Center for Independent Experts (CIE) Independent Peer Review Report

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

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Executive Summary

All the statistical survey designs (i.e. with a probability-based sampling scheme) reviewed could be used to provide unbiased estimates of mean scallop abundance in the surveyed areas. These surveys all have the potential to contribute to assessments for non-scallop species and other issues apart from assessment purposes. Annual surveys are required to support the management process with fishery specification adjusted every year in addition to spatial management procedures.

Dredge surveys provide more accurate measurements of shell height and proportion of dead scallops compared to optical surveys. Collection of physical samples with dredges is necessary to estimate the spatio-temporal variation in shell height to meat weight relationship and other measurements that require physical and laboratory examination of specimens. However, optical surveys provided almost complete detection of exploitable scallops, better detection of recruitment, and better information on predator-prey interactions compared to dredge surveys. However, optical surveys provide less accurate information on the exploitable (i.e. 40mm+) size composition because of greater measurement error in shell size compared to dredge surveys.

Variance estimates of abundance and biomass estimates from dredge surveys did not take into account uncertainty in efficiency corrections. The efficiency probably varies from site to site which is a source of measurement error and possibly bias if the sites sampled by dredges (i.e. sand vs gravel) are disproportionate to the population of sites. Variance estimates of exploitable stock size from optical surveys did not take into account measurement error in the size of scallops.

Statistical inferences for surveys of fish stocks and specifically scallops should not be based only on the randomness in the sampling design. Models are required to address measurement error. Models can give more precise estimates even if there is no measurement error. However, statistical inference should not rely solely on a model for a well-designed survey. Combined design and model based inference is a better general approach.

Analyses of surveys have been integrated in a few ways. It is preferable to do a combined analysis of observations with adjustments for relative catchability where appropriate rather than averaging estimates. However, when surveys are not done at the same time then the populations being surveyed could be different due to growth and mortality processes. In this case there may be no choice but to integrate them within a stock assessment model that accounts for such differences. If the surveys cover different areas and if there are large changes in the spatial distribution of the stock then a spatio-temporal stock assessment model will be required to integrate all the surveys.

It is difficult to fully evaluate the monitoring program for scallops in this area without understanding the potential information in commercial CPUE and within-season depletion information about stock size and harvest rates.

Dredge surveys conducted on research vessels

This was the best monitoring survey because it has used a fairly standard sampling design for a long time period. However, the sampling intensity has been reduced significantly in recent years which make this survey less useful for contemporary monitoring purposes.

Dredge surveys conducted on commercial vessels

The Virginia Institute of Marine Science (VIMS) dredge surveys on commercial vessels are less useful as stand-alone monitoring surveys because of incomplete coverage for the entire stock. These surveys have had multiple objectives and the systematic design seemed reasonable to jointly achieve these objectives. However, there are well known difficulties in computing the variance of estimators based on systematic designs and this is another reason why variance estimates for abundance and biomass estimates are probably too low.

SMAST video drop camera system

This survey has achieved good coverage of the resource in some recent years. It has had multiple objectives and the centric systematic design seemed reasonable to jointly achieve these objectives. The edge-effect correction method for this survey will under-estimate the abundance of small scallops and over-estimate large scallops. This is another reason why variance estimates for abundance and biomass estimates are probably too low. The field of view of the SMAST drop camera is approximately fixed. Variance calculations are based on two-stage cluster sampling but should be based on stratified random sampling with proportional allocation, where grids are strata. Even if variances are correctly calculated they may still be biased low because of the centric sampling within a grid and the likely spatial autocorrelation of scallops.

HabCam camera and sensor sled

The HABCAM V4 survey technology had the greatest potential in providing information on bottom habitat, gear impacts, species interactions, and spatial structure on a variety of scales

The HAMCAM V2 survey has generally followed a systematic transect sampling design with high intensity sampling along transects but in small portions of the stock area. The HABCAM v4 survey has not followed a statistical survey design and it is difficult to make conclusions about bias of associated estimates of abundance or biomass for this survey.

HABCAM imaging processing procedures are more advanced and further research in this area is encouraged. The field of view of the towed cameras is variable but this was not identified as an important source of uncertainty. HabCam V4 with the side scan sonar system is the only sampling procedure reviewed that could be used to detect direct physical impacts of fishing gear.

Abundance and biomass estimates, and their variances, were obtained using a complex model. Variances are likely under-estimated because model degrees of freedom were not adjusted for and model uncertainty is an unaccounted source of variation. The model occasionally 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.

Combined surveys

There is already some cooperation among these surveys in terms of producing information for the assessment and management of the stock. The information from the various surveys is complementary or additive in some aspects. The optical methods have provided additional information on species habitat, sea scallop ecology, and ecosystem studies.

Survey efforts should be further integrated to provide a standard monitoring survey of the entire stock distribution; however, the combination of optical and dredge surveys are complementary and should be maintained. The continuity of time-series should be also be maintained to the fullest extent possible.

As long as sufficient transects are sampled, the HABCAM v4 technology can provide a much larger "area swept" with continued improvements in automatic pattern recognition and annotation of images. This should lead to improved precision in estimates of abundance and biomass. Dredge sampling is still required but its future could be more in providing biological samples like in acoustic surveys rather than stand-alone estimates.

Background

The *Review of Sea Scallop Survey Methodologies and Their Integration for Stock Assessment and Fishery Management* was held in New Bedford, Massachusetts, from March 17-19, 2015. The purpose of the meeting was to review survey methodologies currently being used which provide data for sea scallop stock assessments and related fishery management models. These included scallop dredge surveys conducted on research vessels (e.g. Northeast Fisheries Science Center - NEFSC) and commercial vessels (e.g. Virginia Institute of Marine Science - VIMS), the drop camera survey implemented by the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST), and the HabCam system developed by the Woods Hole Oceanographic Institution (WHOI) and NEFSC. The basic objectives of the review were 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 Panel was composed of four independently appointed Center for Independent Experts (CIE) reviewers (Dr. N. Cadigan, Canada; Dr. M. Cryer, New Zealand; Dr. J.H. Vølstad, Norway; Dr. B. Wise, Australia). The meeting was chaired by Dr. J.-J. Maguire, Canada. The review was supported and assisted by 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 (NEFMC). Documents and presentations were provided by Paul Rago, Dvora Hart, Dave Rudders, Kevin Stokesbury, Scott Gallager, Richard Taylor, Burton Shank, Jui-Han Chang and Deirdre Boelke. The support of all of these scientists and staff to the review process is gratefully acknowledged.

The CIE reviewers were collectively required to have experience/expertise with optical imaging in estimating abundance in marine biological surveys, statistical design and estimation of surveys for stock assessments, model-based estimation of abundance using geostatistical tools, and the use of dredge surveys for sessile benthic organisms. Approximately two weeks before the review meeting the reviewers were given background documents and reports on the various survey programs. The reviewers were required to read all documents in preparation for the peer review. During the review meeting each reviewer was required to actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks were focused on the stock assessment ToRs. After the meeting each reviewer was required to prepare an independent peer review report formatted as described in Annex 1. Each CIE reviewer's duties were not to exceed a maximum of 14 days to complete all work tasks.

Role of reviewer

All assessment documents and most supporting materials were made available to me during February 28 - March 5, 2015 on a NEFSC website. These documents are listed in Appendix 1. I reviewed these backgrounds documents. I attended the entire Panel review meeting and reviewed presentations and reports and participated in the discussion of these documents, in accordance with the SoW and ToRs (see Appendix 2). I also contributed to the review panel summary report. My CIE report is structured according the required format and content described in Annex 1 of Appendix 2. After the meeting I participated in email discussions and writing to finalize the review panel report.

Key findings

A brief summary of the review panel's (RP) findings is presented for each ToR, followed by my assessment of whether the ToR was successfully completed, and the strengths and weakness of the research conducted where appropriate, and further elaboration on specific issues. Only a draft version of the RP's summary report was available to me when writing my CIE report.

1. ***ToR 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***

Peer review summary report findings

This term of reference was addressed satisfactorily by all presentations. The RP concluded that all surveys had strengths and weaknesses. The dredge surveys conducted on research vessels use a stratified random statistical sampling design since 1977 and have covered a fairly consistent area since 1975 (strength) but coverage and sampling intensity has been reduced in recent years (weakness). The VIMS dredge surveys conducted on commercial vessels have provided detailed information (strength) on specific areas using a systematic sampling design, but this survey does not cover the entire range of the stock (weakness). The SMAST video drop camera system also used a type of statistical uniform systematic design and this survey has achieved good coverage of the resource in some recent years (strength). The HAMCAM V2 survey has generally followed a systematic transect sampling design with high intensity (strength) sampling along transects, but in small portions of the stock area (weakness). Work is continuing on finalizing a statistical sampling design that would be set before the beginning of a survey with the HABCAM V4.

All the statistical survey designs considered by the Panel could be used to provide unbiased estimates of mean abundance in the surveyed areas. The uniform systematic sampling design of the SMAST drop camera and VIMS dredge surveys are inefficient for estimating abundance (weakness) because the sampling intensity is the same in areas of low and high scallop abundance. However, these surveys pursue multiple objectives which may justify the systematic sampling designs. The HabCam V4 surveys provide very detailed information along transects but the typical distance between transects seemed wide (weakness).

The RP considered that surveys with greater spatial coverage and samples allocated throughout the survey area tend to reduce bias and provide more accurate estimates of stock size, especially for populations whose spatial distribution can vary substantially from year to year or on longer time horizons. More intense sampling in areas of high scallop abundance should increase the precision of the overall biomass estimate but spatial management measures may require more detail sampling in rotational areas to achieve optimal use of the resource.

My additional findings

I conclude that this term of reference was addressed satisfactorily by all presentations.

Statistical design

We need to distinguish surveys that have specific objectives that may vary from year to year, and long-term monitoring surveys that are more useful for stock assessment purposes.

I find that the dredge surveys conducted on research vessels is the best monitoring survey because it has used a fairly standard sampling design for a long time period. However, the sampling intensity has been reduced significantly in recent years (i.e. only 122 stations in 2014 compared to 400-500 typical of most other years) which make this survey less useful for contemporary monitoring purposes. This survey uses an adaptive sampling allocation procedure, with a mix of optimal allocation based on previous survey results and proportional allocation to achieve some coverage in all strata. This approach seems reasonable but was not described in much detail and I cannot evaluate its efficacy, nor was such an analysis presented. I find that this survey is now combined with the HABCAM v4 survey because they are carried out jointly, and considerable effort has shifted from dredge sampling to HABCAM sampling.

I appreciate that the VIMS dredge surveys on commercial vessels and the SMAST video drop camera surveys are in response to perceived objectives of NEFMC which may change from year to year. However, this makes them less useful as stand-alone monitoring surveys for the entire stock. I conclude these surveys achieved their objectives which could be different from monitoring the status of the entire stock. The systematic designs of these surveys seemed reasonable to jointly achieve their multiple objectives.

The HABCAM v2 survey provides detailed information for a small part of the stock. The HABCAM v4 survey does not yet seem to follow a statistical sampling design. Hence it is not possible to evaluate the design unbiasedness of estimators derived from this survey and the RP conclusion that this survey can provide an unbiased estimate of mean abundance in the surveyed areas is vague. Unbiased would have to be evaluated in a model-based context. Simulation results provided for the stock size estimation procedure for this survey were based on different survey tracks in each simulation. This seemed to involve a randomization in the sampling design and it is not clear how relevant this is to the actual survey design; that is, will tracks be varied in future surveys like in the simulations? Hence, the simulation results are not specific to the actual survey track achieved.

The HABCAM surveys usually tow across depth gradients, with tows along depth gradients between transects. I don't think they used the latter information in abundance estimation. I appreciate that there will be less serial correlation across depth gradients but this design will produce little information on the short-lag correlation along depth gradients.

Multiple and variable survey objectives make it difficult to optimize a survey design. In practice we rarely get to implement an intended design because of unforeseen operational difficulties. Hence, the design we actually get may be different and sub-optimal compared to the intended design. I think many survey statisticians do not focus too much on detailed optimization of the design. Rather, the focus should be on avoiding sampling gaps and otherwise keeping the design as practical as possible but with the capability of providing robust inference. With the model-based approach it is especially clear that extrapolations to unsampled areas can be unreliable and a potentially large source of uncertainty.

There were presentations on optimal sampling designs for dredges and HABCAM surveys. Within-season adaptive allocation was mentioned as a possibility for the VIMS dredge survey. I point out that the specific proposal, following the approach of Smith and Lundy (2006), is not a fixed-sized sampling design because you do not know how many stations will be sampled before the survey. Care must be taken for estimation as well because standard design-based estimators may be biased with this adaptive design. There are other adaptive procedures that are fixed sized (e.g. Jolly and Hampton, 1990; Francis, 1984) that also seem to result in some bias, and other adaptive designs have been proposed (e.g. Moradi and Salehi, 2010) that can be used with conventional estimators.

A variety of transect sampling designs were investigated for the HABCAM V4 survey. This work seemed thorough although I wondered why a zig-zag design (e.g. Rose, 2003; Overholtz et al, 2006) was not considered especially if there is anisotropic correlation which you may not know too much about. A zig-zag design can produce autocorrelation information in all directions. The zig-zag design is more efficient in terms of total transect length because there is no down time travelling between transects, but it may be less efficient in terms of precision (e.g. Kalikhman, 2002, 2005, 2006).

I appreciate that there is some cooperation among these surveys in terms of producing information for the assessment and management of the stock. This makes it difficult to review these as stand-alone surveys.

Data collection procedures

see ToR3

ToR 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.).

Peer review summary report findings

All presentations addressed this term of reference satisfactorily. The RP concluded that the dredge surveys provide more accurate measurements of shell height compared to optical surveys. Collection of physical samples with dredges is necessary to estimate the spatio-temporal variation in shell height to meat weight relationship and other measurements that require physical and laboratory examination of specimens. The RP concluded that the optical surveys provided almost complete detection of exploitable scallops and better detection of recruitment compared to dredge surveys; however, recruitment information was still only qualitative. The RP concluded that the edge-effect correction method for SMAST drop camera surveys will under-estimate the abundance of small scallops and over-estimate large scallops. The RP expects that optical surveys produce less reliable estimates of the proportion of dead scallops (false alive or dead) but the magnitude of this was not quantified.

There are many confounding factors (i.e. optical distortion, attenuation, etc.) for optical surveys and many of these have been addressed in the SMAST drop camera and the HabCam surveys. The review panel considered that the HabCam 4 imaging processing procedures are more advanced and encourages further research in this area.

My additional findings

The SMAST drop camera has a fixed camera height and orientation whereas this is not the case for the HABCAM. Its tow height can vary and the field of view can also be affected by pitch and roll. As far as I can understand, HABCAM v4 field of view varied from 0.2 to $>4 m^2$ with a mean of $0.72 m^2$. Hence, the "swept area" of the SMAST drop camera is approximately fixed whereas it is not fixed for HABCAM. This issue was not addressed during the review. It was not clear from the documentation provided how the variations in field of view were accounted for. Some text was provided in the document TOR4_NEFSC_HabCam.pdf but it was not clear to me what was done.

The angle of the scallop can contribute to measurement error in size. It was mentioned that there may be an initiative to do automatic perimeter measurements and that this could improve shell height measurements. For example, because the scallops are almost circular the maximum diameter of the "oval" may be a better measurement of shell height. I encourage such an initiative.

The SMAST drop camera and HABCAM surveys were assumed to have complete or full selectivity, at least for exploitable sizes. There seemed to me some potential that scallops could be covered by silt or not detected for some reason, especially for small scallops. Some data was presented on laboratory analyses of drop camera and HABCAM measurement error for size. This does not really address detectability. Only one slide was presented on this but more comparisons were provided in Fig. 2.5 in NEFSC_Dredge_allv2.pdf in which the size distributions from SMAST drop camera and HABCAM v4 were compared to the size distribution from research dredge tows. There were sometimes substantial differences. There are many sources of variation that can contribute to these differences in addition to selectivity. A major source is the area covered by each survey. A more detailed analysis of the size composition information that includes a factor to standardize for area surveyed seems useful. For example, the data from these surveys could be gridded and size compositions compared only for grids that have samples from at least two of the surveys. This would be something like comparative fishing.

The optical surveys have been used to estimate the efficiency of dredge surveys: 40% on sand and 24% on gravel, i.e. the dredge catches 40% of what the optical systems saw on sand and 24% of what the optical systems saw on gravel. This clearly demonstrated that dredges do not capture all available scallops. These efficiency estimates are used to raise dredge biomass estimates to represent stock biomass. We did not review the procedure used to provide these efficiency estimates but some background material was provided. An innovative model was used and, given the potential importance of these efficiency estimates, this methodology deserves a dedicated review on its own.

ToR 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.).

Peer review summary report findings

All presentations addressed this term of reference satisfactorily. Both towed and dropped cameras provide potential information on predator-prey interactions. The RP concluded that the HabCam V4 with the side scan sonar system is the only sampling procedure reviewed that could be used to detect direct physical impacts of fishing gear. The physical capture of scallops using a dredge or other techniques is necessary to collect other biological information. While the optical surveys have higher detectability of scallops < 20 mm than the dredge surveys, and therefore provide better information on recruitment, they provide less accurate information on the exploitable (i.e. 40mm+) size composition because of greater measurement error in shell size compared to dredge surveys. The RP recommended that the total number of baskets and fraction sampled be recorded on dredge surveys, and that the between basket variation in scallop counts (for subsamples) be recorded. This could provide useful information on this source of variation.

My additional findings

Some results were presented on how well the research dredge survey tracks size classes. I feel more could have been done here. For example, bubble plots of size compositions over time would be informative. A similar comment applies to the other surveys, although such an analysis might have to be stratified somehow to deal with changes in spatial coverage for the other surveys.

During the review we discussed tow length. It was mentioned that there are sometimes problems handling and processing the catch. Saturation is also an issue so that the dredge catchability may decrease when scallop abundance is high. The chance of gear malfunction increases with tow duration as well. However, shortening tows may have a detrimental effect in areas of low scallop abundance. This issue needs further investigation.

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

Peer review summary report findings

All presentations addressed this term of reference satisfactorily.

The VIMS dredge survey is post-stratified into 9 sub-areas and the standard design-based methods for stratified random sampling are used to estimate abundance and biomass within sub-areas and to aggregate estimates for all areas. The survey uses both a commercial and a survey dredge. The efficiency of both gears has been previously estimated and corrections applied to estimate abundance and biomass. The RP agreed with the VIMS scientist that the variance estimation had issues related to 1) the systematic sampling design, 2) unaccounted measurement error, 3) efficiency corrections.

The RP concluded that the abundance and biomass estimation methodology, and variance estimators, for the SMAST drop-camera survey seemed appropriate, subject to the probably positive bias associated with the method of correcting for edge effects and the probable negative bias associated with detectability of <100% towards the edges and corners of each photograph. Variance estimation for this survey also has bias issues related to 1) the systematic sampling design, 2) unaccounted measurement error, 3) uncertainty due to edge corrections.

For both HABCAM V2 and V4, three model-based methods were tested through simulations. The RP noted that there was no single method that performed best across all simulations. The RP concluded that the geostatistical modelling approach seemed reasonable but that biomass variance estimates are likely under-estimated because degrees of freedom were not adjusted for and model uncertainty is an unaccounted source of variation in the biomass and abundance estimates.

Model-based methods should be used with care. The RP noted that in a few cases the model estimated the highest abundance in areas with no samples and it is not clear why this occurred. This could be seriously misleading if the modeled biomass estimates were used in a spatial management procedure.

My additional findings

Background perspective

Statistical inference in the common "design-based" approach is based only on the randomness in the sampling design. This leads to inferential problems with sampling designs that have no randomness (i.e. systematic sample with a fixed start location) or are subjective. In the design-based approach observations at sampled sites are assumed to be exact. Usually fisheries surveys do not fit well in this inference framework because the survey measurements have a couple of sources of error (see below). Also, the realized sampling design is often different from what was intended for a variety of reasons and it is difficult to factor this into statistical inference.

Fisheries surveys include measurement error because fish are often not stationary within the time-frame of a survey (although this is not a problem for scallops) and only a random subset of fish at a given site are caught. Efficiency estimates clearly demonstrate this for scallop dredges. Models have to be used to fully account for these sources of variation that are in addition to sample site selection. Model-based approaches can account for the latter two sources of variation but they typically ignore the variation due to the sampling design. These problems are not unique to fisheries surveys. Even in the simple design-based situation with no measurement error, models still find much use (e.g. Särndal et al, 2003) and this idea has been around for some time in fisheries science (e.g. Smith, 1990). I like the approach used by Chen et al. (2004) in the context of fisheries surveys, in which the three sources of variability are accounted for. They discuss three model-assisted estimators that all have the desirable properties of being more efficient than the usual design-based estimators when the model is correct, but still design-unbiased when the model is not correct. The latter model-robustness property is appealing to many. Chen et al. (2004) highlight that the pseudo-empirical likelihood method can easily be modified and improved by including basic information from previous surveys. This may be something that could be usefully exploited for scallops. However, I think the approaches discussed by Chen et al. (2004) have some deficiencies that need to be resolved.

The first problem is their stochastic assumption about trawl catches which they basically assumed were over-dispersed Poisson random variables. I usually find survey data do not support this assumption. I favor the Negative Binomial (e.g. Cadigan, 2011). In any event, reliably estimating the over-dispersion parameter can be difficult especially when the model is complex with many parameters (e.g. Cadigan and Tobin, 2010). In this case there is a well-known bias problem for maximum likelihood estimates of variance parameters, due to the large difference between the errors degrees of freedom and the sample size. We have recently submitted another paper on this issue (Wang et al.) where we show that restricted maximum likelihood can also be used fairly easily to address this bias issue. Chen et al. (2004) also favored local linear regression to model the mean of trawl catch as a function of location, depth, and possibly other covariates. Others (e.g. Breidt and Opsomer, 2000) also used this approach in generalized regression estimators of population averages in the survey context. However, as we demonstrated in Cadigan and Chen (2010), the local linear method can give negative estimates and other kernel smoothers may be better in a couple of aspects.

In summary, basing statistical inferences only on the randomness in the sampling design seems insufficient for surveys of fish stocks and specifically scallops. Models are required to address measurement error. Models are also quite useful and can give much more precise estimates even if there is no measurement error. However, statistical inference should not rely solely on the model for a well-designed survey. Various model-assisted approaches are available that give the best of both worlds – improved precision when the model is correct and design-unbiasedness even when the model is not correct. This addresses potential criticism of model based approaches when the model is complicated. However, in this active area of research there is no best model but I like local smoothers because they are easy to explain and can behave better when extrapolations are required. However, standard methods for estimating variance parameters may be biased for complex and highly parameterized models. Modelling spatial dependency via covariance, while commonly done, is more difficult to explain and diagnose. Fairly robust theory is available for kernel smoothers and the choice of smoothing for sub-domain estimation of means and totals in the survey context. This is not as critical as for point-wise estimation. I am unaware if this is the case for kriging; i.e. how does it work when the variogram is mis-specified?

Findings

The model used to estimate abundance indices for the HABCAM v2 and v4 surveys is a complicated hurdle Gam model plus kriging of residuals. The design-unbiased robustness property is not an option for these surveys because they do not follow a statistical sampling design in which all parts of the stock area have a non-zero probability of being sampled. Also, the kriging variance, used in part to derive the variance of the biomass or abundance estimate, is conditioned on the sample sites selected (e.g. Kimura and Somerton, 2006) and may under-estimate the variance with repeated sampling at different sites. However, in the simulations of the estimation procedure the start point was varied. In the end the simulation bias in the coefficient of variation for the mean was fairly small but I am unsure why and find it difficult to conclude that this is a robust result. In what may have been a worst-case illustration the researchers demonstrated that their estimation procedure could produce some possibly anomalous results in regions with sparse samples. The proposed estimation method is one possibility among many and I feel more research is required, with robustness a priority. One thing that is easy to do is check if the average residual is zero; that is, the mean of observed versus predicted, i.e. $xiyi+zi$ in Eq. (5) in TOR4_NEFSC_HabCam.pdf. The rationale is that if the model is wrong on average at the sampled sites then it may be wrong on average at the un-sampled sites, although this is speculative. Cadigan and Chen (2010) discuss this point.

Research is ongoing to address these issues for the VIMS systematic survey and I encourage this initiative. I think the same issues apply to the SMAST survey however subsequent to the review I realized there may be an error in their variance estimation. As far as I understand, they grid the total survey area and conduct 4 camera drops in each grid cell, towards the center of the grid. They refer to this as two stage sampling and use the sampling formulae described in Cochran (1977) for this design. However, if every grid is sampled then the grids are not randomly sampled primary units but rather they are like strata that are all sampled. They should be using Eq. 5.8 in Cochran (1977) and not Eq. 10.23 to get the standard error of the mean. I hope I have not misunderstood something. Also, within a grid, the centric sampling design will probably result in an under-estimate of variance because of positive spatial auto-autocorrelation; that is, the between drop variation may be smaller than the total within-grid variance.

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

Peer review summary report findings

Analyses of surveys have been integrated in a few ways. One was to do a combined analysis of survey observations, internally adjusting for differences in catchability where appropriate. This has been done for VIMS+NEFSC dredge surveys. However, these two surveys are not at the same time and the populations being surveyed could be different due to growth and mortality processes. A co-kriging model was also presented to combine observations from all surveys in a single model.

Another approach was to integrate/combine survey biomass estimates. However, the issue of timing of surveys also applies here. Two methods were used: straight average and inverse variance weighting. Averaging surveys is only appropriate if the survey biomass estimates are for the same area. Raw averaging of surveys does not account for the different precision of the estimates. However, inverse variance weighting is reliable only if there are reliable estimates of variance which is uncertain for at least the surveys with uniform systematic designs (SMAST drop camera and VIMS dredge) where variance is expected to be overestimated.

My additional findings

The co-kriging approach did not seem too promising. From what I read in Cressie (1993), that approach has been developed for multivariate data at the same sample sites rather than observations from different surveys at different sample sites.

When two surveys are conducted at approximately the same time but possibly covering different areas then I prefer that they be integrated via a model of the survey observations to produce one combined biomass estimate. It is less preferable to simply average the biomass estimates because of possible differences in area surveyed. It is also less preferable to use both surveys as independent indices in a stock assessment model because the model will not know anything about area covered or overlap in the surveys. To combine survey observations in one model will require some information about the relative catchability of the different gears. This could come from comparative fishing or at least fishing in some of the same strata. A statistical model like the one used to estimate the dredge efficiency compared to HABCAM (Miller, 2015) could be used for this. This sort have thing has been done for the DFO research vessel surveys and industry crab surveys in the Southern Gulf of St. Lawrence (Benoît and Cadigan, 2014 and 2015). They used information from comparative fishing and when both surveys fished in the same strata to estimate effects for 9 or 10 vessels. Some of the vessel effects could not be accounted for using surveys on their own.

If the surveys are conducted at different times of the year then there may be no choice but to integrate them within a stock assessment model that accounts for changes in the within-year size of the stock. I have no good ideas of how a space-aggregated model could deal with surveys that cover only part of the spatial distribution of the stock. Clearly this could be done in a spatio-temporal stock assessment model but I recognize such a model is a major initiative (see ToR 8).

ToR 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.

Peer review summary report findings

All surveys have the potential to contribute to assessments for non-scallop species and use data apart from assessment purposes. In many cases the information from the various surveys is complementary or additive. The optical methods have provided additional information on species habitat, sea scallop ecology, and ecosystem studies. All of the surveys were demonstrated to provide information on changes in abundance of other species. The RP considered that the HABCAM V4 survey technology had the greatest potential in providing information on bottom habitat, gear impacts, species interactions, and spatial structure on a variety of scales.

My additional findings

I agree with the RP findings and have nothing to add further to this, other than to say I was impressed with the level and variety of sampling.

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

Peer review summary report findings

No specific proposals for optimal frequency of surveys were evaluated. The RP finds that annual surveys are required to support the management process with fishery specification adjusted every year in addition to spatial management procedures. Yearly surveys also make it possible to detect and protect recruitment events, and avoid under- and over-harvesting of stock components.

To some extent the VIMS dredge survey, NEFSC dredge survey, and the HabCam V2 and V4 surveys are integrated because they cooperate to address survey gaps and standardize dredge catch rates. The RP recommends that survey efforts should be further integrated to provide a standard monitoring survey of the entire stock distribution; however, the combination of optical and dredge surveys are complementary and should be maintained. The continuity of time-series should be also be maintained to the fullest extent possible.

My additional findings

The scientists demonstrated no significant vessel effects when conducting dredge surveys and it appears that multiple vessels can be used with the appropriate standard fishing protocols. Hence I find it quite appropriate that VIMS and NEFSC dredge survey data are currently combined where appropriate.

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

Peer review summary report findings

To devise an optimal and integrated statistical survey design and estimation procedure for stock size, spatial distribution, and other primary objectives, the RP recommended that information from all surveys be thoroughly analyzed. This will be assisted by further understanding the efficacies of different dredge tow lengths.

In a survey design with increased dredge coverage, the RP found no compelling advantage in using both dredge and HABCAM sampling gears on the same vessel. However, statistically-designed dredge sampling that includes a portion of samples that overlap with the HabCam track is still required. The designer of HABCAM felt that the best usage of this technology is continuous sampling and the RP agreed with this. A joint integrated survey using two vessels (one for HABCAM and one for dredge) could result in a better survey with improved coverage.

My additional findings

The survey situation for scallops seems to be in flux, with a transition from primarily dredge surveys to combined dredge+optical or perhaps primarily optical survey gears. There should be more focus on developing a practical and reliable long-term monitoring survey design. This should involve optical and dredge sampling.

The only advantage I discerned in the SMAST drop camera technology compared to the HAMCAM v4 technology was a more stable field of view. However, variation in this was not identified as an important source of uncertainty so I do not conclude that this is much of an advantage. The vastly greater “area swept” by HAMCAM compared to the drop camera suggests to me that this is a better optical survey tool, aside from cost considerations. My perspective is that a census is most desirable, and otherwise a survey with a large sample size. The HABCAM transect sampling provides a much larger sample size as long as sufficient transects are sampled. With improvements in the automatic pattern recognition and annotation of images I think there is potential to provide a much larger “area swept” from HABCAM which should improve the precision of estimates of abundance and biomass. Dredge sampling is still required but I see its future more in providing biological samples like in acoustic surveys rather than standalone estimates of abundance.

I will be bold and probably naive and suggest that investigators and institutions should collaborate towards this objective – a long term monitoring survey using statistically-designed transect sampling with HAMCAM, and statistically-designed biological sampling using dredges and another vessel. There can still be roles for additional dredge and drop camera sampling to focus on specific areas or other objectives.

Size distributions from SMAST drop camera and HABCAM v4 were compared to the size distribution from research dredge tows. There were sometimes substantial differences. A more detailed analysis of the size composition information that includes a factor to standardize for area surveyed should be conducted.

The efficiency estimates of dredge surveys using HABCAM surveys are used to raise dredge biomass estimates to represent stock biomass. An innovative model was used and, given the potential importance of these efficiency estimates, this methodology deserves a dedicated review on its own.

Dredge survey tow length needs further investigation.

It is difficult to fully evaluate the monitoring program for scallops in this area without understanding the potential information in commercial CPUE and within-season depletion information about stock size and harvest rates. This has been investigated by Walters et al. (2007) for the sea scallop fishery in Georges Bank. I am involved a similar project for snow crab in which I am developing a spatial depletion model that accounts for within-season changes in the spatial distribution of the fleet. The model is conceptually similar to Robert et al. (2010), Roa-Ureta (2014) and others, but spatio-temporal and not just temporal. It is computationally very demanding primarily because of large spatial covariance matrices. Other challenges include incomplete spatial information for some trips and hyper-stability in CPUE. It will be at least a few years before this model is potentially operational. Something like this would provide a good tool to evaluate the benefits of having additional scallop survey information, or the costs of having less. It could also be used to evaluate the efficacy of proposed survey designs. I also think such an approach would mesh well with the SAMS model that is currently used for management projections of this stock. This is a longer-term research objective proposal and not a recommendation.

Critique of the NMFS review process

The ToRs were too broad with too much review material for a single meeting - both background material and presentations during the review (see Appendix I). I found I could not spend enough time on individual documents and subsequent to the review meeting I realized there were important aspects of some surveys that I did not fully understand. In particular I did not understand well how variations in the HABCAM field of view were accounted for, and I am uncertain about the SMAST standard error estimation. Also as a result of the amount of material, there was, in some instances, not enough time during review presentations for questions.

Appendix 1: Bibliography of materials provided for review

Documents Provided Before the Review Workshop

Dredge-NEFSC

Chang, J, Hart, D, Shank, B. A Comparison of Model-Based and Design-Based Methods to Estimate Sea Scallop Abundance and Biomass from Vessel-Towed Underwater Camera Data. NEFSC, Woods Hole, MA. 33 p.

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Appendix 1: Rudders, D. 2015. Field and Shore-Side Protocols Used by VIMS Sea Scallop Research Program. 66p.

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Appendix 3:VIMS.2015. A Simulation Study to Evaluate Sampling Designs for Highly Autocorrelated Populations With an Application to Sea Scallop Closed Areas. 49p.

Appendix 4:VIMS. 2015. Calibrating Industry Vessels to the NMFS Sea Scallop Time Series: Commercial Vessels and the R/V *Albatross IV*. 54p.

Appendix 5: Rudders, D.B. and DuPaul, W.D. 2010. Continuing the Time Series: Calibrating the NMFS Sea Scallop Survey to the R/V *Hugh R. Sharp*. 36p.

Appendix 6: Rudders, D.B. Continuing the Time Series: Calibrating the NMFS Sea Scallop Survey to the R/V *Hugh R. Sharp*—A Re-Estimation Due to Changes in Area Swept. 5p.

Appendix 7: Rudders, D.B., DuPaul, W.D., Hudson, J., Bergeron, J. 2014. An Assessment of Sea Scallop Abundance and Distribution in the Mid-Atlantic Bight. Presented August 26-27, 2014. 30 slides.

Appendix 8: Rudders, D.B., DuPaul, W.D., Bergeron, J. 2013. An Inventory of the Sea Scallop Resource in the Georges Bank Closed Area II and Surrounds. Presented to New England Fishery Management Council, Jan. 17, 2013. 28 slides.

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Appendix 11: SMAST, VIMS. 2010. SMAST Bycatch Fleet Mailing 5-10-10. 5p.

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TOR 3: Biological Sampling Aspects of the Surveys. 13p.

TOR 4: Methods for Using Survey Data to Estimate Abundance Indices. 20p.

TOR 5: CoKriging As a Method for Combining Resource Surveys, Decreasing Uncertainty, and Mitigating Bias. 13p.

TOR 6: Potential of HabCam Surveys for Non-Scallop Species, Habitat, Sea Scallop Ecology, Ecosystem Studies. 9p.

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Appendix 2: CIE Statement of Work

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

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 14 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: NTVI (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 (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 Summary Report will not be submitted, reviewed, or approved by the CIE.

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 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.

NTVI 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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Key Personnel:

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Annex 1: Format and Contents of CIE Independent 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 Panel Summary 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 for the Peer Review

(These Terms of Reference (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.

Annex 3: Tentative Agenda

Review of Sea Scallop Survey Methodologies and

Their Integration for Stock Assessment and Fishery Management

March 17-19, 2015, Fairfield Inn and Suites, 185 MacArthur Dr., New Bedford, Mass.

DRAFT AGENDA* (version: March 3, 2015)

TOPIC PRESENTER(S) RAPPORTEUR

Tuesday, March 17 (DAY 1)

8:45 – 9 AM Welcome

9 – 9:15

Agenda J.-J. Maguire, Chair TBD

Conduct of Meeting

Address TORs 1-4

9:15 – 9:30 Introduction (Paul Rago, NEFSC) TBD

Method: DREDGES

9:30 – 10:30 NEFSC (Dvora Hart) TBD

10:30 – 11:30 VIMS (Dave Rudders) TBD

11:30 – 11:40 Public Comments about Dredges

11:40 – 11:50 Break

Method: DROP CAMERA

11:50 – 12:50 SMAST (Kevin Stokesbury) TBD

12:50 – 1 Public Comments about Drop Camera

1 - 2:10 Lunch

Method: HabCam

2:10 – 3:10 NEFSC (D. Hart) TBD

3:10 - 3:20 Break

3:20 – 4:20 WHOI (Scott. Gallager) TBD

4:20 – 5:20 Arnie's Fisheries (Richard Taylor) TBD

5:20 – 5:30 Public Comments about HabCam

TOPIC PRESENTER(S) RAPPORTEUR

Wednesday, March 18 (Day 2)

TORs 1 – 4 (cont.)

Method: HabCam (cont.)

8:30 – 10 Statistical Estimation and Survey Design

(NEFSC, B. Shank, Jui-Han Chang) TBD

10 – 10:10 Public Comments about HabCam: Statistics/Design

10:10 – 10:25 Break

Address TORs 5 and 7

10:25 – 10:40 Overview/Relation to Management

(Deirdre Boelke, NEFMC) TBD

10:40 – 11:40 NEFSC (D. Hart, B. Shank) TBD

11:40 – 12:40 Lunch

12:40 – 1:40 SMAST (K. Stokesbury) TBD

1:40 – 2:40 VIMS (D. Rudders) TBD

2:40 – 2:50 Break

2:50 –3:50 WHOI (S. Gallager) TBD

3:50 –4:20 Arnie's Fisheries (R. Taylor) TBD

4:20 – 4:30 Public Comments about TORs 5 and 7

Address TORS 6 and 8

4:30 – 4:45 NEFSC (D. Hart) TBD

4:45 –5 SMAST (K. Stokesbury) TBD

5 – 5:10 Public Comments about TORs 6 and 8

TOPIC PRESENTER(S) RAPPORTEUR

Thursday, March 19 (Day 3)

TORS 6 and 8 (cont.)

8:30 – 8:45 VIMS (D. Rudders) TBD

8:45 – 9 WHOI (S. Gallager) TBD

9 – 9:15 Arnie's Fisheries (R. Taylor) TBD

9:15 – 10:15 Discussion (All presenters; w/ Chair leading)

10:15 – 10:30 Break

10:30 – 11:30 Discussion (cont.)

11:30 – 11:45 Public Comments about TORs 6 and 8

11:45 – 1 Lunch

Wrapping Up

1 – 3 Review Key Findings

J. –J. Maguire, Chair TBD

3 – 3:15 Break

3:15 - 6 Drafting of Review Panel Summary Report

J. –J. Maguire, Chair TBD

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

During scheduled "Public Comment" periods the Chair will welcome questions, clarifications, and opinions. Each person will have a 3 minute limit. The "Wrapping Up" session on Day 3 is primarily intended for the Panel to discuss and write its report. During that time, comments from the presenters and the public will be restricted to clarifications that are solicited by the Chair and Panel.