The School for Marine Science andTechnology

Cooperative Fisheries Science Forum I:

Scallops

May 2-3, 2002

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COOPERATIVE FISHERIES SCIENCE FORUM I

Scallops

May 2-3, 2002

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Report prepared by Kevin Stokesbury

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Overview – Perspectives on forum and expectations

Paul Diodati, Paul Howard, Brian Rothschild, Michael Sissenwine

This forum is the first in a series dealing with studies in marine science. It was inspired by the partnership between the University of Massachusetts and the Massachusetts Department of Marine Fisheries in collaboration with the National Marine Fisheries Service and the New England Fisheries Management Council. These forums will focus on topics relevant to New England and particularly Massachusetts fishery management. Examples of future forums are:

1. Status and assessment of fishery stocks including single-species fisheries such as scallops and multi-species fisheries such as groundfish.
2. Techniques including optimization procedures and Bayesian estimation.
3. Issues such as recruitment and economic impacts on fisheries.

The forums are intended to be technical but are open to the public, representatives from the fishing industry, and conservation groups.

This forum focuses on the sea scallop, *Placopecten magellanicus*, its biology, population dynamics, the techniques used to access its abundance and measure its life history parameters, its habitat, its fishery, the groundfish associated with the fishery, and the management requirements used to regulate the fishery. The scallop fishery is doing well and is presently the second most valuable in New England. However, as various lawsuits continue to affect this fishery, either directly or indirectly, there is confusion and uncertainty both in the requirements of management strategies and the resulting regulations. The purpose of this forum is to present this information in an open, positive atmosphere providing intellectually stimulating discussion thereby aiding people in understanding the present issues and leading the way to future research and management.

Each of the presentations is summarized below. Although the presenters addressed questions, the questions are also presented here to provide insight into future research. In a few cases, questions were raised after the forum and these are referenced. The slide presentations can be viewed on the web at http://rfac.smast.umassd.edu/Science_Forum/

Life cycle and fishery of sea scallops, *Placopecten magellanicus*

Kevin Stokesbury, School for Marine Science and Technology, University of Massachusetts Dartmouth, 706 South Rodney French Boulevard, New Bedford, MA 02744-1221

Sea scallops have an aggregated distribution on the scale of both kilometers and centimeters, which is a result of a complex mosaic of inter- and intraspecific interactions and the physical environment. The sea scallop is a gonochoristic broadcast spawner. Eggs are externally fertilized and success rate may be related to the size of scallop clumps on the scale of cm and spawning synchronicity. Spawning occurs from August to October but may also occur during the spring months, particularly in the scallop's southern range. The larvae spend approximately 30 days in the water column. Larval distribution is strongly influenced by water currents. It is unknown if and on what physical scale scallop aggregations are self-sustaining. Oceanographic models suggest that different aggregations are linked via larval distributions. Sea scallops feed on a variety of items including bacteria, detritus, and phytoplankton. Sand-gravel (granules and pebbles) predominantly characterizes scallop beds. However, not all sand-gravel substrates supported high scallop densities, suggesting that other factors also influenced distribution. Filamentous flora and fauna distributions may influence where scallop spat settles. High sea scallop spat settlement is not consistently associated with scallop densities, but the filamentous organisms on which scallops settle appear to be more abundant in scallop beds, possibly enhancing recruitment. Following settlement, scallop survival is influenced by predation. For example, in an enhancement experiment in Nova Scotia 10,000 scallops (4 to 26 m shell height) were released in 40 m^2, and over 50% were eaten by starfish and crabs in the first two weeks. The scallop's highly developed escape response triggered by the presence of starfish suggests that starfish predation has been an intense and chronic selective force on sea scallops over evolutionary time. Decapods appeared to inflict considerable mortality on both small and large scallops. Mollusks may obtain a refuge from decapod predation over a specific shell height. However, field research suggests that sea scallops are not safe from decapod predation even at large shell heights. This has significant implications because decapod prey size selection is an important component of molluscan community structure. The ratio of predation to predator density appears to fluctuate between a linear and a non-linear relationship, depending on the scallop's swimming ability. However, scallops may move for reasons other than to escape predation. Swimming ability is affected by the scallop's size and by environmental conditions such as photoperiod and temperature. Scallops increase their movement in unsuitable habitats dispersing randomly. Swimming in sea scallops may have evolved so that individuals could form clumps, at the scale of centimeters, which may increase fertilization success as well as to escape from predators.

Georges Bank and the mid-Atlantic support the world's largest single natural scallop resource, and have been commercially fished since the 1880s. Annual harvests have fluctuated depending on year class strength, which is influenced by environmental and biological factors. Two recent management strategies have affected scallop population dynamics on Georges Bank. The first in 1977 was the 200 mile (370 km) fishing zone established by Canada and the United States restricting fishing effort into specific locations and replacing the traditional movement of the fleet from one aggregation to another as densities fluctuated. The second in 1994 was the closure of three large areas of the United States portion of Georges Bank to fishing in an effort to protect depleted groundfish stocks. These closures resulted in the fishing fleet concentrating intense pressure on the remaining open areas. Approximately 80% of the sea scallop biomass on Georges Bank is currently in closed areas. The combination of closed areas, fishing restrictions, strong year class recruitment and perhaps other environmental factors has resulted in a massive rebuilding of the sea scallop stock, and associated landings have increased from 6 million lbs in 1997 to 34 million lbs in 2001.

QUESTIONS AND COMMENTS

- On what physical scale are scallop beds self-sustaining?

- What is the relative balance of endogenous verses exogenous recruitment in the Mid-Atlantic?
- Can biological-physical oceanographic models, which examine circulation patterns, be used to examine this question?
- Does the North Atlantic oscillation, or other large scale physical-environmental factors, such as upwelling or retention areas, have an effect on scallop recruitment?
- How do the scallop's life-history characteristics affect recruitment?
- What role does the aggregated distribution of scallops, including densities in the closed areas or other refuges, play in recruitment?
- How does small-scale fluid dynamics interact with scallop abundance, distribution and growth? On what spatial and temporal scale?
- Is there evidence for density-dependent natural mortality?
- Do spawning events occur in the spring as well as the fall on Georges Bank, and if so, how does it vary and what impact might it have on recruitment?

Sustainable fisheries: Significant gains despite confusion and uncertainty

Paul Howard, New England Fishery Management Council, 50 Water Street, Newburyport, MA 01950

The sea scallop fishery of New England has reached maximum sustainable yield targets and is now considered a sustainable fishery. However, it is still difficult to manage. To be successful, a fisheries management plan must contain 1) a specific overfishing definition, 2) measures to prevent overfishing and rebuild fished stocks, 3) a description of the fishery, 4) specific estimates of maximum sustainable yield, capacity, and data requirements, 5) an essential fish habitat assessment (EFH) including select measures to minimize to the extent practicable adverse effects caused by fishing, 6) bycatch assessments, including select measures to minimize bycatch to the extent practicable, 7) bycatch mortality, and 8) a fishery impact statement. Most lawsuits, including the present successful one on the groundfish fishery, focus on the process used to develop these plans, which must adhere to MS/SFA and NEPA requirements. If the fishery management plan is not completed correctly and on time, the consequences are huge.

QUESTIONS AND COMMENTS

- For the different management plans and policies there are a variety of examinations; in some cases these are formal models predicting effort, trip limits and so on, while in other cases only partial models exist, and in some cases the council must develop the model as the plan is developing. Can these be standardized and improved?
- The National Standards present 10 objectives; some are mutually exclusive and most are partially exclusive. Further, they are defined as maximums or minimums to the extent practicable. This terminology makes the application of operation research and modeling difficult. How can this issue be addressed? How can the 10 objectives be prioritized?
- How do we move from managing a single species to managing a fishing ground?

- With the present groundfish regulations, the number of vessels fishing scallops and lobsters under general category are likely to increase rapidly. Is setting a TAC the best way to deal with this increase in effort?
- Once a stock is rebuilt, how is the management plan shifted from rebuilding to sustainable?
- The main issues facing the scallop fishery are bycatch and habitat. Addressing these issues requires a large amount of scientific research. It is not sufficient to say, "We do not have any information." Should dividing lines be determined between what we know, what we do not know and what is feasible to determine? If so how?
- The bycatch issue is a multispecies dynamic question. How can it be addressed in that context?
- Capacity can be measured in a number of ways including latent effort, the number of day-at-sea and the number of crew a vessel could employ. How are these measured and included in the various management alternatives?

Optimization in fisheries management: Case of sea scallops

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An optimization problem for fisheries management was formulated and applied to Area Management policies where fishing grounds were divided into several management sub-areas and fishing mortalities for each sub-area in each year were determined. The formulation also takes into account concerns about sustainability, stability and bycatch. To solve the formulated problem, an optimization technique was proposed that combines simulation to genetic algorithms. Simulation, which answers "what if" questions, returns an objective function value for any given scenario. Genetic algorithms use search processes to find the optimum management policy, answering "what to do" questions. Numerical examples were presented with Georges Bank's scallop data in order to compare status quo fishing policy, an area rotation fishing policy and the optimal fishing policy. The optimization program created better fishing yield with less sub-areas in comparison to other area rotation approaches.

QUESTIONS AND COMMENTS

- What if a mistake is made in the rotational plan? What type of feedback and evaluation procedures can be employed to address this?
- How do you validate decision variables?
- How do you measure the uncertainty within the model? How do you assess risk?
- The model is made of a series of components. How robust is each component?
- How do we examine the Yield per Recruit verses Recruitment question in this fishery?
- What is the cost of ignorance? How much are we losing by not knowing?
- Presently an area rotation model that is controlled by the factors influencing population dynamics within each location based on our knowledge could be designed or a model that takes our limited knowledge and estimates a yield for next year could be implemented

and then added to as new data becomes available. Which approach is the best way forward?

- Could the model be used to estimate the cost of different policies that are not part of the scallop management strategy. For example, what is the cost in scallop landings of closing an area for groundfish?

Rotational management of sea scallops in practice and in theory

Dvora Hart and Paul Rago, National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543

In the seven years since the closure of three large areas on Georges Bank to trawling and dredging in December, 1994, sea scallop biomass on Georges Bank has increased by more than a factor of twenty. Limited fishing in the closed areas in 1999 and 2000 yielded about 11 million lbs of scallop meats while still allowing for increases in biomass in these areas. Dramatic increases in biomass have also been seen in the Mid-Atlantic Bight after two areas were closed to scallop fishing for three years in 1998. Over seven million pounds of scallop meats have been landed from these two areas since they were reopened in 2001. The redirection of effort into the closed areas, together with effort reduction measures and good recruitment has brought open area biomass and commercial catch rates to levels much higher than those observed in the previous twenty years. Strong recruitment observed since the closures suggests the possibility that the closed areas have also become important sources of scallop larvae, due to increased biomass and perhaps an Allee effect. These experiences indicate that area closures and reopenings (i.e., rotational fishing) can be an effective way to rebuild shellfish stocks and alleviate growth and quite possibly recruitment overfishing.

Due to their rapid growth, low natural mortality, and sessile nature, sea scallops are an ideal candidate for rotational management. Rotational yield-per-recruit analysis indicates that rotation improves both yield and biomass slightly at F_{max}. Rotation gives a greater advantage at higher fishing mortalities because it allows at least a portion of the scallops to grow to a large size regardless of the level of fishing mortality. Further improvements in yield can be obtained by adaptive rotation, where areas with high densities of small, rapidly growing scallops are temporarily closed. This approach was investigated using a model that simulates scallop growth, natural mortality, spatial-temporal recruitment patterns, and fishing behavior. Best results were obtained from low growth rate thresholds, three year closures, and a cap on the maximum amount of area closed. Both theory and practice indicate that rotational management, where areas are successively closed and then opened to fishing, can increase both yield and spawning-stock biomass in the sea scallop fishery.

Area management, including long-term and rotational closures, can cause difficulties with standard spatially averaged measures of fishing mortality. Averaging fishing mortality temporally, rather than spatially, can give a metric that can be reasonably compared to standard reference points such as those obtained by yield-per-recruit analysis.

QUESTIONS AND COMMENTS

- What is the result of shifting F_{max} calculations from an area average to a site-specific time average?
- How will closed areas, for reasons other than scallop management, effect the estimation of fishing mortality?
- It is difficult to achieve constant *F*, for example $F = 0.2$; however, the comparisons presented in the model assume that that the fisheries are regulated that way. How can the uncertainty of achieving constant *F* be included in the analysis?

Scallop surveys: comparison among research vessels, fishing vessels and photographic methods

Paul Rago, National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543

Three different surveys were conducted in recent years to examine differences in scallop abundance and distributions: the National Marine Fisheries Service scallop survey using the research vessel *Albatross;* cooperative dredge surveys using commercial fishing vessels, fishermen and scientists; and photographic surveys including the SMAST survey. Dredge surveys provide a relative estimate of density. Estimates of the selectivity and efficiency of the dredge are required to calculate the absolute abundance of the sea scallop stock. Comparisons of density estimates between the research dredge, standard commercial fishing gear and photographic surveys varied. However, the combination of different survey types and increasing the intensity of observations in areas of high scallop densities has been very successful. The possibility of modifying the dredge gear and survey strata, the development of new techniques including automated image processing, and in-depth comparisons between photographic and dredge gear may all lead to improved stock assessment estimates for sea scallops and increased information on the habitat of Georges Bank.

QUESTIONS AND COMMENTS

- How much information is available using new techniques? Can photographic surveys identify groundfish distributions such as skate and flounder?
- Can calibration experiments between video techniques, the NMFS scallop dredge and commercial scallop dredges be conducted?

Examination of sea scallop, *Placopecten magellanicus*, aggregations using a video survey in closed areas of Georges Bank

Kevin Stokesbury and Brad Harris, School for Marine Science and Technology, University of Massachusetts Dartmouth, 706 South Rodney French Boulevard, New Bedford, MA 02744-1221
(Abstract and similar paper presented at the National Shellfish Association 94th Annual Meeting, April 14-18, Mystic, Connecticut.)

Georges Bank is the world's largest natural scallop resource. During the summer months of 1999/2000/2001 SMAST, in association with the scallop industry, developed and conducted 23 video surveys on Georges Bank. These surveys produced a series of maps of the sea floor containing high aggregations of sea scallops. The video survey detailed the distribution of substrate, depth, number of live and dead scallops, and macroinvertebrates (sponges, starfish, filamentous fauna). The video technique allows a previously unattained precise, accurate measure of these variables and allows correlation analyses between them. Further, the closed areas of Georges Bank have scallop densities higher than any previously observed. For example, the three areas surveyed in 1999 (1940 km^2) contained approximately 652 million scallops representing approximately 17 million kilograms (32 million lbs worth approximately $161 million) of harvestable scallop meats. Preliminary comparisons of video to commercial fishing dredges indicates an average efficiency of 25% (for all size classes) with a great deal of variation between tows and vessels.

QUESTIONS AND COMMENTS

- How do we design an experiment to measure dredge efficiency? Given that dredge efficiency may vary with scallop density, how can this be quantified?
- How do we deal with the combination of selectivity and efficiency for dredge and photo surveys? For example, are small and large scallops sampled/observed at the same efficiency?
- How do we sort out the variation between sampling design and variation in gear within gear efficiency experiments?

Fleet dynamics of the Atlantic sea scallop fishery

Paul Rago and Dvora Hart, National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543
(Abstract and similar paper presented at the National Shellfish Association 94th Annual Meeting, April 14-18, Mystic, Connecticut.)

The sea scallop (*Placopecten magellanicus*) supports the second most valuable commercial fishery in the northeast USA. Closure of large areas of Georges Bank to scallopers in 1994 not only resulted in rapid increases in scallop biomass but also altered the spatial distribution of fishing effort. Detailed electronic information on the hourly position of each vessel was used to study the behavior of the fishing fleet for the period 1998 to 2000. Additional information from at-sea observers corroborated the analyses of vessel monitoring data. Limited re-openings of the

closure areas in 1999 and 2000 induced marked shifts in fishing effort. Fine-scale changes in fishing patterns can be related to the scallop density, size composition and economic value as well as the presence of bycatch species. The scallop fishery is conducted over an area of about 12,000 nm^2, but more than 75% of fishing activity is concentrated within an area of about 3,000 nm^2. When scallop density is low, however, fishing vessels disperse more widely. Such variations in the concentration of fishing activity have important implication for impacts on habitat and finfish bycatch and provide insight into management strategies for bivalve fisheries.

QUESTIONS AND COMMENTS

- This approach provides a footprint of the fishery not easily attainable in any other way. However, as the data is currently presented, any vessel traveling below 5 knots is considered to be fishing and is used to estimate dredge time on the sea floor. This includes time when the vessel is not fishing, such as processing the scallops (cutting), and laying due to bad weather and variations in wind and current. How can these variables be considered and deleted to provide a more accurate estimate of the sea floor area swept?
- How much of the habitat is being affected by the scallop fishery?
- Reducing the footprint of the fishery could be viewed as equivalent to closing an area. However, the first pass of the dredge may be the most detrimental to habitat. How can the impact of repeated towing over the same dredge path be quantified?
- The scallop fishery in Canada has used side-scan sonar effectively. What would the result of this type of information be without the output controls that regulate the Canadian fishery?

Growth and movement of sea scallops in the southern part of the Great South Channel on Georges Bank: A tagging study

*Brad Harris and Kevin Stokesbury***,** *Intercampus Graduate School of Marine Science and Technology, University of Massachusetts Dartmouth, 706 Rodney French Boulevard, New Bedford, MA 02744-1221*
(Abstract and similar paper presented at the National Shellfish Association 94th Annual Meeting, April 14-18, Mystic, Connecticut.)

A rotational fisheries management strategy is being considered for the sea scallop, *Placopecten magellanicus,* fishery of the northeast United States. To implement a rotational management strategy, site-specific information on sea scallop population dynamics is required. For example, the sea scallop is the best swimmer of the 400 known species of scallops, and can move as much as 15 km on Georges Bank. This could influence the size of the rotational areas closed or open to harvesting. Further, sea scallop growth rates show substantial variability over their geographic range. This could influence the time period rotational areas are open or closed. To begin the development of a site-specific data set, a sea scallop growth and movement experiment was conducted in the southern part of the Great South Channel of Georges Bank. Approximately 13,000 scallops were tagged and released in May 2001. Presently, 677 tagged shells have been returned showing movement of up to 7 km, and growth spanning more than 9 months. This

preliminary data illustrates the need for further site-specific movement and growth experiments over the sea scallops range.

QUESTIONS AND COMMENTS

- The current von Bertallanfy growth equation used for the scallop resource is based on annual measures of growth. Should seasonal variation be included in the equations and if so how?
- The present natural mortality of sea scallops is estimated at m = 0.1 based on the length of time a clapper hinge remains intact after the scallop dies. Are there better ways to calculate this mortality?
- How can mass mortalities be examined and incorporated into the models?
- Predation is a key component of natural mortality. How does predation vary spatially and temporally?
- What is the effect of the vessels fishing pattern on estimates of tag scallop movement?

Interactive dynamics of scallop and groundfish fisheries

Steve Murawski, National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543

Scallop fisheries are not single-species; rather, dredges catch a variety of finfish species and other animals as unintended (or in some cases, intended) bycatch. Data on spatial overlap and bycatches from scallop fisheries are reviewed. In particular, significant bycatches of flatfishes and skates are an issue in assuring integrated management under the scallop, groundfish and skate FMPs. Documented catches of marine turtles in the Mid-Atlantic Bight indicate that the impact of the scallop fishery on these listed species needs to be considered. Research recommendations for enhanced understanding of the interrelationships between scallop and groundfish fisheries and other bycatch species include: (1) systems of pre-fishery surveys for closed-area rotations, (2) increases in the coverage of general sea sampling to better assess quantities of bycatch mortalities and their spatial and temporal variability, (3) discard survivorship studies, (4) conservation engineering to minimize non-target species catches, (5) modeling of effort distribution and allocation patterns to attain multiple management objectives, and (6) systems of incentives to develop gear and practices to improve fishery selectivity.

QUESTIONS AND COMMENTS

- How can bycatch inside and outside closed areas be accurately estimated? What intensity of observer coverage is required?
- Presently, all species collected in the scallop dredge and not landed are considered bycatch mortality. Some of these animals may survive the capture and release process. How can this be quantified?
- Would a small-scale, intense tagging study to examine discard mortality be the best way forward?
- Can observer information posted in real-time be used to reduce bycatch as it was in the

Closed Area II 1999 fishery and is being used in Alaska?
- What are the effects of energetic subsidies provided by shucking of scallops at sea on other components of the food web? (Question posed after the workshop.)
- The frequency of barndoor skate samples in NMFS survey (scallop, finfish) tows has increased sharply in recent years. How robust is the trend of increasing barndoor skate abundance?

Gear effects and habitat studies in the Georges Bank closed areas

Frank Almeida (presented by Robert Reed), National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543

The benthic habitat in the southern portion of Closed Area II was assessed prior to and one year after scallop fishing. The sampling protocol included 20-minute video drift transects with still images recorded every 60 seconds, three replicated benthic grab samples at the end of the video transect, a 15-minute fish tow and a 6- to 12-hour side-scan sonar survey. Preliminary results indicate that fish species-diversity, distribution, size distribution were similar inside and outside the Closed Areas. Haddock, yellowtail flounder and emergent sponge epifauna were significantly more abundant within the closed area. Similar cruises were completed for Closed Area 1 and the Nantucket Lightship Area, although the sample size for the final cruise was very low due to logistical difficulties. The results of the Habitat Mapping Workshop were presented as well as information on the Canadian mapping program.

QUESTIONS AND COMMENTS

- What is the statistical power of the inside/outside comparisons from the Closed Area II study?
- Without a control area, can shifts in variables between the before and after surveys be significantly determined? For example, the observed lower measure of carbon in the sediment was lower in the samples collected after the fishing event. Was this an effect of fishing or a temporal shift (between seasons or years)?
- How are samples prioritized given that Essential Fish Habitat area is created for finfish species and not invertebrates?
- What are the next steps in developing RNA/DNA ratio indices for fish and the invertebrates they prey upon in these areas of Georges Bank?

SMAST environmental assessment: A before-after-control-impact study of the sea scallop aggregations of Georges Bank

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A Before-After-Control-Impact (BACI) study is the optimal environmental impact experimental design in which every manipulative ecological experiment has a contemporaneous control. The

BACI design requires both temporal and spatial controls. The null hypothesis is "an impact resulted in no biological damage." Fisheries management often relies on time series of data but unless there is a control all before-after comparisons must assume homogeneity over time, an assumption that has been found invalid time and again. We surveyed the historic scallop fishing grounds of Georges Bank that have been closed to mobile gear since 1994. Our survey design was a BACI with a 1-year set of baseline observations, 2 experimental areas (NLSA and north of 43660 in CAI) that were exposed to intense fishing pressure, two control areas (the northern portion of CAII, and south of 43660 in CAI) with no fishing, and one control with constant fishing (South Channel). The NMFS monitored the fishing effort, including the location and amount of scallops collected. Within each experimental area we conducted a high-resolution video surveys using a multistage design with stations separated by 0.85 nautical miles. The video surveys were designed using sea scallop densities, as they are the most common macroinvertebrate in these areas with a 5% to 15% level of precision for the normal and negative binomial distributions. Mounted on the pyramid were two video cameras and several lights. Four quadrat images of the sea floor including counts and sizes of scallops, other macroinvertebrates and benthic fishes and sediment types, were relayed in real time to the surface. These images were video taped and the exact position (latitude and longitude from differential GPS) depth, and time. During all surveys the same stations were sampled throughout the experiment. Changes in species composition, density and distribution of scallops, other macroinvertebrates and groundfish, and in sediment structure (for example sand ripple structure, which may be critical juvenile fish habitat) will be compared.

QUESTIONS AND COMMENTS

- How does changing the fishing pattern from a constant *F* over time to a pulse perturbation–for example, intensely fished one year in three–affect the benthic habitat? (Question posed after the workshop.)

Concluding remarks and questions for future research

The information presented and the questions raised during each presentation indicate key issues that future research and management should focus on. These are summarized below.

1. Reproduction and recruitment: Are sea scallop aggregations self-sustaining?

1.1. How does scallop spatial distribution, density and synchronized spawning events affect fertilization success?

> Sea scallops are broadcast spawners, and therefore fertilization success depends upon the density of scallops on the sea floor, the distance between spawning individuals and the synchronicity of the spawning event. A sea scallop spawning event has never been observed in the field, and the exact physical and biological conditions of the event are unknown. This is a key question as it relates to both the density of zygotes in the water and density dependent/independent questions.

1.2. What factors affect recruitment of scallops? Where and when do spat settle and what constitutes nursery areas?

How far are sea scallop larvae dispersed from the adult bed? How do oceanographic conditions effect larval distributions? Do larval scallops have a preferred settlement substrate? Is there a relationship between the density of adults on the sea floor and the number of larval scallops that will settle from the water column?

2. Life-history parameters: How do these parameters vary over space and time?

2.1. How does the sea scallop's ability to move affect its survival rate?

How much do scallops move? Is scallop movement directional (individually or as a group) or is it completely dominated by tidal currents? Do juvenile scallops settle in different areas and migrate into adult aggregations? Do scallops move to form aggregations on the scale of cm, and if so why? How does fishing effect the distribution of scallops on the sea floor, and do scallops re-aggregate themselves after they are disturbed?

2.2. What factors determine the growth rates of scallops?

The growth rate of the sea scallop is presently described using one of two von Bertalanffy equations, one for Georges Bank and the other for the mid-Atlantic. These equations are the bases for the Beverton-Holt yield-per-recruit estimate that presently defines the overfishing definition for sea scallops. However, to obtain the maximum benefit from a rotation management plan site-specific growth rates must be determined. For different geographical areas how do growth rates vary in relation to physical conditions, primary production levels, scallop densities, and/or genetic characteristics?

2.3. What are the effects of fishery-induced injuries and handling on mortality?

Dredging can damage scallops, some of which are not brought to the surface. Management strategies need to incorporate this mortality but few studies have examined this issue.

2.4. What is the natural mortality rate of scallops?

Scallops natural mortality rates are poorly understood. Mortality rates probably differ with locality, age structure, local physical conditions and benthic community structure.

3. Bycatch and habitat

3.1. What are the ecological effects of sea-scallop dredging on the sea floor and benthic community?

3.2. What is the rate of groundfish bycatch in the scallop fishery? How does it spatially and temporally vary? What is the survival rate of fish collected in the scallop gear and/or brought on deck, and then released?

Research recommendations for enhanced understanding of the interrelationships between scallop and groundfish fisheries, and other bycatch species include: (1) systems of pre-fishery surveys for closed area rotations, (2) increases in the coverage of general sea sampling to better assess quantities of bycatch mortalities and their spatial and temporal variability, (3) discard survivorship studies, (3) conservation engineering to minimize non-target species catches, (5) modeling of effort distribution and allocation patterns to attain multiple management objectives, and (6) systems of incentives to develop gear and practices to improve fishery selectivity.

4. Management

There are many considerations for the future management of the sea scallop. The present overfishing definition needs to be examined and compared/contrasted to other estimates. The components of rotation management plans need to be examined. For example, what is the appropriate size for area management? Is there a stock-recruitment relationship and do we presently have enough information to determine it? Are there critical nursery areas? Is there a benefit to having long-term area closures? Can scallops be managed in a multispecies context? How does the bycatch of other species affect the management of scallops?

5. Sampling methods: Comparison of commercial and scientific dredges to video techniques

Determining the characteristics of the commercial scallop dredge, the scientific dredge and other techniques used to harvest and examine this species is critical to improving both the science and management. Comparison studies are needed.

Interested researchers may wish to refer to the document, "Alaska Department of Fish and Game and University of Alaska Fairbanks. 2000. A workshop examining potential fishing effects on population dynamics and benthic community structure of scallops with emphasis on the weathervane scallop *Patinopecten caurinus* in Alaskan waters. Alaska Department of Fish and Game, Division of Commercial Fisheries, Special Publication 14, Juneau," which discusses some of these questions in greater detail.

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Gabrial Miranda	F/V Capt.	
Han Davidsen	F/V Owner	508-995-6662
Jaime Santos	FSF	508-997-2197
Jason Hedges	FSF	202-662-9700
Jim Kendall	NEFMC	508-997-0013
Joe Deck	SMAST	508-999-8925
Kevin Stokesbury	SMAST- Scallop Research	508-910-6373
Lou Goodman	SMAST	508-910-6375
Marty Manley	City of New Bedford	508-979-1456
Max Isaksen	F/V Owner	508-989-4300
Melvin Kvilhaug	FSF	508-993-3670
Michael Sissenwine	NOAA/ NMFS	508-495-2233
Paul Diodati	MA DMF	
Paul Howard	NEFMC	978-465-0492
Paul Rago	NMFS (WH)	508-495-2341
Pete Christopher	NMFS / RO	978-281-9288
Steve Correia	MA DMF	508-563-1779
Steve Edwards	NMFS	508-495-2266
Steven Murawski	NMFS (WH)	508-495-2303
Thomas Saunders Jr.		
Tu Truong	SMAST	508-910-6359