Center for Independent Experts (CIE) Independent Peer Review Report

Review of Sea Scallop Survey Methodologies and Their Integration for Stock Assessment and Fishery Management

By

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Executive Summary

The five survey methods under review have supported successful fishery advice and management in recent years. The Atlantic sea scallop fishery is the most valuable single-species fishery in the United States, and the sustainability of this fishery suggests that the comprehensive spatial management practices supported by the multiple surveys and implemented by all stakeholders in the fishery have been successful. This suggests that a form of complemented dredge and optical surveys be continued. Annual surveys are recommended to support the current management regime that aims to protect recruitment events, and avoid under- and over-harvesting of stock components. All survey methods have demonstrated that they provide useful data for habitat mapping and assessments for non-scallop species.

The NEFSC dredge survey provides then longest time series of abundance estimates by size and biomass. Dredge surveys is a critical component of a monitoring program to support stock assessment of sea scallops since this is the only current method that allows actual collection of specimens for biological samples. The catching of sea scallops with dredges is necessary to estimate shell height to meat weight relationships critical to biomass estimation. The spatial coverage of the resource by the NEFSC dredge survey has been reduced in recent years, which can lead to bias. Although optical methods fill in gaps in the dredge surveys and provide abundance estimates by size, the conversion to biomass relies on shell-height to meat weight derived from the dredge surveys. It is recommended that a statistical survey design be developed to integrate dredge and optical surveys. The dredge survey method also provides the most accurate estimates of shell height distribution of commercially sized sea scallops (i.e. 40mm+), and also is required to obtain other measurements that require laboratory examination of specimens. The use of complementary optical surveys is advised because these methods have higher delectability of scallops < 20 mm than the dredge surveys, and therefore provide better information on recruitment. However recruitment information is still only qualitative. The choice of optical survey methods should be based on cost-benefit analysis which was not part of this review.

In general, it is recommended that all aspects of the sub-sampling and data collections at each station in the dredge surveys be evaluated. In particular, it is recommend that data on numbers of scallops per shell-height be recorded for each subsample (basket) which would allow an assessment to determine adequate subsample size, and that the sub-sampling of scallops for determining shell-height – meat weight relationships be evaluated. The subsampling of sea scallops for meat weight estimation currently involves the collection of 5 meats per NEFSC dredge sample. It is recommended that a statistical sampling design that involves systematic sampling of one or more meats per shell-height bin be considered.

Currently each survey largely covers separate spatial areas. Abundance estimates by shell height from non-overlapping areas could in principle be treated as independent and added up to provide a global estimate that covers the maximum portion of the resource. The main issue with the current approach is related to the timing of the surveys – especially if some areas are subject to fishing. In areas where two or more surveys overlap in time and space, the separate estimates could be combined using inverse variance weighting (see. e.g., Rao 2003). However, an issue here is that the current variance estimates for the systematic sampling designs are biased upwards

because they area treated as simple random samples. Alternative variance estimators are suggested in this report that could reduce bias in variance estimates for systematic surveys. The analysis of optical and dredge survey data using a single kriging model is work in progress. This approach is difficult because of the big variation in sampling unit sizes and the systematic spacing of samples which results in lack of information to fit spatial autocorrelation at smaller spatial scales (at the distance between evenly spaced samples).

In general, the survey designs and sampling methods considered here are statistically sound, following principles of either random or systematic sampling, but the survey design for the HabCam V4 is still under development. Providing reasonable synoptic sampling coverage and a suitable overall survey design, data from the dredge surveys and HabCam V2 and V4 transect surveys could be combined using model-based estimators, such as methods that have been applied to combine acoustics and trawl surveys. This could possibly lead to improved precision for a given survey effort. Some possible approaches with references are provided in this report. The HabCam survey component may most effectively be conduced using different vessels than the dredge survey to allow continuous towing according to a systematic transect design, and to maximize survey coverage. Further research in this area using available survey data and additional experiments in future surveys is encouraged.

The quality-control and quality assurance program implemented by NEFSC and VIMS to standardize dredge sampling protocols and dredge performance (determining actual time on the bottom using tilt sensors) and the estimation of gear efficiency through experiments allows the standardization of area-swept estimates of abundance and minimize sources of errors due to changes in survey vessels over time. NEFSC and VIMS currently use 15 min towing time in their dredge surveys. Many studies suggest that a reduction down to 5 min towing time with the current dredge, accompanied by an increase in the number of stations, could improve precision for the same survey time and also reduce bias related to gear saturation and sub-sampling of large catches. The HabCam optical transect surveys provide valuable information that can be analyzed in simulation studies (using resampling methods) to determine optimal sampling unit size for the dredge survey. The SMAST drop camera survey methods and choice of optic equipment have also been developed through exemplary pilot studies. The drop camera method has the advantage that it is relatively easy to operate from commercial vessels. This method therefore seems particularly useful for detecting recruitment events.

1. Background

The Atlantic sea scallop (*Placopecten magellanicus*) resource is mainly distributed along the Atlantic coast from the Mid-Atlantic to the US/Canada border, and now supports the most valuable single species fishery in the U.S. In the early 1990s, the fishery for Atlantic sea scallops in the northeastern U.S. took unsustainable large catches. In 1994, new management measures were introduced, including the limit of effort through a moratorium on new permits, limitations on days at sea, gear and crew restrictions, and year-round closed areas (Hart et al. 2006). Today, the Atlantic sea scallop population is near record highs and the fishery operates at sustainable levels according to stock assessments based on multiple surveys and MSC certification. The

scallop fishery uses predominantly paired or single scallop dredges throughout the entire range of the fishery.

A peer review meeting was held at the Waypoint Event Center at the Marriott Fairfield Inn and Suites, New Bedford, MA 17-19 March 2015 to review material prepared by four independent scientific teams conducting surveys on Sea Scallops (Arnie's Fisheries, NEFSC, SMAST, and VIMS). The review panel was composed of four scientists appointed by the Center for Independent Experts: Noel Cadigan, Martin Cryer, Jon Helge Vølstad, and Brent Wise. J.-J. Maguire, from the New England Fisheries Management Council's Scientific and Statistical Committee, chaired the peer review meeting very efficiently.

The review panel was assisted by the NEFSC Stock Assessment Workshop (SAW) Chairman, Dr. James Weinberg, Dr. Paul Rago, Acting Chief of the NEFSC Resource Evaluation and Assessment Division and Deirdre Boelke from the New England Fisheries Management Council. This meeting was open to the public, and a total of 49 people participated in the sea scallop survey methodologies review meeting.

2. Description of the Individual Reviewer's Role in the Review Activities,

Preparations in advance of the peer review meeting included a review of background material and reports provided by the NMFS Project Contact James Weinberg (Listed in Appendix A) on March 3 and 5 via email with link to a website with files organized in subdirectories by "gear type/organization". The files in each subdirectory were listed to match the order of presentations on the meeting agenda, which made it much easier for the reviewer panel to consult the background material during presentations.

The review meeting was kicked-off with the welcome by Bill Karp (Director, NEFSC) and Jon Mitchell (Mayor of New Bedford), and then participants in the peer review and everyone in the audience introduced themselves. A series of very informative power-point presentations were given during the review meeting. Presentations were made by

- Paul Rago (TOR overview),
- Dvora Hart and Dave Rudders (Dredge survey methods),
- Kevin Stokesbury (Drop camera survey methods),
- Scott Gallager and Richard Taylor (HabCam video survey methods)
- Burton Shank, Jui-Han Chang and Deirdre Boelke (Statistical estimation and survey design)

My fellow peer reviewers and I asked questions during the presentations and participated in the panel discussions on validity, results, recommendations, and conclusions. The presentations covered each Term of Reference in depth, and the presenters answered questions when needed to clarify specific points. Toni Chute and Larry Jacobson from the NEFSC acted as rapporteurs and provided thorough summaries of the discussions for each day.

Presentations during the review meeting

Boelke, D. (NEFMC). 2015. Review of Sea Scallop Survey Methodologies, TOR 5 & 7, Overview/ Relation to Management. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 14 slides.

Gallager. 2015. 2007, 2008, 2009 Joint Tows: Relative Dredge Efficiency and Variability in Multiple Scallop Resource Areas. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 29 slides.

HABCAM Group. 2015. TOR 1--Introduction. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 15 slides.

HABCAM Group. 2015. TOR 1-3. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 118 slides.

HABCAM Group. 2015. TOR 4—Methods for Using HabCam Survey Data to Estimate Abundance Indices.. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 31 slides.

HABCAM Group. 2015. TOR 6 & 8. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 60 slides.

NEFSC. 2015. Scallop Dredge Survey, TORS 1-4. Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 25 slides.

NEFSC. 2015. Scallop Dredge Survey, TORS 5 & 7. Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 14 slides.

NEFSC. 2015. Scallop Dredge Survey, TORS 6 & 8. Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 5 slides.

Rudders, D.B. (VIMS). 2015. Sea Scallop Survey Methods Review, TORS 1-4. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 33 slides.

Rudders, D.B. (VIMS). 2015. Sea Scallop Survey Methods Review, TORS 5 & 7. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 7 slides.

Rudders, D.B. (VIMS). 2015. Sea Scallop Survey Methods Review, TORS 6 & 8. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 6 slides.

Stokesbury, et al. 2015. SMAST Scallop Survey, Drop Camera Review TORS 1-4. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 69 slides.

Stokesbury, et al. 2015. SMAST Scallop Survey, Drop Camera Review TORS 5 & 7. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 40 slides.

Stokesbury, et al. 2015. SMAST Scallop Survey, Drop Camera Review TORS 6-8. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 25 slides.

Taylor, R. 2015. HABCAM V2. Review of Sea Scallop Survey Methodologies and Their Integration for Stock Assessment and Fishery Management, TORS 1-4. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 60 slides.

Taylor, R. 2015. HABCAM V2. TOR 4. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 32 slides.

Taylor, R. 2015. HABCAM V2. TORS 5-8. PowerPoint Presentation to Scallop Survey Methodologies Peer Review, March 17-19, 2015. New Bedford, MA. 24 slides.

3. Summary of Findings for each ToR

1. Review the statistical design and data collection procedures for each survey system
   a. Dredge surveys conducted on commercial vessels
   b. SMAST video drop camera system
   c. HabCam camera and sensor sled
   d. Dredge surveys conducted on research vessels

All the survey methods discussed during the meeting have strengths and weaknesses that affect the accuracy (bias and precision) of key estimates at various spatial scales. In general, the survey methods considered here are statistically sound and have very high standards for quality assurance and quality control (QA/QC). The NEFSC dredge survey employ stratified random sampling, while the VIMS dredge survey and the SMAST drop camera surveys employ systematic designs with uniform (equal inclusion probability) deployment of stations in the entire survey area covered by each method. The HabCam V2 survey has generally followed a systematic transect sampling design with high intensity sampling along closely spaced transects in targeted areas, while the survey design for the HabCam V4 is under development, and has included ad-hoc opportunistic sampling between dredge stations that are far apart.

The use of a uniform systematic survey design as employed in the VIMS dredge survey and the SMAST drop camera survey is in general likely to be inefficient for estimating abundance and biomass of scallops because significant effort is spent in areas with minimal abundance.

However, such uniform allocation of effort can be advantageous for other objectives, such as mapping and classification of habitat, quantification of abundance of species subject to by-catch in the scallop fishery, and monitoring of a range of other bottom-dwelling species. These additional considerations may justify the systematic sampling designs.

The accuracy (precision and bias) of sea scallop abundance by size class and biomass estimates are particularly related to the spatial sampling coverage of the resource, the selectivity and efficiency of the sampling gear, survey design including estimators, and sampling intensity. Improvements in accuracy in these programs will generally require increased sample sizes, increased spatial coverage, and advanced experimental studies for determining gear efficiency and selectivity. Such improvements are costly, and therefore it is important that data needs and level of accuracy required for stock assessments be prioritized.

The five complementary survey methods under review have supported successful fishery advice and management in recent years. The Atlantic sea scallop fishery is the most valuable single-species fishery in the United States, and the sustainability of this fishery suggests that the comprehensive spatial management practices supported by the multiple surveys and implemented by all stakeholders in the fishery have been successful.

Virginia Institute of Marine Science (VIMS) has contracted commercial vessels to conduct cooperative industry based surveys since 1999. Their focus is on estimates of biomass (total and exploitable) to support spatial management. The survey design is a systematic random placement of stations on a regular grid, with a random starting point every year. The survey area is constrained by depth. The current design has incomplete spatial coverage since strata with low abundance are deleted. Uniform allocation of stations in survey area is OK for multiple species surveys but may be inefficient for single species survey since areas of low abundance are oversampled. It should also be noted that systematic sampling on a grid has a longer cruise track than stratified random sampling (Harbitz and Pennington (2004).

Area-swept estimates of absolute abundance and biomass are obtained by correcting for gear efficiency (SARC 2014; an estimated 65% of scallops in the area swept is caught by commercial dredge on average; and 40% for the NEFSC dredge). The VIMS survey takes 15 min tows and uses a tilt sensor to determine the start and end of dredge tows. Numbers at length per tow are transformed to biomass per tow using the shellheight versus meat weight conversion. The stratified mean is scaled up to the total survey area. Random sampling in variance estimation is assumed, even though stations are systematic. Methods in Dunn and Harrison (1993) and references therein may reduce the bias in the variance estimates. This is particularly important if estimates from multiple surveys are combined based on inverse variance weighting.

According to the presentations, VIMS is in the process of redesigning the survey, and are considering adaptive sampling approaches. Precision in abundance and biomass estimates can likely be improved for the same survey ship time by using prior year's data to stratify the survey area and allocate stations to strata so that more effort is spent in areas with high abundance and variance. When sampling allocation of stations among strata is dynamic, it is important to fix the sample sizes for all strata in advance. For efficient systematic spatial sampling see Stevens (1997) and Stevens and Olsen (2004). Because scallops are fairly sessile, the spatial distribution

of scallops for the survey year can be predicted based on last year's data (especially for closed areas). This could potentially significantly improve precision, as compared to the current uniform distribution of sampling effort, which results in too much effort in areas with low abundance. Since the scallops do not recruit to the fishery until they are about 4 years old, they would have to be missed for several years in a row to be overlooked, and this is unlikely. This suggests that too much sampling effort is spent to determine recruitment at the expense of more sampling in areas of commercially sized scallops.

VIMS have conducted nice experiments to test for vessel effects, with paired tows over large area. Using mixed effects models to estimate relative efficiency they provide further evidence of no significant vessel effects in catch per unit effort (cpue) and length distributions in dredge surveys of scallops.

NEFSC has conducted a dredge survey to quantify abundance and biomass of Sea Scallops since 1960, with variable and limited spatial coverage in the early years. The spatial coverage has increased in 1975 and has been more consistent since, and NEFSC has used a stratified random statistical sampling design annually since 1977. The spatial coverage of the NEFSC dredge survey has been reduced in recent years, potentially causing bias in abundance and biomass estimates. To alleviate systematic sampling errors caused by incomplete spatial coverage NEFSC has devoted considerable resources to the development of the HabCam camera and sensor sled (a computerized video camera system), and to support industry-based or cooperative surveys that complement the NEFSC long-term monitoring survey of Sea scallops. Complementary surveys of areas/species not well covered by the standard NEFSC surveys have been particularly important in recent years. The NEFSC dredge and HabCam V4 surveys have been able to compensate for reduced survey time due to less R/V availability by reducing sampling in areas that are covered more intensely by either the VIMS survey or by Arnie's Fisheries with the Habcam V2. The NEFSC dredge survey in recent years has been conducted in 36 days of shiptime, which does not allow full spatial coverage of the resource. The Research Set-Aside Program (RSA) projects, originally designed to obtain fine scale information on scallop densities in areas that were expected to receive heavy fishing pressure, therefore now have become important to ensure sufficient spatial coverage of the resources.

The NEFSC spatial strata boundaries for the dredge survey are not necessarily optimal for scallops. Until 2001 the stations were allocated mostly proportional to area, while since 2001 adaptive allocation based on prior year's survey data have resulted in increased sampling effort in areas of high abundance (and variance). The time series data of the dredge survey could be used to in a simulation study to assess alternative strata boundaries and sampling effort allocation.

Post-stratification is used to account for closed areas within survey strata. Rotational closed areas cut across spatial strata, and therefore it is important to account for different inclusion probabilities in different parts of the closed areas (using, for example, domain estimation methods (Lehtonen and Pakinen 2004; Cochran 1977)).

Time series of annual abundance and biomass estimates based on the survey methods discussed here are likely to be robust to changes in vessels used, which is advantageous, especially when

significant portion of the monitoring is conducted through Research Set-Aside (RSA) programs. The NEFSC dredge survey has been conducted on different vessels, mostly on NOAA R/V Albatross IV and Hugh Sharp, but comparative fishing experiments have shown no vessel effect on the survey estimates. Thus, the use of commercial vessels as a component in the long-term monitoring can be effective and is viable. The use of the HabCam sled would require vessels of sufficient size, and that allow for modifications on deck to handle the deployment, towing, data recording, and retrieving of the HabCam.

NEFSC and VIMS currently use 15 min towing time in their dredge surveys. Multiple sea scallop towing time experiments and comparisons of surveys with different size of sampling units (area-swept) suggest that a reduction down to 5 min towing time, accompanied by an increase in the number of stations, could improve precision for the same survey time (Pennington and Vølstad 1991). Also, bias related to gear saturation and sub-sampling of large catches could be minimized. Since accurate tow length is determined using a dredge sensor in the VIMS and NEFSC surveys, regression models can be used to correct towing distance for depth effects, and normalize it to 1 nm to ensure comparable estimates in the time series. One way to confirm that towing time can be reduced is to embed tow duration experiments in the standard monitoring surveys. At, say, 10% - 20% of sampling stations, selected randomly, hauls of 5 min, 10 min, and 15 min (in random order) could be taken. Over time, this would build up more data to determine appropriate towing time. The HabCam data could also provide valuable information to determine the appropriate sampling unit size for the dredge since photos are taken continuously along transects. Analysis of scallop abundance data from the HabCam transect survey could look at coefficients of variation and relative standard errors for units of different size in a simulation study. The paired HabCam and dredge data can also be used to calibrate the dredge for skate indices etc. One issue to check for is that the HabCam data often are recorded across depth gradients, while dredge tows often are taken along depth gradients.

Since 1999, SMAST has completed >175 cruises surveying Georges Bank and the Mid-Atlantic (>1000 days at sea), with support from the commercial fishing industry. The survey has covered the entire scallop resource from 2003 through 2012, and in 2014. In addition, the survey provides data on scallop abundance in closed areas of Georges Bank and the Mid-Atlantic.

The SMAST drop camera survey is conducted using industry boats in cooperation with the industry. The way I understand the design, it is a systematic survey, with stations (primary sampling units, PSUs) allocated uniformly at the center of each grid-cell on a 3x3 NM grid over the survey area, and with a cluster sample of four replicate photos (quadrats) taken at each station. I agree with the variance estimator for two-stage sampling, under the (strong) assumption of simple random sampling. However, it appears that the sampling fractions f_1 and f_2 used in the finite population correction in slide 10 in the SMAST presentation on the Scallop Survey Drop Camera Review ToR 1-4 are in error (Figure 1). A station (PSU) covers an area of 130 m^2, and each secondary sampling unit (SSU=photo quadrat) within a station covers an area of 2.841 m^2. Thus, for a survey area of, say, 10^8 m^2 the sampling frame of PSUs has N=769231 possible units, and the sampling fraction (f_1=n/N) for 100 stations is then 0.00013. The total number of secondary sampling units (SSUs), M ~ 46 units, and the sampling fraction for the second stage sample is f_2=m/M= 0.087. The two-stage variance estimator is useful for determining the components of the variance. However, since f_1 is approximately zero, sampling with

replacement can be assumed under the simple random sampling assumption used for variance estimation, and, hence, the variance estimate can be based on the PSUs only (Williams 2000).
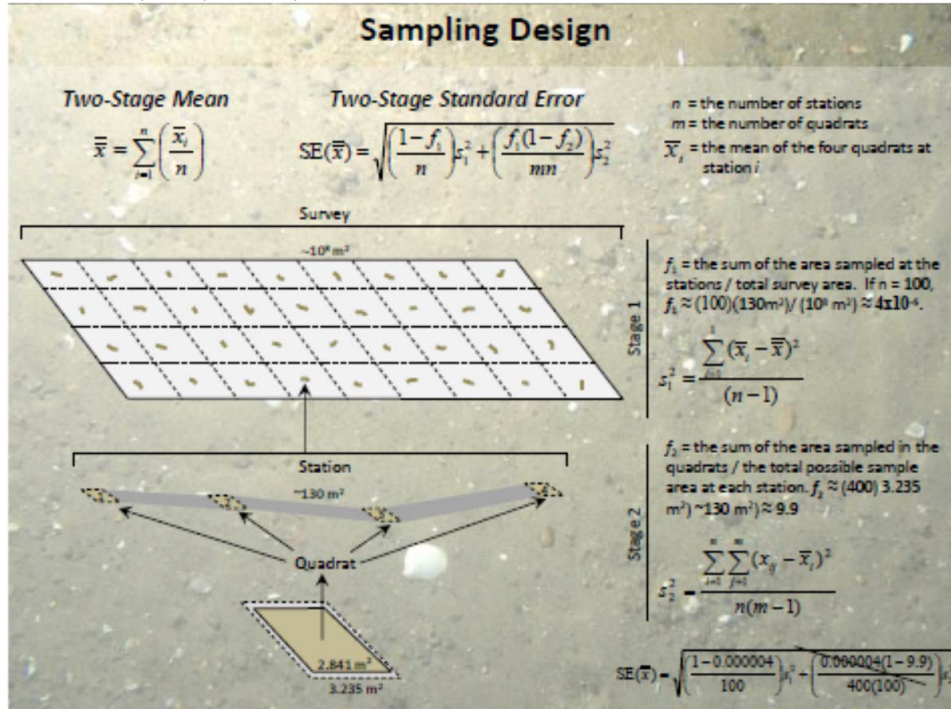

Figure 1. Slide 10. Presentation, SMAST Scallop Survey Drop Camera Review ToR 1-4.

Since the SMAST survey was systematic, the variance estimate under a simple random sampling assumption is likely to be overestimated (Cochran 1977). Methods in Wolter (1985), Bartolucci and Montanari (2006), Dunn and Harrison (1993) and references therein may be used to reduce the bias in the variance estimates. This is particularly important if estimates from multiple surveys are combined based on inverse variance weighting.

The SMAST drop camera survey methods have been developed through exemplary pilot studies where different camera types have been tested, the number of replicates per station versus number of stations has been assessed, and other subsampling procedures have been tested. Measurement errors were studied in calibration experiments (observations by divers; comparison of dredge versus drop camera observations). There were determinations made of live versus dead scallops (use of video for some time; can see closing of shell – helps assure count of live scallops), and of errors due to edge effects, and silt cover of scallops.

The HabCam camera and sensor sled V2 is deployed from a commercial vessel (Arnie's Fisheries), while HabCam V4 is deployed. The HabCam survey method is still under development. In 2011 HabCam V2 was tested in a pilot study during 7-8 days at the end of the dredge survey, using HabCam. In 2012 HabCam was used during days after the dredge survey was completed, using a somewhat opportunistic design (not probability-based). In 2013 the HabCam survey mostly followed a standard regular systematic transect design, with some additional opportunistic sampling in low abundance areas to detect a recruitment (~ 2 year old

10

cohort) event in deeper water. Clearly, the HabCam system lends itself to using well tested methods in acoustic transect surveys.

The use of the stereo camera system on the V4 provides more accurate measures of scallops, especially since 3-D measurements can determine if a scallop is off bottom and correct for this. A particular advantage of the HabCam sled is that it can be towed at 5-7 knots, and since there are six photos taken are per sec (partially overlapping) data on scallop distributions at multiple scales can be assessed. The HabCam V2 surveys generally follows a stratified systematic transect design, and the analysis of the data can therefore be based on similar methods as for acoustic transect surveys (e.g., Jolly and Hampton 1990).

To cover the whole are of occupancy of the resource with HabCam it would take about 30 days of ship time towing at 6 knots to get transects 3.7 nm apart over the resource, according to Paul Rago's calculation. This could be comparable to the distances between the grids for the drop camera grid. It takes 8 or 9 weeks for a full drop camera survey.

2. For each survey, evaluate measurement error of observations including shell height measurement, detection of scallops, determination of live vs. dead scallops, selectivity of gear, and influence of confounding factors (*e.g.,* light, turbidity, sea state, tide etc.)

The information provided to the review panel suggests that the dredge surveys provide more accurate measurements of shell height compared to the drop camera and the HabCam towed camera sled. The measurement of shell height of scallops observed by the SMAST drop camera is likely to be prone to errors when scallops are photographed at particular angles, or when swimming above the ground. The HABCAM 4 imaging processing procedures have largely eliminated systematic errors related to the orientation of scallops, and the distance from bottom.

The dredge samples are likely to most accurately determine the fraction of live scallops. The SMAST drop camera sampling protocol has improved the determination of live versus dead scallops by use of a video camera when it is difficult to determine from photos. Given sufficient spatial coverage and sample sizes, the dredge surveys appear to provide the most reliable data to estimate the size compositions for the size-based assessment model, and also provide biological samples that are used to establish the shell height to meat weight relationship that allows the use of data from optical methods in the estimation of biomass. Thus, having a dredge survey(s) with sufficient spatial coverage is a critical component of long-term monitoring to support stock assessment.

The optical surveys are clearly affected by light and turbidity, but appear to provide nearly unbiased estimates of abundance of exploitable sized scallops, and also better detection of small scallops to estimate recruitment, as compared to dredge surveys. However, none of the methods provide unbiased estimates of small scallops, and thus only provide relative indices of recruitment. The efficient spatial management of sea scallops suggests that estimates of recruitment based on optical surveys are very useful. NEFSC dredge efficiency experiments based on paired dredge/HabCam tows suggests that the selectivity of the dredge causes bias in counts of scallops with shell height less than 38 mm, but minimal selectivity for scallops with

shell height 40 mm or greater. I refer to the consensus summary report for more detailed discussion of bias (underestimates of small scallops and overestimates of abundance of very large scallops) related to the SMAST drop camera edge-effect correction. The HabCam 4 appears to minimize bias in mean size (shell height), but random measurement errors results in wider distributions of shell heights around the means. The use of the stereo camera system on the V4 provides more accurate measures of scallops, especially since 3-D measurements can determine if a scallop is off bottom and correct for this. The system can measure 3-4 mm scallops 0 -35 cm off bottom and then correct for this when measuring scallop heights, which is amazing. Measurement error of size increases with tangent and angle of attack; shell width should be converted to shell height depending on orientation; this provides more accurate height, and then more accurate weight.

When shell heights are converted to meat weight using conversion functions with approximately power of 3 in shell height to weight, then such random errors can cause bias in the biomass estimates since random errors in shell height above the mean will overestimate the meat weight more than the underestimate due to random errors in shell height below the mean.

Based on optical methods used in experimental gear efficiency studies it has been estimated that the standard NEFSC sampling dredge on average captures 40% of the scallops in the area swept on sandy bottom, and 24% on gravel. Based on such experimental studies, it is possible to approximately correct for dredge gear efficiency (at least for commercial sizes of scallops) and thus obtain absolute estimates of abundance and biomass that can be combined with estimates from optical methods.

The optical methods may also have bias issues related to differential detectability of scallops near the borders of the photo frames. It appears to be particularly difficult to detect all scallops in the corners of the SMAST photos, and this probably leads to undercounts.

3. Review the biological sampling aspects of the surveys, including sub-sampling procedures and the ability to sample all size classes. For each survey, evaluate the utility of data to detect incoming recruitment, assess the potential ability to assess fine scale ecology (*e.g.,* Allee effect, predator-prey interactions, disturbance from fishing gear, etc.).

According to the presentations, around 20% of the NEFSC dredge tows are subsampled. Since these are large catches, bias due to subsampling at these stations could have substantial influence on the overall abundance and biomass estimates. Currently, subsamples of baskets from large catches are composited, and no information is recorded for individual baskets. It would be advantageous to start recording data for subsamples. This could be used to assess variability among subsamples and determine optimal subsample sizes of baskets. Both the VIMS and NEFSC dredge programs record the subsampling procedures and expand estimated size frequencies by the ratio of total weight of scallops caught to the total weight of scallops sampled. However neither of the programs estimates the between basket variation for subsamples. Subsampling for meat weights is currently done by selecting five meats at random per NEFSC dredge survey station. A statistical sampling design should be developed and applied. In

particular I recommend that NEFSC assess systematic subsampling of meats (for example colleting one meat per X mm shell height class). In subsampling of otoliths for age determination of fish, it has been showed that such systematic sampling can improve precision in estimates of numbers at age for a given number of otoliths as compared to simple random sampling (Aanes and Vølstad, 2015). It is likely that systematic sampling of meats by size classes could improve the precision in estimates of biomass from size-based estimates.

The optical methods are more efficient than the dredge for detecting incoming recruitment because there are better able to detect small scallops than the dredge. The HabCam method is particularly suited for ecological studies because of its ability to assess fine scale ecology such as quantifying patch size for predators and prey (an example was provided where the distribution of whelks and scallops were mapped.)

4. Review methods for using survey data to estimate abundance indices. Evaluate accuracy (measures of bias) of indices as estimates of absolute abundance.

The methods employed to estimate absolute abundance within areas covered by each surveys are reasonable. Bias is primarily related to size selectivity of the gear and gear catching or efficiency (of dredges) or the detection probability of the optical methods. For global estimates of absolute abundance, additional bias is primarily related to spatial coverage. All methods appear to provide reasonable estimates of abundance of commercially sized scallops for the spatial areas they cover. For small scallops all methods have issues related to their ability to detect or catch scallops. Therefore, estimates of the abundance of scallops below 40 mm are biased, and for very small newly recruited scallops the counts will only serve as an indicator. For commercially sized scallops, experimental studies have provided estimates of gear efficiency for the dredge that are used to obtain absolute estimates from the dredge samples. Although the experiments were not discussed in detail, the methodology and estimates seemed valid. The optical methods provide direct estimates of absolute abundance based on counts, but are subject to some systematic errors for example due to edge effects (SMAST) and other measurement errors.

The design-based estimates of abundance follow standard methods. The VIMS dredge survey is post-stratified into nine sub-areas, and standard stratified estimators are used to estimate overall abundance for all areas. However, potential biases in the gear efficiency estimates (over time or space) will affect the accuracy of the survey biomass estimated.

As pointed out earlier, the design-based estimates of variance of abundance estimates for the systematic surveys (SMAST and VIMS) are likely to be biased upwards. Alternative methods are provided in Harrison and Dunn (1993).

For both HabCam V2 and V4, three model-based methods (ordinary kriging, GAM/GAMM with kriging) and a design-based method (stratified mean) were tested through simulations. A model based approach involving a hurdle-GAM for large scale trend plus kriging on residuals was used for several (~14) large areas.

The model-based approaches employed for the HabCam data are complicated. No single method performed consistently best across all simulations. The geostatistical modelling approach seems

reasonable but it was concerning that the interpolation method estimated the highest abundance in areas with no samples. This could be seriously misleading if the modeled biomass estimates were used in a spatial management procedure. The use of kriging to estimate the precision in biomass and abundance estimates is strongly dependent on the assumption of isotropic variograms since the HabCam transects are systematically spaced in the E-W direction. For a check, alternative methods for estimating variance based on post-stratification could be applied (for example grouping two transects, and use methods in Harrison and Dunn 1993; see also Jolly and Hampton1990). Also, the autocorrelation in HabCam counts at spacing similar to the spacing between transects could be compared to the correlation between neighboring transects to assess the assumption of a direction-invariant variogram.

5. Evaluate any proposed methods for integrating and using surveys outside of a stock assessment model for management purposes.

Since no survey method provides a complete coverage of the entire stock area on a regular basis the NEFSC scientists are forced to integrate the information from the surveys before they provide managements advice. Within reason, all the survey methods provide abundance estimates of commercially sized scallops by size class, and indices of recruitment for the spatial areas they cover. When each method covers separate spatial areas, the estimates could in principle be treated as independent and added up to provide a global estimates for an area that covers the maximum portion of the resource. I believe the main issue in this case is related to the timing of the surveys – especially if some areas are subject to fishing. In areas where two or more surveys overlap in time and space, it would be advantageous to give more weight to the more precise estimates, for example by using composite estimators with inverse variance weighting (Rao 2003). However, inverse variance weighting would perform best when there are reliable estimates of variance, which is difficult for surveys with systematic sampling designs (the SMAST drop camera and VIMS dredge). The estimators presented assume simple random sampling and, hence, the variances of estimates from these surveys are expected to be overestimated. Wolter (1985) and Dunn and Harrison (1993) provide alternative methods for estimating the variance for systematic sampling.

One presentation showed the use of a co-kriging model to combine observations from all surveys. This is work in progress. It seems particularly difficult to apply one model to data derived from surveys with sampling units that are of very different spatial scales (e.g., SMAST photo data, versus dredge tows, or HabCam transects).

It would be advantageous to have an overall design for dredge and optic survey methods that would support design-based and simple model-assisted estimates of abundance and biomass with associated precision. In particular, reliable estimates of global biomass across methods would require that the dredge survey (biological sampling) be designed in a manner that provides reliable shell-height to weight estimates for each survey area so that abundance estimates from optical methods also can be used to estimate biomass.

Also, improved estimates of dredge efficiency and visual count accuracy by habitat type have potential for improving accuracy in combined estimates. Some survey areas have hard bottom habitats or sand. It may be possible to get separate gear efficiency estimates for the NEFSC

dredge for these habitats based on HabCam paired observations. Areas with very poor visibility may also be better surveyed with a dredge.

HabCam and dredge observations could be paired to refine gear efficiency estimates (by habitat classes, such as sand, hard-bottom, gravel). Post-stratify dredge and HabCam tracks by habitat classes and use different dredge efficiency in each class in regression estimator may be an idea.

The simulation study presented to compare estimators was impressive. The modeling suggests that proper stratification for the HabCam survey based on previous years and long-term data can result in the most precise estimates, with no bias (bias is caused by the post-hoc stratification).

6. Comment on potential contribution of each survey to assessments for non-scallop species and use of data apart from assessment purposes such as characterizing species habitat, understanding sea scallop ecology, and ecosystem studies.

The NEFSC Scallop dredge index is used in assessments for goosefish, GB yellowtail flounder, and skate, and for haddock recruitment (but spatial coverage an issue for some species). The dredge surveys are also effective for capturing flounders.

The HabCam camera and sensor sled is a non-invasive method of observing and recording underwater stereo images, and collecting oceanographic data, such as temperature, salinity, and conductivity. In addition to the main mission of surveying the population of scallops, the HabCam is well suited to mapping the substrate of the ocean floor and changes related to fishing activities. The presence of roundfish (eel, sea snakes, monkfish, ocean pout, and hake), flatfish (flounders and fluke), whelk, crab, and skates is also recorded. Although sea stars (starfish) are a major predator of scallops, they are currently not included in the standard data stream. Although there is low taxonomic resolution now, this method has big potential for monitoring changes in the community due to global warming etc.

The SMAST drop camera survey with its systematic design is particularly useful for the mapping of habitat/substrate, and may also provide presence/absence information to map the distribution of demersal fish. Related to fish avoidance, there seem to be a difference between Drop-camera and HabCam. When using drop-camera, it appears that the light causes fish to "freeze" (maybe good for multispecies observations), while species specific fish avoidance may be more of an issue with the towed HabCam.

7. Comment on the current and/or any proposals for optimal frequency and combination of survey methods.

The monitoring surveys of sea scallop support multiple objectives and provide critical information for the complex and dynamic management system. Annual surveys are required to support the spatial management that includes yearly changes in fishing patterns and closing and opening of areas for fishing. Yearly surveys also make it possible to detect and protect recruitment events, and avoid under- and over-harvesting of stock components. With annual surveys using a combination of dredge and optical sampling gears, estimates of abundance and

biomass can be provided at local and global scales, allowing managers to regulate the fishery in quick response to mortality/predation and recruitment events. Since the value of the fishery is very large relative to cost of the surveys, the current level of frequency and broad coverage seems warranted, especially taking into account the success of scallop management in recent years.

NEFSC listed three approaches they have considered for combining results from multiple surveys: simple averages, inverse variance weighted means, co-kriging/other modeling approaches. They were doing inverse variance weighted means but backed away from this approach for some reason. The inverse variance weighting seems reasonable for commercially sized scallops if done for spatially overlapping areas. However, since variance is related to the mean, there are concerns that higher abundance areas would be down-weighted and the sum over areas of inverse-variance weighted means could be less than the sum over areas calculated with other methods. This problem would be minimized if surveys only are combined for areas where they overlap.

The multiple surveys are coordinated through a cooperation to minimize gaps in the spatial coverage. Also, VIMS and NOAA have standardized the dredge sampling protocol, and have conducted experiments to estimate dredge catching efficiency and have standardized methods to provide area-swept estimates of abundance and biomass that can be pooled across spatial strata. However, an issue is that the VIMS and NEFSC dredge surveys are not conducted at the same time. The HabCam V2 and V4 surveys are also coordinated with the VIMS and NEFSC dredge surveys so that the collective effort reduces gaps in the spatial coverage. It is strongly recommended that the overall monitoring efforts be further integrated to provide synoptic coverage of the entire area of sea scallop occupancy. Using information from prior year's data, the stratification and allocation of sampling effort among strata could likely be optimized to balance the need for precise estimates of biomass and abundance of commercially sized scallops at multiple scales and need for detecting new recruitment.

Dredge surveys provide the most reliable estimates of size distributions of commercially sized scallops, and are required to obtain representative biological samples used for shell-height to meat weight conversions and disease studies. Biological samples collected by observers onboard fishing vessels can provide useful complimentary data. However, since fishing is on concentrations of sea scallops, and does not occur in closed areas, estimates based on such data will likely be biased for the overall stock, but will be representative for the landings.

A combination of dredge and optical methods seems to be an efficient approach, but the combination of methods could be more effective if the surveys are integrated. The use of optical methods is particularly important for the detection of recruitment events. If methods are modified, particular care should be given to maintain the continuity of time-series. Given the wealth of data, it should be possible to come up with a more efficient overall survey design that allows the combination of data from complementary survey methods to provide more reliable estimates of abundance by size class, biomass, and spatial distribution of sea scallops. Data from integrated designs that combine dredge surveys and HabCam surveys could be combined using model-assisted estimators as in the method used by Hjelvik et al. (2007) and Everson et al. (1996) for combining trawl and acoustic survey data. If there is high correlation between the

counts from the HabCam transect sections (of similar length as dredge tows) and counts from paired dredge tows, then combining the estimates could substantially improve precision in abundance estimates. See also Catchpole and Catchpole (1993) for an example.

8. Identify future research and areas of collaboration among investigators and institutions.

It is recommended that that historic data from all surveys as well as data from the fisheries be used in a simulation study to improve the strata boundaries, and the allocation of sampling effort among strata. The habitat maps of substrates could be used to improve stratification.

It is recommended that probabilistic survey designs be used in all studies, and if systematic surveys are favored, I recommend that methods in Stevens (1997) and Stevens and Olsen (2003) be consulted for stratified surveys.

Experimental studies to provide estimates of dredge efficiency and visual count accuracy by habitat type has potential for reducing bias and improving precision. Gravel is a difficult habitat for visual counts while hard bottom habitat is difficult for dredge sampling. It could be possible to get separate gear efficiency estimates for these habitats based on HabCam paired observations.

For dredge surveys, it would be advantageous to start recording sample data for subsamples. This could be used to assess variability among subsamples and to determine optimal sizes of the basket subsamples.

Subsampling of meat weights is currently done by selecting five meats at random per NEFSC dredge survey station. In an embedded experiment, it is recommended that a statistical sampling design be developed and tested. In particular I recommend that NEFSC assess the use of systematic ("size-stratified") subsampling of scallop meats.

Analysis to assess the correlation between dredge tow catches and HabCam scallop counts at various spatial scales is strongly encouraged. If a proper sampling unit size (segment length within HabCam transects) for the optical observations can be established, and high correlation between paired dredge and HabCam observations can be established, then model-based estimators can be effectively used to combine data from the two sources and improve precision in estimates of stock size while maintaining the continuity of the NEFSC dredge time series. The advantage of the HabCam is that it can be towed at fairly high speed, and can get counts along random-systematic transects that can be used as covariates to improve the abundance/biomass estimates based on the dredge counts.

4. Comment on the Review Process

The peer review process was very well organized, and the presentations and discussions at the peer review meeting were invaluable for understanding the complexity of the five survey methods currently employed for seas scallops. The review meeting was effective, and held in a collegial atmosphere. The extensive background material was provided in due time before the

review, and was well organized by topic. This was much appreciated. However, it would be very useful if all the supporting documents were prioritized in terms of their importance for answering the terms of reference since it is not possible to study all the material in detail within the allotted time. For a review with such a wide range of survey methods and topics to be addresses expertise in multiple disciplines is clearly required, and my independent report does not cover all topics equally well. For technical aspects of the optical survey methods and in particularly discussion of measurement errors related to sea scallop counts and measurements of shellheight, I have deferred to fellow CIE team members who are specialists in this field. The CIE review team with four members had a range of expertise that was complimentary, and allowed each of us to focus more on the topics within our core expertise, and I felt that we jointly covered the ToR well. I was impressed by the expertise and experience of the scientific teams, and my team panel members, and found this review to be very interesting and rewarding.

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Appendix 2: Statement of Work

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Statement of Work

**Review of Sea Scallop Survey Methodologies and
Their Integration for Stock Assessment and Fishery Management**

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BACKGROUND

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Representative (COR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are independently selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

SCOPE

Project Description: On April 20, 2012, the New England Fishery Management Council voted to task its Science and Statistical Committee (SSC) "to 1) review the sea scallop HabCam survey technology and methods to determine if the HabCam is appropriate at this time for performing annual sea scallop surveys; 2) review how HabCam results will be integrated into sea scallop assessments for determining biomass and fishing mortality, and determine the impacts of reduced survey coverage from current dredge and SMAST video surveys." Further discussions broadened the scope of this task to examine all of the primary survey methods for assessing sea scallop abundance. Methods include scallop dredge surveys conducted on research vessels, scallop dredge surveys conducted on commercial vessels, the drop camera survey implemented by SMAST, and the HabCam system developed by WHOI and NEFSC. The objectives of this broadened scope are to assess the strong and weak points of each sampling approach, and identify the complementary facets of each survey methodology and opportunities for each method as part of the scallop survey sampling program going forward.

The purpose of this meeting will be to provide an external peer review of survey methodologies currently being used which provide data for sea scallop stock assessments and related fishery management models.

OBJECTIVES

The review panel will be composed of four appointed reviewers from the Center of Independent Experts (CIE), and an independent chair from the SSC of the New England or Mid-Atlantic Fishery Management Council. The panel will write the Panel Summary Report and each CIE reviewer will write an individual independent review report.

Duties of reviewers are explained below in the "**Requirements for the Reviewers**", in the "**Charge to the Review Panel**" and in the "**Statement of Tasks**". The Terms of Reference (ToRs) are attached in **Annex 2**. The draft agenda of the panel review meeting is attached in **Annex 3**.

Requirements for the reviewers: Four reviewers shall conduct an impartial and independent peer review of **sea scallop** survey methodology, and this review should be in accordance with this SoW and ToRs herein. Collectively, the reviewers shall have advanced knowledge, recent experience and:

1. Expertise in use of optical imaging in estimating abundance in marine biological surveys
2. Expertise in statistical design and estimation of surveys for stock assessments including stratified random, systematic and transect surveys.
3. Expertise with model-based estimation of abundance using geostatistical tools.
4. Expertise in the use of dredge surveys for sessile benthic organisms.

Knowledge of sessile invertebrates and spatial management would be desirable.

PERIOD OF PERFORMANCE

The contractor shall complete the tasks and deliverables as specified in the schedule of milestones within this statement of work. Each reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Not covered by the CIE, the Chair's duties should not exceed a maximum of 10 days (i.e., several days prior to the meeting for document review; the peer review meeting; several days following the meeting for Panel Summary Report preparation).

PLACE OF PERFORMANCE AND TRAVEL

Each reviewer shall conduct an independent peer review during the panel review meeting scheduled in New Bedford, Massachusetts during March 17-19, 2015.

STATEMENT OF TASKS

Charge to the Review Panel:
The panel will review field and analytical procedures used by each survey in estimating sea scallop abundance and biomass and collecting biological data that contribute to resource assessment and management of sea scallops and other species. Describe the strengths, weaknesses and the opportunities for improvement in the surveys, including their methods and estimators, as an overall program that serves as a basis for abundance and biomass estimates used in annual area-based scallop fishery management procedures and triennial benchmark stock assessments. Finally, describe opportunities for using each survey in monitoring and managing resources other than sea scallops.

Each reviewer shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Tasks prior to the meeting: The contractor shall independently select qualified reviewers, without conflicts of interest, to conduct an independent scientific peer review of reports and presentations prepared by NEFSC and other groups in accordance with the tasks and ToRs within the SoW. Upon completion of the independent reviewer selection by the contractor's technical team, the contractor shall provide the reviewer information (full name, title, affiliation, country, address, email, FAX number, and CV suitable for public distribution) to the COR, who will forward this information to the NMFS Project Contact no later than the date specified in the Schedule of Milestones and Deliverables. The contractor shall be responsible for providing the SoW and ToRs to each reviewer. The NMFS Project Contact will be responsible for providing the reviewers with the background documents, reports for review, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact will also be responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COR prior to the commencement of the peer review.

Foreign National Security Clearance: The reviewers shall participate during a panel review meeting possibly at a government facility, and the NMFS Project Contact is therefore responsible for obtaining the Foreign National Security Clearance approval (if the meeting is held on federal property) for the reviewers who are non-US citizens. For this reason, the reviewers shall provide by FAX (or by email if necessary) the requested information (e.g., 1.name [first, middle, and last], 2.contact information, 3.gender, 4.country of birth, 5.country of citizenship, 6.country of permanent residence, 7.whether there is dual citizenship, 8.country of current residence, 9.birth date [mo, day, year], 10.passport number, 11.country of passport) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/.

Pre-review Background Documents and Working Papers: Approximately two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the Chair and CIE reviewers the necessary background information and reports (i.e.,

working papers) for the peer review.   Should documents need to be mailed, the NMFS Project Contact will consult with the COR on where to send documents. The reviewers are responsible only for the pre-review documents that are delivered to the contractor in accordance to the SoW scheduled deadlines specified herein. The reviewers shall read all documents deemed as necessary in preparation for the peer review.

Tasks during the panel review meeting: Each reviewer shall conduct the independent peer review of documents and presentations in accordance with the SoW ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs shall not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COR and contractor.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

(Chair)
Act as chairperson, where duties include control of the meeting, coordination of presentations and discussions, ensuring all Terms of Reference are reviewed, controlling document flow, and facilitating discussion.

During the question and answer periods, provide appropriate feedback to the scientists on the sufficiency of their analyses and presentations. It is permissible to request additional information if it is needed to clarify or correct an existing analysis and if the information can be produced in the time allotted.

(CIE reviewers)
Participate as peer reviewer in panel discussions on validity, results, recommendations, and conclusions. From a reviewer's point of view, determine whether each Term of Reference was completed successfully. During the question and answer periods, provide appropriate feedback to the scientists on the sufficiency of their survey methods and related analyses. It is permissible to request additional information if it is needed to clarify or correct an existing analysis and if the information can be produced in the time allotted.

Tasks after the panel review meeting:

CIE reviewers:
Each CIE reviewer shall prepare an Independent CIE Report (see **Annex 1**). This report should comment, for each TOR as appropriate, on the strengths and weaknesses of the surveys, both individually and as a group going forward. The report should follow the guidance provided in the "Charge to the Review Panel" statement.

During the meeting, additional questions that were not in the Terms of Reference but that are directly related to the assessments may be raised. Comments on these questions should be included in a separate section at the end of the Independent CIE Report produced by each reviewer.

The Independent CIE Report can also be used to provide greater detail than the Panel Summary Report.

Chair:
The Chair shall prepare a document summarizing the background of the work to be conducted as part of the review process and summarizing whether the process was adequate to complete review of the Terms of Reference. If appropriate, the chair will include suggestions on how to improve the process. This document will constitute the introduction to the Panel Summary Report (see **Annex 4**).

Chair and CIE reviewers:
The Chair, with the assistance from the CIE reviewers, will prepare the Panel Summary Report. Each CIE reviewer and the chair will discuss whether they hold similar views on each ToR and whether their opinions can be summarized into a single conclusion for all or only for some of the ToRs. For ToRs where a similar view can be reached, the Panel Summary Report will contain a summary of such opinions. In cases where multiple and/or differing views exist on a given ToR, the Panel Summary Report will note that there is no agreement and will specify - in a summary manner – what the different opinions are and the reason(s) for the difference in opinions.

The chair's objective during this Panel Summary Report development process will be to identify or facilitate the finding of an agreement rather than forcing the panel to reach an agreement. The chair will take the lead in editing and completing this report. The chair may express the chair's opinion on each Term of Reference, either as part of the group opinion, or as a separate minority opinion.

The Panel Summary Report (please see **Annex 4** for information on contents) should address each of the ToRs, keeping in mind criteria in the "Charge to the Review Panel".

The contents of the draft Panel Summary Report will be approved by the CIE reviewers by the end of the Panel Summary Report development process. The chair will complete all final editorial and formatting changes prior to approval of the contents of the draft Summary Report by the CIE reviewers. The Chair will then submit the approved Summary Report to the NEFSC contact.

DELIVERY

Each reviewer shall complete an independent peer review report in accordance with the SoW including required format and content as described in **Annex 1**. Each reviewer shall complete the independent peer review addressing each ToR listed in **Annex 2**.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting in New Bedford, MA, scheduled during March 17-19, 2015.
3) Conduct an independent peer review in accordance with this SoW and the ToRs (listed in **Annex 2**).
4) No later than April 3, 2015, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and to Dr. David Sampson, CIE Regional Coordinator, via email to david.sampson@oregonstate.edu. Each CIE report shall be written using the format and content requirements specified in **Annex 1**, and address each assessment ToR in **Annex 2**.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

February 6, 2015	Contractor sends reviewer contact information to the COR, who then sends this to the NMFS Project Contact
March 2, 2015	NMFS Project Contact will attempt to provide reviewers the pre-review documents
March 17-19, 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting in New Bedford, MA. Chair and CIE reviewers work at drafting reports during meeting
April 3, 2015	Reviewers submit draft independent peer review reports to the contractor's technical team for independent review
April 3, 2015	Draft of Panel Summary Report*, reviewed by all CIE reviewers, due to the Chair
April 10, 2015	Chair sends Final Panel Summary Report, approved by CIE reviewers, to NEFSC contact
April 17, 2015	Contractor submits individual peer review reports to the COR who reviews for compliance with the contract requirements
April 22, 2015	The COR distributes the final individual reports to the NMFS Project Contact and regional Center Director

* The Summary Report will not be submitted, reviewed, or approved by the CIE.

The NEFSC Project Contact will assist the chair prior to, during, and after the meeting in ensuring that documents are distributed in a timely fashion.

NEFSC staff and the Chair will make the final Panel Summary Report available to the public.

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COR within 10 working days after receipt of all required information of the decision on substitutions. The COR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: The deliverables shall be the final peer review report from each reviewer that satisfies the requirements and terms of reference of this SoW. The contract shall be successfully completed upon the acceptance of the contract deliverables by the COR based on three performance standards:

(1) each report shall be completed with the format and content in accordance with **Annex 1**,
(2) each report shall address each ToR listed in **Annex 2**,
(3) each report shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Upon the acceptance of each independent peer review report by the COR, the reports will be distributed to the NMFS Project Contact and pertinent NMFS science director, at which time the reports will be made publicly available through the government's website.

The contractor shall send the final reports in PDF format to the COR, designated to be William Michaels, via email William.Michaels@noaa.gov

Support Personnel:

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NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
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Key Personnel:

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Annex 1: Format and Contents of Independent Individual Peer Review Report

1. The independent peer review report shall be prefaced with an Executive Summary providing a concise summary of the strengths and weaknesses of the reviewed sea scallop surveys, both individually and when used in combination.

2. The main body of the report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Key findings on work reviewed, and an explanation of their conclusions and recommendations (strengths, weaknesses of the analyses, etc.) for each ToR.

    a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including a concise summary of strengths and weaknesses of the analyses and recommendations for the future.

    b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

    c. Reviewers should elaborate on any points raised in the PanelSummary Report that they feel might require further clarification.

    d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

    e. The individual independent report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not others read the Panel Summary Report. The independent report shall be an independent peer review of each ToR, and shall not simply repeat the contents of the Panel Summary Report.

3. The reviewer report shall include the following appendices:

    Appendix 1: Bibliography of materials provided for review
    Appendix 2: A copy of this Statement of Work
    Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference

(These ToRs are to be carried out by the scientists involved with scallop survey methods and analyses. The Peer Review Panel will then address the strengths and weaknesses of the various survey approaches and survey methodologies, with a focus on these ToRs.)

1. Review the statistical design and data collection procedures for each survey system
   a. Dredge surveys conducted on research vessels
   b. Dredge surveys conducted on commercial vessels
   c. SMAST video drop camera system
   d. HabCam camera and sensor sled

2. For each survey, evaluate measurement error of observations including shell height measurement, detection of scallops, determination of live vs. dead scallops, selectivity of gear, and influence of confounding factors (*e.g.,* light, turbidity, sea state, tide etc.)

3. Review the biological sampling aspects of the surveys, including sub-sampling procedures and the ability to sample all size classes. For each survey, evaluate the utility of data to detect incoming recruitment, assess the potential ability to assess fine scale ecology (*e.g.,* Allee effect, predator-prey interactions, disturbance from fishing gear, etc.).

4. Review methods for using survey data to estimate abundance indices. Evaluate accuracy (measures of bias) of indices as estimates of absolute abundance.

5. Evaluate any proposed methods for integrating and using surveys outside of a stock assessment model for management purposes.

6. Comment on potential contribution of each survey to assessments for non-scallop species and use of data apart from assessment purposes such as characterizing species habitat, understanding sea scallop ecology, and ecosystem studies.

7. Comment on the current and/or any proposals for optimal frequency and combination of survey methods.

8. Identify future research and areas of collaboration among investigators and institutions.

Appendix to Annex 2:

In their presentations and reports for the peer review, analysts (as opposed to the peer reviewers) will cover a broad range of topics, such as:
   1. Summaries of historical scallop survey indices, and their components (e.g., frequency, spatial extent, data collected), from the NEFSC sea scallop survey, the SMAST video survey, relevant VIMS cooperative industry surveys, and HabCam surveys from WHOI and Arnie's Fisheries.

For each of these surveys, additional topics include survey design, objectives, methods, and any relevant changes over time.

2. Summaries of current approaches for using abundance indices in stock assessment and management models. (Stock assessment models describe the dynamics of populations over time and estimate total stock size and mortality rates. Management models are used to evaluate the short-term effects of alternative harvesting scenarios at varying degrees of spatial resolution.)

3. Summaries of procedures for data acquisition, post processing, archiving, availability to outside investigators, publication of derived products in primary literature, and use for stock assessments.

Rules of Engagement among analysts on Working Groups preparing for peer reviews:

Anyone participating in working group meetings that will be running or presenting results from an design or model based estimator is expected to supply the source code, a compiled executable, an input file with the proposed configuration, and a detailed description in advance of the meeting. These measures allow transparency and a fair evaluation of differences that emerge among design and model based estimates of abundance.

Annex 3: Draft Agenda

Sea scallops Survey methods review

March 17-19, 2015

(Location: New Bedford, Mass.)

DRAFT AGENDA*   (version: October 17, 2014)

TOPIC	PRESENTER(S)	RAPPORTEUR

Tuesday, March 17

9 – 9:30 AM
Welcome   **Chair**   **TBD**
Introduction
Agenda
Conduct of Meeting

9:30 – 10:30 AM   Presentation #1
                                                               TBD   **TBD**

12:30 – 1:30 PM   Lunch

1:30 – 3:30 PM   Presentation #2

                                                               TBD   **TBD**

3:30 – 3:45 PM   Break

3:45 – 5:45 PM   Presentation #3

                                                               Chair   **TBD**

5:45 – 6 PM   Public Comments

TOPIC	PRESENTER(S)	RAPPORTEUR

Wednesday, March 18

9 – 10:45 AM Presentation #4		
	TBD	**TBD**
10:45 – 11 AM Break		
11 – 12:30 PM Presentation #5		
	TBD	**TBD**
12:30 – 1:45 PM Lunch		
1:45 – 3:15 PM Presentation #6	TBD	**TBD**
3:15 – 3:30 PM Public Comments		
3:30 -3:45 PM Break		
3:45 – 6 PM Presentation #7		
	TBD	TBD
7 PM **(**Social Gathering **)**		

Thursday, March 19

8:30 – 10:15 Review of Key Findings	Chair	**TBD**
10:15 – 10:30 Break		
10:30 – 12:30 Review/edit Panel Summary Report	Chair	**TBD**
12:30 – 1:45 PM Lunch		
1:45 – 2:15 PM Review/edit Panel Summary Report **(cont.)**	Chair	**TBD**
2:15 – 2:30 PM Break		
2:30 – 5 PM Review/edit Panel Summary Report	Chair	**TBD**

*All times are approximate, and may be changed at the discretion of the Chair. The meeting is open to the public.

The NMFS Project contact will provide the final agenda about four weeks before meeting. Reviewers must attend the entire meeting.

Annex 4: Contents of Review Panel Summary Report

1. The main body of the report shall consist of an introduction prepared by the Chair that will include the background, a review of activities and comments on the appropriateness of the process in reaching the goals of the Review. Following the introduction, for each ToR the report should address the issues described earlier in the "Charge to the Review Panel" within the "Statement of Tasks".

2. To make its determinations, the Chair and CIE reviewers should consider whether the survey methods provide a scientifically credible basis for estimating sea scallop abundance. Scientific criteria to consider include: whether the methodologies and estimators are adequate and used properly, and are leading to conclusions that are correct/reasonable. If the CIE reviewers and chair do not reach an agreement on a Term of Reference, the report should explain why. It is permissible to express majority as well as minority opinions.

3. The report shall also include the bibliography of all materials provided during the review, and relevant papers cited in the Summary Report, along with a copy of the CIE Statement of Work.

4. The report shall also include as a separate appendix the Terms of Reference (Annex 2), including any changes to the ToRs or specific topics/issues directly requiring Panel advice.