, but we need to keep pushing fisheries science, management and stakeholder dialogue forward towards more sustainable solutions.

"If fisheries management was easy, we would have solved the problems by now. It is a difficult enterprise."
– federal scientist

Photo credit: Rebecca Zeiber/NHSG

"If we make more mistakes with the science, we won't have a fishery. The biggest depletion is in fishermen. We are not the industry. The scientists have good jobs, normal, civilized lives. Now that you are the industry, you need to do good science and management to keep us guys working. I hope you know what you are talking about."
– fisherman

Workshop Contributors

Oral presentations

Karen Alexander, University of New Hampshire
"Catch density and the spatial distribution of fisheries"

Michael A. Armstrong, Massachusetts Division of Marine Fisheries
"The application of small scale fishery closures to protect Atlantic cod spawning aggregations"

Robert Beal, Atlantic States Marine Fisheries Commission
"Relationship of political boundaries, stock structure and the interstate management process"

Yong Chen, University of Maine
"Spatial scale and population structure in modeling fisheries population dynamics"

Jamie Cournane, University of New Hampshire
"Spatial and temporal patterns of river herring bycatch in the directed Atlantic herring fishery"

Carolyn Creed, Rutgers University
"Climate change and scale issues in Atlantic surfclam management"

Greg DeCelles, University of Massachusetts Dartmouth
"Reconsidering the spatial scale of winter flounder management in southern New England"

Denise Desautels, NOAA Fisheries Northeast Regional Office
"Legal considerations and implications of reconciling stock and management boundaries"

Daniel Goethel, University of Massachusetts Dartmouth
"Modeling spatially structured populations in stock assessments: Trying to keep pace with population ecology"

Teresa Johnson, University of Maine
"Socio-ecological mismatches and the collapse of the Maine sea urchin fishery"

Lisa Kerr, University of Massachusetts Dartmouth
"Ecological and fisheries consequences of a mismatch between biological population structure and management units of Atlantic cod in U.S. waters"

Adrienne Kovach, University of New Hampshire
"Identifying the spatial scale of population structure in anadromous rainbow smelt"

Sean Lucey, Northeast Fisheries Science Center
"Spatially explicit operational fisheries in New England"

David Martins, University of Massachusetts Dartmouth
"Improved management of southern New England cod fisheries based on movement patterns and stock structure"

Tom Nies, New England Fishery Management Council
"Challenges to incorporating fine-scale spatial structure into management of northeast multispecies"

Workshop Contributors

Cate O'Keefe, University of Massachusetts
"Incorporating incentives to define spatial and temporal scales for 'Accountability Measures' in the Atlantic sea scallop plan"

Graham Sherwood, Gulf of Maine Research Institute
"The downeast cod problem and how to begin to deal with it"

Carl Wilson, Maine Department of Marine Resources
"Are Maine's Lobster Zones sized appropriately for decisions to be made?"

Jim Wilson, University of Maine
"What does the spatial complexity of ocean ecology mean for the human side of the system?"

Industry panel

Bill Chaprales, *F/V Rueby*, Marstons Mills, Mass.

David Goethel, *F/V Ellen Dianne,* Hampton, N.H.

Joe Jurek, *F/V Mystique Lady,* Gloucester, Mass.

Mike Walsh, *F/V Tahoma*, Stoughton, Mass.

Josh Wiersma, Northeast Fishery Sectors XI & XII, Inc.

Poster presentations

Alia Al-Humaidhi and James A. Wilson
"Scaling down fisheries management: Can we take it too far?"

Edward P. Ames
"Alewives and the cod family: Insights into their relationship during the 1920s"

N. David Bethoney and Bradley Schondelmeier
"Alternative scales to address river herring bycatch in U.S. Northwest Atlantic mid-water trawl fisheries"

Heather Deese, Robert Snyder, Shey Conover and Amanda LaBelle
"What do maps of fishing grounds tell us about fish, fishermen and fisheries management?"

Christopher Gurshin, W. Huntting Howell and J. Michael Jech
"Synoptic acoustic and trawl surveys of spring-spawning Atlantic cod in Ipswich Bay"

Anna Henry and Yong Chen
"Developing a sentinel groundfish survey/fishery in the eastern Gulf of Maine"

Adrienne I. Kovach, David Berlinsky, Timothy S. Breton and Amanda Clapp
"Fine-scale adaptive genetic variation in Atlantic cod"

William B. Leavenworth, Karen Alexander and Jeff Bolster
"Comparing spatial distribution of historical and modern fisheries in the Gulf of Maine"

Workshop Contributors

Ellen McCann Labbe, Theo Willis, Karen Wilson, Jason Stockwell and Zachary Whitener
"Population genetic structure of river herring in the Gulf of Maine"

Derek Olson and Yong Chen
"Designing surveys to monitor fine-scale dynamics of depleted populations"

Jason D. Stockwell, Zachary Whitener, Ellen McCann Labbe, Theo Willis and Karen Wilson
"Alewife stock structure in the Gulf of Maine"

Douglas Zemeckis, William Hoffman, Michael P. Armstrong and Steven X. Cadrin
"Movements of Atlantic cod from a Massachusetts Bay spring spawning ground"

Rapporteurs

Sharon Benjamin, Penobscot East Resource Center

Christian Canache, University of New Hampshire

Ben Metcalf, University of New Hampshire

Resources

To view recordings of presentations made at the workshop, please visit:

http://www.northeastconsortium.org/about/events.shtml

http://extension.unh.edu/marine/FA_FMGMT.htm

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