JOINT US-CANADA SCIENTIFIC REVIEW GROUP

External Independent Peer Review by the Center for Independent Experts

Review of 2015 Pacific Hake/Whiting Assessment and Management Strategy Evaluation

Vancouver, BC
February 2015

François Gerlotto
Center for Independent Experts (CIE)

EXECUTIVE SUMMARY

The Pacific hake (*Merluccius productus*) represents one of the largest stocks in the NW Pacific Ocean. It ranges(in this area) from Mexico to Canada, along the continental shelf and break. The northern stock is exploited jointly by Canada and USA, and a treaty has been signed between the two countries in order to define a common assessment protocol. It includes a review of the fishery and research on an annual basis in order to evaluate how its recommendations for assessment have been followed and to give new recommendations improving the monitoring and assessment of the stock.

My expertise in this review was mostly focused on three areas: acoustic methods; geostatistics and measures of precision; and habitat and environmental information. I did not focus on the assessment methods, with which I am less familiar. Within these topics, the recommendations of SRG for 2014 were the following.

The survey protocol and the sampling strategy are good and are unlikely to be substantially improved using different strategies. Experiments on target strength and trawl sampling showed that under normal conditions the fish identification by trawling is satisfactory. Some sources of error have been pointed out when hake is mixed with Myctophids, and the value of this error should be determined more precisely by continuing the experiments already performed (video observation of fish behaviour inside the trawl). Target strength studies should be continued in order to evaluate the fitness of the Traynor model on hake.

The effects of reduced transect coverage with existing data or novel techniques. It has been demonstrated through experiments and simulations that transect coverage can be reduced (by increasing inter-transect distances) with no major effect on the biomass estimate (but with effects on the CV). Coverage is quite satisfactory inside the survey area. It would be certainly more useful to reduce the number of transects and use the extra time for extending them up to the end of the distribution area than to maintain or increase the coverage spending more days at sea.

The impact of a change in survey direction and developing appropriate calibration if direction were changed. There is no need for changing the direction of the survey. If migration exists, it would result in biases whatever the direction (overestimate if migration and survey are in the same dimension, underestimate in the opposite case). I recommend evaluating the migration during surveys in order to evaluate the bias produced on the biomass estimate. In any case, if migrations exist and have already affected the results of historical surveys, I recommend not changing the survey direction as long as a complete knowledge of the migration pattern is not obtained in order to maintain the same bias for all the surveys.

Geostatistical methods used to estimate biomass as well as data processing approaches. The method presented is satisfactory. I am not sure that the alternative method suggested by the teams i.e. the use of 1D transitive models, would improve the results. This method is still under discussion inside the fisheries acoustics community. The question of extrapolation of the kriging results outside the survey area has been discussed in details, and my conclusion and recommendation are that extrapolation should be avoided as long as no real argument can be

given to define its area of application. I recommend that the potential habitat of hake be studied in order to get sound information prior to extrapolate.

Survey variance estimates. This is a weak point in the methods and the CV used by the assessment team is only representing the error due to kriging. The actual CV of a survey is much higher and is still unknown in the case of hake. I recommend listing the sources of variance and either to refer to literature studies when they apply or to achieve particular experiments to get an evaluation of the variance for each step of the method. The other steps of the method, and especially the geostatistical method, are probably the best possible to use and no change is actually needed.

Viable alternative transect sampling designs. There is no real alternative to the method already used. Other transect sampling designs should be decided upon after weighting the gain in time and the loss in precision. Most of them would result in a lower precision of the interpolation and should not be recommended.

Besides these particular recommendations, I would suggest that research explore three domains:

- The acoustic data are not fully exploited for environmental studies, and they could bring valuable information (water masses, species assemblage, trophic levels, in particular). The information provided by acoustic instruments deployed by the team should be exploited and maximized (multifrequency data, for instance, are collected and not used).
- There is another source of direct information that is not yet used for assessment, i.e. the acoustic data collected by the fishing vessels. A series of experiments around the world showed that these (free) data present scientific quality and could improve substantially the understanding of the stock dynamics and the precision of the biomass estimate, by evaluating the extrapolation area and by increasing the sampling in very dense concentrations (from where the bulk of the variance - and the catch - comes).
- The team should extend its acoustic methodology towards the description of the habitat. There is a need to define and design the habitat of the hake, for at least two reasons: definition of the extrapolation area and understanding of the changes in its biomass related to changes in the environment. It is demonstrated that the hake is subject to strong changes in its abundance, mostly related to the results of annual recruitment. Having an idea of the effect of the habitat dimension and quality provides a way to study its dynamics.

GENERAL

The Pacific hake (*Merluccius productus*) represents one of the largest stocks in the NW Pacific Ocean. It ranges (in this area) from Mexico to Canada, along the continental shelf and break. The northern stock is exploited jointly by Canada and USA, and a Treaty has been signed between the two countries in order to define a common assessment protocol. It includes a review of the fishery and research on an annual basis in order to evaluate how its recommendations for assessment have been followed and to give new recommendations improving the monitoring and assessment of the stock.

The only fishery independent source of data comes from acoustic surveys, which provide annual or bi-annual estimates of biomass. In 2014 no survey was done and the assessment was mostly performed using the 2013 (and previous) survey information and the fishery data. In 2013 some results appeared to be different from the former surveys, and particularly it was observed that the survey did not cover completely the distribution area of the hake; therefore an important point to consider was that of extrapolation of the acoustic results towards the unexplored area where fish was obviously present. The question of extrapolation became an important topic of discussion in 2014 in order to define whether it should or should not be done (and how).

The question of the effects of the SaKe surveys, which study jointly small pelagics (sardine, anchovy, horse mackerel etc.) and hake, was also discussed. Indeed during 2013 the survey lost a rather important number of days at sea during the part mostly devoted to hake because of various reasons, with one of them being the priority that was given to sardine studies as this population is collapsing. Therefore some important information concerning the hake, and particularly environmental information, was not collected.

All these reasons lead to a rather detailed study of the acoustic surveys and data analysis, and my expertise was mostly related to this point.

BACKGROUND

My activities were described by the Terms of Reference of the Review and were as follows:

1. *Become familiar with the draft Pacific hake/Whiting stock assessment(s) and background materials.*

I had the opportunity to study in detail the activities of the US team working on hake, due to the expertise I gained by participating in the sardine-hake (SaKe) joint surveys in 2014. This background was useful as many of the terms of references were also considered during the present review. Additionally I read the documents (see bibliography in Annex 1) that I received in advance of the review, which allowed me to get a good understanding of the methods applied to the hake assessment (and surveys) and of the major questions, weaknesses and required improvements that had to be discussed during the review. Incidentally I must note that some information on the SaKe project was not delivered, and I would have had problems to follow some discussions if I had not been a member of the SaKe review group in 2014.

2. *Participate in the multiple-day meeting in a manner specifically agreed upon by the Scientific Review Group (SRG). It is anticipated that the CIE reviewers will participate in the review panel meeting as "officially invited members" of the SRG rather than "formally appointed members", as outlined in the U.S. Canada Pacific Whiting Treaty. CIE participation in official SRG discussions and decisions will be at the discretion of the SRG co-chairs. However, it is hoped that their roles will be no less than discussants, seated at the SRG table, if not de facto, fully functioning SRG members.*

As specified in 2015 Meeting Report, "*it was noted that (Dr. François Gerlotto) was participating as an "officially invited member" of the SRG. His participation occurred in response to the recommendation at the 2014 review that the advice of an external expert with expertise in acoustic survey design and estimation would benefit SRG discussions and inform the review of the acoustic survey*". Therefore my activities inside the SRG panel were facilitated by my participation as full member to all the discussions and works.

3. *Review the current systematic transect design for acoustic sampling of hake utilized by the joint Pacific sardine and Pacific hake survey and the geostatistical approach used to estimate biomass to provide recommendations in the following areas (list).*

This part of my activities will be detailed below.

DESCRIPTION OF THE INDIVIDUAL REVIEWER'S ROLE IN THE REVIEW ACTIVITIES

Personal background

My main field of expertise is in the use of acoustic methods for studying the pelagic fish populations. This general expertise covers different areas, i.e. the knowledge of acoustic methods and instruments; the calibration procedure; survey design methods; statistical measurements of confidence intervals for the abundance estimates; fish behavior and its effects on the precision of the estimates and particularly the biases due to dynamic movements of the population (e.g. migrations) and the patchiness and aggregation behavior (requiring adaptation of the survey design); statistical methods adapted to the particular case of an acoustic survey and its distribution constraints (geostatistics); the relationships between fish population behavior and environment; and statistical methods for calculating abundance estimates with their confidence intervals.

Reviewer's role in the review activities

My expertise in this review was mostly focused on three areas: the acoustic methods for evaluating the fish abundance; the survey design and the application of geostatistics for calculating biomass indexes with variance estimates; and the effect of fish ecology as an aid for understanding the fish distribution and providing information on the fish habitat and biology. By contrast I did not focus on the assessment methods, with which I am less familiar.

Instead of specifying each ToR independently, which would result in a series of repeated paragraphs, I will present in this report the results of my expertise in the three aspects listed above:

- Acoustic methods
- Geostatistics and measures of precision
- Habitat and environmental information

Additionally I will present some comments that I provided during the SRG meeting on the use of acoustic data from the fishing vessels, another source of valuable direct data that are not exploited so far and could represent an important source of fishery independent data.

1. **Acoustic methods**

The major points that need discussion are the quality of acoustic data and the precision and accuracy of the results. These points are presented in the following topics. :

Data collection and calibration. Calibration is evidently a major issue, as the characteristics of the equipment are driving all the results. Nowadays it is not difficult anymore, thanks to the important work done by both the scientists (e.g. ICES-SGCal, 2011) and the manufacturers who provide built-in calibration procedures with their echo sounders and software. The calibration protocol applied by the teams corresponds to the international recommendations and does not require any major improvement.

Scientific vessel intercalibrations, on the contrary, are important and are to be encouraged. There already exist a series of protocols for such activity which do not present major issues.

The effect of vessel noise has been studied in detail by the ICES/WGFAST (Fisheries Acoustics Science and Technology) in a study group devoted to this point (Parrish and Gerlotto, 2012) and an important document has been published as WGFAST report, which I recommend as a reference. The ICES CRR 209 (Mitson, 1995) should not be considered any longer as state-of-the-art. Comparison between noisy and silent vessels showed that although a silent vessel seems to be more efficient than a noisy one, the vessel is still producing reactions from fish that are not linearly correlated to the actual noise of the ship. Avoidance is more related to fish behaviour and physiology than to actual noise level. This means that measurements of fish avoidance should be performed, ideally during each survey, and no permanent “conversion factor” can correct the biomass estimate from the bias of fish avoidance. Intercalibration is needed because the results of each vessel may be affected by different specific biases, and it is a way to define a common (unknown) bias to all the results and make the data comparable. Nevertheless, as long as there is no behavioural study or measurement of the fish avoidance it will remain impossible to evaluate the magnitude of this common bias. I recommend to the teams to study the effects of fish avoidance. Depending on the vessel, the fish species, and the ecological conditions of the survey, these biases may be consistent.

Target strength. One of the major questions in fisheries acoustics is the choice of a proper Target Strength. Indeed any error on this conversion factor has an equivalent effect on the whole biomass estimate. As an example, if the operator selects a TS of -53 dB while the true value is -50 dB, i.e. applying a TS 3 dB lower than the real value, then the biomass estimate will be twice the actual biomass (a logarithmic 3 dB represents a factor x2 in arithmetic units). Moreover many biological and behavioural factors have an impact on TS value, such as natural fish tilt angle, swimbladder compression when diving or feeding, fish avoidance producing an additional tilt angle, etc. As such, the problems related to TS precision are more related to biases than to statistical error related to the huge number of echoes registered, the variance due to errors and small variability of individual echoes. Therefore it is essential to have a correct TS value. When obtaining a new and better TS value, the biomass of former surveys can be re-calculated.

Various experiments have been performed which provide important information, and especially those on TS in situ, by the US and Canadian teams. These experiments show that the TS variability is extremely important (e.g. TS histogram of single targets recorded only once were covering a range of 30 dB, i.e. a factor x1000) although they fit with the experimental TS model applied. This means that a huge variability exists which is certainly due to the multispecific biomass (mixed echoes of hake, other fish, plankton, micronekton, etc.) and more research is needed. The experiments presented gave interesting results and should be repeated.

Some other questions/issues that were studied by the team:

- The representativeness of TS estimates measured in situ for the whole population. Indeed the TS are measured on dispersed fish, which occur only by night close to the surface; by contrast, the abundance estimate is done by day on deeper layers. Several studies have shown that fish present a different tilt angle by day and by night, which would lead to different values of abundance if the wrong TS is applied. These strong differences were mostly observed on Clupeids (herring, sardine, anchovy) and it seems less an issue on Gadoids. Nevertheless this point has to be evaluated.
- The TS of the Humboldt squid. This species has no swimbladder therefore does not strongly reverberate ultrasounds. As this species is likely to significantly affect the ecosystem, being a strong predator of most of the fish, it is important to evaluate it more fully. Some trials for measuring TS of squid have been performed by the teams. It is worth reminding that other teams in the world are working on *Dosidicus gigas,* and particularly in USA (Benoit-Bird, 2008), Peru (works of IMARPE: www.imarpe.org.pe), Chile (works of IFOP: www.ifop.cl), Mexico (Carlos Robinson, UNAM, robmen@servidor.unam.mx), and reviewing these studies and contacting the teams is recommended.

As a general conclusion, I recommend continuing to study TS in situ in order to get a large series of data and help define the proper TS model. Other methods deal with TS modeling and should be considered too, in order to evaluate the value of in situ results. We can consider that the TS the team is using represents the best choice available so far. It is unlikely that an “improved” TS value would be very different from the present one, but the variance is likely to decrease significantly. It should also be noted that TS measurements have no meaning if they are not accompanied by behavioural studies (e.g. using video cameras, acoustic cameras, multibeam sonars, etc.) which I would recommend to the teams performing such research.

Survey design. Several points were listed in the ToR, namely the effects of reduced transect coverage with existing data or novel techniques; the impact of a change in survey direction and developing appropriate calibration if direction were changed; the design of viable alternative transect sampling designs, with particular reference of those areas that are not sampled by the survey but where other information show that some consistent part of the biomass is likely to be present (the question of extrapolation); and the effect of a survey design that is adapted for the sampling of two different groups of fish in a SaKe survey, i.e. small pelagic species (sardine, anchovy, horse mackerel etc.) and hake. Considering this point, theoretically there is no major problem due to multispecific survey design, and the report of the CIE experts on SaKe design gave all the information needed. The common protocol is to perform a survey from south to north (from the Mexican border until the northern limit of hake distribution in Canada) using a grid of parallel equidistant systematic transects, ideally perpendicular to the coastline. In order to fulfill the requirement of a random sampling, the geographical point where the survey should be initiated is selected at random in the southern limit of the area. Transects for hake surveys should ideally completely cover the distribution area, which mostly affect the western limit of the transects. In some cases this is impossible to do and some transects have to end before reaching the western limit of the distribution area, which would theoretically imply some extrapolation be performed (see below). In the particular case of hake, the abundance estimate is obtained during the day, when fish are easier to identify (monospecific layers) and in mid-waters. The behaviour of hake allows particularly efficient acoustic surveys, as very few fish are present inside inaccessible areas (immediately below the surface of very close to the bottom). Sampling of fish using pelagic trawls is also performed by day, and environmental stations (plankton, CTD, etc.) are performed mostly by night.

The general survey design applied for hake is probably the best one possible. It presents only two potential drawbacks: (1) the possible existence of fish outside the survey area, and (2) the risk of biases in the case of migration of the population during the survey. The first point will be considered when detailing the geostatistics. The second point can be an issue, due to the duration of the surveys. Indeed an important assumption when designing a survey is that it should represent a snapshot image of the distribution, i.e. the data from north to south are collected “simultaneously”. This requires the shortest duration possible, which still represents a long period (6 to 9 weeks), when distributions are wide as is that of the hake. When migrations occur, two cases can be considered: (a) the migration is from north to south, i.e. in opposite direction to the survey, and the biomass is underestimated; (b) the migration is from south to north (same direction as the survey) and in this case the biomass is overestimated. The only way to correct for this bias is to get a correct idea of the migration scheme, either through tagging experiments, through the fishery statistics or another other indirect method. The risk being consistent for hake surveys, it is recommended that the teams pay attention to this behaviour of the fish. Some other movements of the fish may affect the estimate, such as the vertical daily movements of the fish that make night and day values difficult to compare, but this is not an issue in hake surveys that are performed exclusively by day or east-west movements (daily of at different rhythms), which are rather unlikely.

Other types of survey design exist in the literature, e.g. zigzag transects (allowing the same coverage in shorter time) or other designs. Many works (through experiments or simulations) have shown that the parallel equidistant transect grid is statistically the most appropriate. But as in all the steps of the acoustic methods, the operator must select the design that minimizes the biases as much as possible. For instance, if the duration of the survey presents high risks of biases, it should be better to use shorter zigzag designs or wider inter-transect distances, which allow shorter surveys, even though they would increase the variance. Simulations have been performed that show that the inter-transect distance has no real impact on the biomass estimate (at least for reasonable distances, i.e. below 40 NM inter-transect distances), although the variance would increase. Therefore saving time by decreasing the number of transects can be considered if time is more an issue than CVs.

Fish identification. Once the acoustic data of a survey are collected, they must be allocated to species. This is done through trawling. There are some points that deserve consideration in this activity.

The assumption is that the fish proportions in the catch are representative of the actual proportion in the sea. This is only true when fish (all species and all dimensions) present the same catchability. If this is not the case, a bias in the biomass estimate occurs. The teams presented some results from two research experiments, (1) using video cameras inside the net, that showed the fish behaviour inside the cod end, and (2) performing repeated tows in a single concentration. The second series of experiments showed that the fishing samples represented the species and lengths proportions correctly, with the results being identical from one tow to the other. Video observations were able to show the importance of Myctophids in some areas where they are abundant but not captured. Therefore it is likely that in areas where Myctophids are mixed with the hake, an overestimate of the hake biomass could occur.

Some other species may have an impact on the hake estimate, in particular the Humboldt squid. No clear result on the trawl catchability for squid has been given, and if this species becomes an issue, then some work should be performed. It is known that TS for squid is much lower than that for fish (at least fish with a swimbladder), which could lead to underestimate this population if a standard TS is applied on their echoes. Krill is also an important group, with a different TS. An important body of research worldwide has been published on acoustics on krill, and this group is easily observed by acoustic devices. It can even be separated from fish using multifrequency filters.

There is a concern in the SRG on the need for measuring an age-1 index for hake. Indeed the dynamics of this species is highly related to the existence of successful recruits, and having pre-recruitment information could dramatically help to assess the stock. This is only possible if the age-1 individuals are easy to record acoustically, to catch in the trawl hauls, and to discriminate from the rest of the population. Some results presented by the teams show that this is likely to be the case. Considering that hake is easily caught by trawls (demonstrated by the multiple sets experiments), the proportions of individual by age are certainly correct; therefore an age 1 index should be rather easy to calculate.

While fish identification and biomass allocation is feasible using trawling, a rather important variability and risks of biases exist. There is potentially another way to observe fish assemblages that could help in improving fish identification: the use of multifrequency. Some works have been done using such methods, and although the methods cannot precisely identify the fish species, the studies have been shown to at least be able to discriminate the acoustic data in several main groups. In the case of hake surveys, such methods are potentially able to evaluate separately the fish (which would not resolve the problem of mixed species), the krill (including other plankton organisms such as copepods and other crustaceans), probably the Humboldt squid. The SaKe teams (SWFSC and NWFSC) commonly record multiple frequencies and it is recommended that these methods should be applied for relevant research activities.

2. Geostatistical methods and measurement of precision

Variogram. Before performing kriging, a variogram must be calculated on the whole data set. The teams have selected a single variogram for the whole survey area. One may wonder whether stratification in sub-areas with a particular variogram for each stratum would not be more appropriate considering the overall dimension of the survey area (e.g. design of three strata, from South to North, depending on the average direction of the coastline; or any other a priori stratification); but the choice is a matter of balance between the gain in precision and accuracy of the results and the magnitude of additional processing effort. Both are acceptable.

The variogram model selected is generally the exponential model. I would personally prefer the spherical model which requires less implicit hypotheses, and in particular, contrarily to the exponential model, assumes that at distances longer than the range there is no more correlation (or interactions) between the distributions. But as far as biomass estimate is concerned, the final result would practically not be affected by this choice, both models being rather close to each other; the exponential model is usually simpler to calculate and to fit on the experimental variogram; and if I understood clearly, the choice of exponential was precisely made because it requires less calculation time. This choice can be considered when the variogram is used also for ecological and behavioural purposes, which is not the case so far.

The team has developed a complete set of methods and tools for geostatistical work after its visit to the *Centre de Géostatistiques* of Mines-ParisTech, Fontainebleau, France. Being connected with the Geostatistics School in Fontainebleau was a good initiative, as this is the place where the most important works in geostatistics are performed in the world (The *Ecole des Mines* is the place where geostatistics were conceived by G. Matheron in the 1970s), and especially geostatistics applied to marine stock assessment (Rivoirard et al., 2000). The methods applied by the team are of the highest level.

A clear anisotropy (correlation of distributions in longer distances in direction parallel to the coastline than perpendicular to the coastline) is observed in the spatial distribution of the hake. In this case, in order to allow kriging, two methods can be used: (1) using two variograms calculated in the two different direction of the anisotropic ellipse (i.e. one E-W and one N-S), or (2) correcting the data by an anamorphose that would remove the anisotropic effect. This last solution has been chosen by the team, in order to fit a single isotropic variogram, an anamorphose is performed on the data: the 200 m isobath is located on longitude 125ºW for all the survey. Once the kriging is performed the mappings and analyses are achieved on the real maps. This means that the anamorphose has no impact on the actual calculation of biomass and CVs, neither on the ecological studies to be performed on the data. Nevertheless, considering this last point, it must be recalled that a variogram is not only a tool for kriging, but also a descriptor of the distribution behaviour of the fish. In this case, separate analyses of the two variograms (E-W and N-S) would be necessary.

Kriging. The SRG had a long discussion on the question of the search radius to be applied for interpolating the data and extrapolating the variogram and kriging outside the survey window. Indeed the variation of the search radius produces changes in the results, in terms of biomass as well as precision (CV) (see the tables presented during the SRG meeting by Dr. Chu). Logically, the major differences appeared to be related to extrapolation, regardless of the search radius.

Interpolation does not seem to be an issue, and some comparisons between the search radii allow selecting the proper one. In any case the smallest search radius must be longer than the inter-transect distance: on the contrary the model would be calculated only on small distances, that are only existing on along-transect data (E-W) and the N-S distribution would be biased. We may suspect then that the model would not correctly represent this N-S distribution. It should also be smaller than the distance between two independent concentrations.

The extrapolation is another story. The team presented some maps of extrapolated biomass estimates. Apart for year 2013, the biomass is not deeply affected by the extrapolation: usually the biomasses calculated outside the major distribution area are very low. But the conceptual question remains: should we extrapolate in non-sampled areas, especially when other sources of information (e.g. fishery catches) show that there is some concentration outside the survey area?

My personal analysis is the following. The survey area ("survey window") is limited in longitude by the E-W limits of transects, and in latitude by the extreme north and south transects (adding a distance representing half of the intertransect distance in each border). Extrapolation in latitude is not an issue, as it would represent a very small additional area. The question is on extrapolation over longitudes. It must be noted that the biology, ecology and behaviour of fish stocks are different along the shore (between the eastern limit of the transects and the coastline) and offshore, but both present different constraints. In the particular case of hake, the onshore extrapolation does not seem necessary, as fish is usually not located close to the coastline. The offshore extrapolation is the only one that matters.

There are two types of transect:

- The transects of which the western limit ends with a series of zero values, which means that the distribution area of hake has been completely covered. In this case there is no need for extrapolation and a boundary can be set at the first zero of the series.

- The transects that do not end with zeros, which means that the distribution area has not been completely covered. In this case it is clear that some biomass of hake exists outside the survey window. This is the place where extrapolation could be considered.

Extrapolating is a decision to be taken that depends on the use of the biomass estimates. To be simple, the extrapolated biomass B would be calculated by B = M*A, where M is the mean abundance per EDSU (Elementary Distance Sampling Unit), e.g. tons by square nautical mile; and A is the area on which this extrapolation should be done. M is rather easily obtained by kriging, assuming that the fish outside the survey area obeys the same distribution laws that the fish inside the survey area. The problem is to get a correct value for A. The team did not give satisfactory answer on the way A was calculated for extrapolation: lacking ecological elements, they used a systematic arbitrary distance all along the western limit of the survey area, e.g. 10 NM west of the transect limits, or similar methods. In any case, as long as A cannot be evaluated correctly, extrapolation will remain mostly subjective.

In the case of hake where such elements are missing, I would personally avoid any extrapolation, because this means (1) defining arbitrarily an extrapolation area and (2) applying to an unexplored area a model calculated on the explored area, i.e. assuming that the model applies everywhere. The risk of inventing wrong data is not null. For biomass estimates, I would recommend providing a non-extrapolated result, adding an indicator on the potential existence of bias that this would induce on the actual result (which can be calculated using different types of information, e.g. the number of incomplete transects over the total number of transects, the actual values of the last density estimates on the transects, etc.).

Incidentally, it is noted that there are cases where extrapolation is indispensable, when the survey area is far from exhaustively covering the distribution area (wide distribution of the fish, political borders and forbidden zones, etc.) and therefore the biomass estimate inside the window has no meaning. I presented as an example some results on the South Pacific Jack Mackerel (*Trachurus murphyi*) where the species' distribution area is orders of magnitude larger than the survey areas. In this case the only way to overcome this problem is to design the habitat model of the fish, to draw the probability map of the habitat and to calculate a potential biomass inside this habitat (see SNP, 2013, 2014 and works presented at www.sprfmo.int). Usually the use of acoustic data from fishing vessels becomes necessary for groundtruthing and for better defining the potential habitat and the probability of presence of fish. The hake does not present these limitations, although it could be the case if for instance the stocks move outside the normal distribution area, or if one of the countries does not survey the stock in a given period.

In conclusion it seems that the choices of geostatistical methods and procedures are correct, not to say optimal, and My only other recommendation is to perform a small series of particular analyses in order to check the effect of the data distribution and interpolation methods on the final results.

CV of the acoustic data. Rather often in the documents the biomass estimate is given with a CV of which the origin is not specified. Actually this CV represents only the uncertainty related to the geostatistical methods, and is quite far from the expected CV which would include all the uncertainties related to the different steps of the survey procedure (survey design, TS measurements, biological sampling, etc.) and from the data themselves. It seems to me important to clarify that the CV given has nothing to do with the actual CV (which is probably impossible to calculate yet), otherwise confusion may occur.

We have seen in the different steps of the acoustic method that numerous sources of error (and even biases) exist: noise in the acoustic data, inaccessible areas, TS values, proportion of hake in the overall biomass, echo variability of individuals, calibration, etc., besides the survey design and interpolation/extrapolation geostatistical methods. When complete precision analyses have been performed in the world, they show that depending on the species, the methods, the conditions at sea, etc., a consistent CV is evaluated between 10% and 40% (which is far from the 4.33% presented for 2013). When conditions are not favorable, the CV can be considerably higher. Everything depends on what is needed, but it is clear that using the CV 4.33% has no meaning.

I would strongly recommend paying attention to this point if a consistent CV is needed. The uncertainty in acoustics comes from three major sources: acoustic techniques and instruments (e.g. calibration, TS measurements, conditions at sea); biological sampling (representativeness of trawls, species assemblage, fish avoidance, etc.) and survey design analysis. Moreover, in each one of these sources biases are likely to occur, which cannot be included in the CV but could affect significantly the final result.

There is no other way to consider these points than by performing specific experiments, such as those already done by the teams on TS and trawling. I recommend that the teams first develop a list of the potential sources of uncertainty and biases in the hake survey, identify those that have been already explored in the literature where usable results can be applied on hake, and design specific experiments to evaluate those that remain undocumented.

3. Habitat and environmental information

Acoustic data potentially provide much more information than the biomass estimate, although it is largely ignored. This information comes from several sources: the standard acoustic data, which can provide environmental information such as the water mass structure (Ballon et al., 2011), and particularly the ping-by-ping vertical location of the oxycline (Bertrand et al., 2010); multifrequency information, where acoustic signals from at least two different frequencies (e.g. the most common frequencies of 38 kHz and 120 kHz) are analyzed and compared for discriminating either different fish species (especially when one of them lacks of swimbladder, e.g. Simfami Project, 2004) or main groups, and particularly the plankton and micronekton from fish (Ballon et al., 2011); and non-conventional instruments such as multibeam sonar and acoustic cameras (Handegard & Williams, 2008) which are particularly adapted to behavioural observations.

Exploiting these sources of data allows for the description of the fish habitat. This knowledge of the habitat presents three major issues:

- Definition of the potential habitat, (Zwolinski et al., 2010; Bertrand et al., 2012) which provides a tool for measuring the probability of presence of fish outside the survey windows when this one does not cover the potential habitat. The SRG gave me the opportunity to present an example of such research applied on the South Pacific Jack Mackerel (*Trachurus murphyi*). This species occupies a wide area, from the coast of South America (from the equator up to 50ºS) to New Zealand and Australia (in the subtropical waters, inside the "jack mackerel belt" limited by 35ºS and 45ºS). Acoustic surveys performed by Peru, Chile and more episodically by other countries (Russia, EU) cover a small part of this area, and it is clear that the biomass is out of reach, even when considering smaller regions where subpopulations have been identified, such as the Peruvian area (Gerlotto et al., 2012). Therefore extrapolation is necessary, and the same remarks as made for the hake apply in this case. In order to evaluate this potential area, the habitat of jack mackerel has been defined, taking into account the limits and preferences of this fish for several environmental characteristics: temperature (superficial as well as along the water column), maps of dissolved oxygen vertical distribution, chlorophyll, water masses, dimensions of the continental shelf, etc. Using these values a conceptual model is calculated and a probability map is drawn. The potential biomass is obtained using this probability map of the potential habitat and the mean biomass estimate calculated inside the area; a biomass is allocated for each level of characteristics of the observed habitat and extrapolated to the potential habitat. Obviously such extrapolation requires some groundtruthing, which can be obtained observing the acoustic data collected aboard fishing vessels. I will comment below on this particular point. Application to the jack mackerel provided promising information (Hintzen et al., 2014).

- Ecological interactions between the fish and the environment. This point is important both to fit the assessment inside an ecosystem approach and to identify indicators on the effects of the environmental changes to the fish biology. This is particularly important for fish such as the hake, because the biomass and the dynamics of the population are depending on a few successful recruitments (e.g. the very large cohort born in 2010). It is still no possible to fully anticipate the recruitment, as its determinism is extremely complex and depending in some way on chaotic events. But based the history of these recruitments, studies can be made to observe changes in the environment and the way the habitat evolves. Such studies have been done on the Peruvian anchovy that allowed to evaluate the 3D habitat of the fish and the values of plankton biomass inside this habitat (Ballon et al., 2011); the studies' results have answered an old question on the rather mysterious inconsistency between the productivity of the Humboldt system (apparently not much different from the other EBUEs (Eastern Boundary Upwelling Ecosystems): such as the California, Canarias, Benguela Currents, and the huge production of fish, around one order of magnitude above what could be explained by the productivity. The answer provided is that plankton samples using nets was underestimating the productivity by one order of magnitude, which when factored, showed that the acoustic estimate of plankton was perfectly compatible with the anchovy production. Indeed the Humboldt Current is substantially more productive than other EBUEs. Measuring these different aspects of the ecosystem is possible using acoustic data if the total biomass can be distributed by trophic group through multifrequency analysis.

- Description of changes in the habitat. The environment is not stable, and several phenomena observed during the hake surveys show that this is the case in this particular population. For instance, the arrival of important biomasses of Humboldt squid is of concern for the dynamics of hake populations (squid being both a predator and a competitor of hake). These changes are linked to changes in the habitat, making it important to obtain more information on it.

As indicated above, the non-conventional instruments provide information on fish behaviour. Fish avoidance can be easily measured using multibeam sonar (Soria et al., 1996; see the works of the sardine team of SWFC, which demonstrated that no noticeable avoidance of sardine schools was affecting the biomass estimates); acoustic cameras were used by several teams to observe the fish behaviour patterns (Handegard & Williams, 2008). It is likely that acoustic cameras could complement video cameras in waters with poor to no visibility to evaluate the fish reactions to gears, etc.

4. Use of acoustic data from fishing vessels

Since the mid-2000, the idea of using the acoustic data from fishing vessels has emerged (Karp, 2007). This has been made possible thanks to following three developments:

- The installation of Vessel Monitoring Systems (VMS) and more generally the recording of GPS positions that allows for the spatial dimension in the databases to be extracted from the fishers' activities.
- The improvements of commercial in-board sensors (acoustics, hydrology, etc.), the quality of which is now almost identical to that of scientific instruments. This is particularly the case for acoustic instruments (vertical echo sounders, omnidirectional sonars, and other acoustic sensors) which are derived from scientific devices (e.g. the SIMRAD ES commercial series of vertical echo sounder is a particular version of the SIMRAD EK scientific equipment).
- The digital technology. Nowadays all the equipment aboard industrial fishing vessels is monitored by computing systems, and it has become possible to record all the digital data on external hard disk drives of very low cost and without any interference with the fishers' activities. This allows for good cooperation between scientists and fishers, as long as the direct information collected has no impact on the fishing and commercial activity of the fishing vessel.

This new source of data presents a huge potential use, and it is important to evaluate whether these data could be used for scientific research, and if so, then which types. This includes the following: Measuring the scientific value of the information, which requires analyses at different levels; feasibility of data collection; calibration of the instruments; precision-accuracy of the data; scientific quality of the information; statistical constraints due to the "sampling strategy" of the fishing vessels; comparison with the similar data collected aboard research vessels; and cost of collection, processing, equipment, calibration, among other factors. Finally the effectiveness of extracting consistent indicators from these data has to be considered.

Apart from certain exceptions (e.g., Barbeaux, 2012; SNP, 2013, 2014), most of the works using fishing vessels were performed hiring ships to perform scientific transects, and not getting data from actual fishing trips (Honkalehto et al., 2011). This may be due to the difficulty to compare a standard survey with a fishing trip, where "sampling strategy" is not statistically easy to consider: it seems difficult to obtain biomass estimates from such data. But indicators and habitat information are easy to extract. Some works have already been done (and a special issue of Fishery Research will be published in 2015 on the theme of "fishing vessels as scientific platforms"), which show that acoustics from these platforms represents an important source of fishery independent data (in fact, not independent from the fishery activity itself, but from the catch data). Combining these data with the scientific acoustic surveys can provide insights on the dimensions and characteristics of the habitat (including outside the survey window), elucidate aspects of fish behaviour, identify the relationship between CPUE and fish density, and cover for the lack of survey every other year, etc. The advantages are numerous and are worth a study, even though the data are not necessarily easy to handle, especially as far as statistical significance is concerned.

SUMMARY OF FINDINGS FOR EACH ToR (IN WHICH THE WEAKNESSES AND STRENGTHS ARE DESCRIBED)

(*Reviewing the stock assessment criteria and methods and survey methodologies used by the Joint Technical Committee*. My contributions in this field concern exclusively the results of the research in acoustics, and mostly the value of biomass estimates. They are presented below following the list of ToR.)

- **Data collection, including target verification and biological data, and survey protocols to assess whether or not the level of sampling is sufficient.** The survey protocol and the sampling strategy are good and are unlikely to be substantially improved using different strategies. On the contrary, changing a protocol would make the time series analysis difficult. I recommend continuing the use of the same protocol, but to perform specific experiments in the diverse points listed in my analysis in order to improve the accuracy and precision of the results. The weak points of the teams are not in this area of research. Experiments on target strength and trawl sampling showed that under normal conditions the fish identification by fishing is satisfactory. Some sources of error have been pointed out when hake is mixed with myctophids, and the value of this error should determined (made precise) by continuing the experiments already performed (video observation of fish behaviour inside the trawl). Target strength studies should be continued, in order to evaluate the fitness of the Traynor model on hake. Environmental sampling is judged insufficient by the team although I am not sure that this is the case. Indeed, the important source of environmental data that represents acoustics is not exploited.

- **The effects of reduced transect coverage with existing data or novel techniques.** It has been demonstrated through experiments and simulations that transect coverage (in terms of inter-transect distances) can be reduced with no major effect on the biomass estimate (but with effects on the CV). Coverage is quite satisfactory inside the survey area. It would be certainly more useful to reduce the number of transects and use the extra time for extending the transects up to the end of the distribution area than to maintain or increase the coverage with more days at sea. Additionally, using acoustic data from fishing vessels could help to increase the sampling in the high abundance areas which are those that produce the highest variance in the survey data, therefore reducing the overall CV (among other advantages).

- **The impact of a change in survey direction and developing appropriate calibration if direction were changed**. The only risk of such changes would appear if there is a migration pattern during the survey. It is recommended to evaluate the migration during surveys in order to select the best direction of survey and evaluate the bias produced by the migration on the biomass estimate (tagging, analysis of the catch data, observation of acoustic data from the fleet, specific experiment following a given concentration, etc.). If migrations exist and have already affected the results of historical surveys, then I recommend not to change the direction of the surveys, in order to keep the same bias for all the surveys as long as a complete knowledge of the migration pattern is not obtained.

- **Geostatistical methods used to estimate biomass as well as data processing approaches**. The method presented is satisfactory. We could discuss the drawbacks and advantages of alternative methods (choice of other variogram models, anisotropy calculation, and search ranges...) but these points would have a marginal effect on the results. I am not sure that the alternative method suggested by the teams, i.e. the use of 1D transitive models, would improve the results. This method (Petitgas, 2001) is still under discussion inside the fisheries acoustics community. The question of extrapolation of the kriging results outside the survey area has been discussed in detail, and my recommendation is that extrapolation should be avoided as long as no real argument can be given to define its area of application. Otherwise extrapolation would be an arbitrary choice, likely to produce subjective results. I recommend that the potential habitat of hake be studied in order to get sound information prior to extrapolate.

- **Survey variance estimates**. This is a weak point in the methods and the CV used by the assessment team (4.33% in 2013) represents only the error due to kriging. The actual CV of a survey is much higher and is still unknown in the case of hake. I recommend listing the sources of variance and either to refer to other studies when they apply or to achieve particular experiments to get an evaluation of the variance for each step of the method. If CV is an issue for the assessment, then this work should be given first priority. The other steps of the method, and especially the geostatistical method, are probably the best possible to use and no change is actually needed. Apart the survey variance, the biomass value can be biased, especially by extrapolation methods (see above).

- **Viable alternative transect sampling designs.** There is no real alternative to the method already used. Other transect sampling designs consist of the following: (1) The choice of different inter-transect distance, which should be decided after weighting the gain in time (decrease of variance due to weak effect of migration) and the loss in precision (increase of variance with the inter-transect distance); (2) Another design, e.g. zig-zag or any other (complicated) design, will result in a lower precision of the data and is not recommended. Within this field I would add the use of fishing vessel acoustics that is likely to dramatically increase the precision of the biomass estimate, by evaluating the extrapolation area and by increasing the sampling in very dense areas (from where the bulk of the variance comes). I strongly recommend studying the possibility to include fishers' acoustic data in the acoustic assessment.

CONCLUSIONS AND RECOMMENDATIONS IN ACCORDANCE WITH THE ToRs

Within this final section, I summarize my main comments. I take also the opportunity to address these comments to the three teams involved in SaKe (and not only to the hake teams), as they could support each other in the research and experiments.

As far as acoustics is concerned, the teams from USA (NWFSC as well as SWFSC) and Canada (DFO) are among the most experienced in the world and their knowledge of acoustic techniques and methods is unsurpassed. There is no doubt that their data are accurate and their protocols highly efficient in most of the cases. Under these conditions, the only recommendation in the technical and methodological areas is to go on using the same survey plan. Some experiments on those points that are still not documented may be advisable, but I am convinced that the teams do not need the comments of an external expert to define these fields of acoustic research.

This however is not the case when observing the ecology of the fish populations. The skills of the teams are not as good in this area as is their acoustics knowledge, and it is clear that they do not extract all the information that the acoustic data could provide, probably because their scientific interest in ecology is lesser than it is in acoustics. I have presented some proposals and recommendations in this report, but my main concern is that this part of the research is insufficiently studied.

In this report, I have commented about the definition, design and use of fish habitat. It is noticeable that the fish populations of the N-E Pacific Ocean, both small pelagic and semi-demersal populations, are suffering huge variations of their biomass independently from the fishing pressure. These variations are a result of environmental variability (particularly, links with the ENSO events). Therefore it is unlikely that a good assessment could be done if there is no knowledge on the relationships between the stock and its habitat.

The SWFSC has produced some preliminary results on potential habitat of sardine, but these are still insufficient to provide a understanding of the dynamics of this species (for instance, the potential habitat designed does not explain the decrease of the sardine biomass). In the case of hake survey, there is practically no information on habitat. This field of research should be put as one of the highest priorities, and I suggest that the teams take advantage of common SaKe surveys to develop common theoretical research on habitat, to be then adapted for each case separately.

Appendix 1: Bibliography of materials provided for review

Documents provided by the SRG

CIE, 2015. Statement of Work External Independent Peer Review by the Center for Independent Experts Review of 2015 Pacific Hake/Whiting Assessment and Management Strategy Evaluation

Chu, D., Thomas, R.E., de Blois, S.K., Hufnagle Jr, L.C., 2015. Pacific Hake Integrated Acoustic and Trawl Survey Methods.

DFO, 2015. WER 2014 Pacific Hake research mission overview. Ppt presentation

Gerlotto, F., 2014. CIE peer review panel review of the joint Pacific sardine and Hake (SaKe) acoustic-trawl surveys

Hicks, A.C., Cox, S., Taylor, N. , Taylor, I.G., Grandin, C., Ianelli, J., 2015. Conservation and yield performance of harvest control rules for the transboundary Pacific hake (*Merluccius productus*) fishery in U.S. and Canadian waters (draft)

JTC. 2012. Joint Technical Committee of the Pacific Hake/Whiting Agreement Between the Governments of the United States and Canada Status of the Pacific hake (Whiting) stock in U.S. and Canadian Waters in 2012. Prepared for the Joint U.S.-Canada Pacific hake treaty process. 195 p.

JTC,. 2013. Joint Technical Committee of the Pacific Hake/Whiting Agreement Between the Governments of the United States and Canada Status of the Pacific hake (whiting) stock in U.S. and Canadian Waters in 2013. Prepared for the Joint U.S.-Canada Pacific hake treaty process. 190 p.

JTC, 2015. Joint Technical Committee of the Pacific Hake/Whiting Agreement Between the Governments of the United States and Canada, 2015. Status of the Pacific Hake (whiting) stock in U.S. and Canadian waters in 2015 (draft)

JTC, 2015. Modeling results of 2015 Pacific Hake/withing stock assessment. SRG meeting, February 23-27, 2015. Ppt presentation

Melvin, G., 2014. CIE peer review panel review of the joint Pacific sardine and Hake (SaKe) acoustic-trawl surveys

NOAA-DFO, 2015. Geostatistics and the Joint U.S.-Canada Pacific Hake Survey. Ppt presentation.

NOAA-DFO, 2015. 2014 Research update. DFO and NWFSC Acoustic teams, February 24, 2015. Ppt presentation

NOAA-DFO, 2015. Joint U.S.-Canada Pacific Hake Acoustic Surveys. Overview of Pacific Hake survey. Ppt presentation

Rose, G., 2014. CIE peer review panel review of the joint Pacific sardine and Hake (SaKe) acoustic-trawl surveys

SRG, 2013. Joint U.S.-Canada Scientific Review Group Report

SRG, 2014. Joint U.S.-Canada Scientific Review Group Report

SRG, 2015. Joint U.S.-Canada Scientific Review Group Report

SRG, 2015. Joint U.S.-Canada Scientific Review Group Report. Notes and questions to be addressed by the SRG during the meeting, February, 2015

Volstad, J., 2014. CIE peer review panel review of the joint Pacific sardine and Hake (SaKe) acoustic-trawl surveys

Other documents cited in the report

Ballón, M., Bertrand, A., Lebourges-Dhaussy, A., Gutierrez, M., Ayón, P., Grados, D., Gerlotto, F., 2011. Is there enough zooplankton to feed forage fish populations off Peru? An acoustic (positive) answer. Progress in Oceanography 91 (2011) 360–381

Barbeaux, S.J., 2012. Scientific acoustic data from commercial fishing vessels: Eastern Bering Sea walleye Pollock (Theragra chalcogramma). A dissertation submitted for the degree of Doctor of Philosophy, University of Washington, 2012: 245 p.

Benoit-Bird, K.J., Gilly, W.F., Au, W.W., Mate, B., 2008. Controlled and in situ target strengths of the jumbo squid *Dosidicus gigas* and identification of potential acoustic scattering sources. J Acoust Soc Am. 2008 Mar; 123 (3):1318-28. doi: 10.1121/1.2832327.

Bertrand, A., Ballón, M., Chaigneau, A., 2010. Acoustic Observation of Living Organisms Reveals the Upper Limit of the Oxygen Minimum Zone. PLosOne, April 2010 , Volume 5, Issue 4, e10330

Bertrand A, Chaigneau A, Peraltilla S, Ledesma J, Graco M, et al. (2012). Oxygen: A Fundamental Property Regulating Pelagic Ecosystem Structure in the Coastal Southeastern Tropical Pacific. PLoS ONE 7(2): 10.1371

Gerlotto, F., Gutierrez, M., Bertrand, A., 2012. Insight on population structure of the Chilean jack mackerel (*Trachurus murphyi*). Aquatic Living Resources, 25, 341–355 (2012)

Handegard, N. O., and Williams, K. 2008. Automated tracking of fish in trawls using the DIDSON (Dual frequency IDentification SONar). – ICES Journal of Marine Science. 65: 636–644.

Hintzen, N., Corten, A., Gerlotto, F., Habasque, J., Bertrand, A., Lehodey, P., Brunel, T., Dragon, A.-C., Senina, I., 2014. Hydrography and Jack mackerel stock in the South Pacific – Final report. Studies for carrying out the Common Fisheries Policy, Open call for tenders No MARE/2011/16 Lot 1

Honkalehto, T., Ressler, P.H., Towler, R.H., Wilson, C.D., 2011. Using acoustic data from fishing vessels to estimate walleye pollock (*Theragra chalcogramma*) abundance in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences, 2011, 68(7): 1231-1242

ICES-SGCal, 2011. Report of the Study Group on Calibration of Acoustic instruments in Fisheries Science (SGCal), Reykjavik, 7-8 May 2011:22 p.

Karp, W.A. (Ed.), 2007. Collection of acoustic data from fishing vessels. ICES Cooperative Research Report, 287, August 2007:90 p.

Mitson, R.B., 1995. Underwater noise of research vessels. ICES Cooperative Research Report, 209: 65 p.

Parrish, J.P., Gerlotto, F., 2012.. Report of the ICES/ WGFAST Study Group on Fish Avoidance to Research Vessels SGFARV, 2012 (http://www.ices.dk/reports/SSGESST/2012/SGFARV12.pdf)

Petitgas, P., Geostatistics in fishery survey design and stock assessment: models, variances and applications. Fish and Fisheries, 2001, 2: 231-249

SIMFAMI, 2004. Species Identification Methods From Acoustic Multifrequency Information, 2002-2004. http://cordis.europa.eu/data/PROJFP5

SNP, 2013. 4th SNP workshop on diagnosis on the status of the Chilean Jack Mackerel (*Trachurus murphyi*) in the Peruvian Fishery. Lima, 26 June-2 July, 2013. Executive summary. SPRFMO, La Jolla, 2013.

SNP, 2014. Report of the 5th workshop on diagnosis of the status of the South Pacific Jack mackerel fishery in Peru *SNP Scientific Committee* Executive summary. SPRFMO, SC-02-JM-12, Honolulu, October, 2014.

Soria, M., Fréon, P., Gerlotto, F., 1996. Analysis of vessel influence on spatial behaviour of fish schools using a multi-beam sonar and consequences for biomass estimates by echo-sounder. ICES Journal of Marine Science, 53: 453–458. 1996

Zwolinski, J. P., Emmett, R. L., and Demer, D. A. Predicting habitat to optimize sampling of Pacific sardine (*Sardinops sagax*). 2010 – ICES Journal of Marine Science, 68:

Appendix 2: A copy of the CIE Statement of Work

Statement of Work

External Independent Peer Review by the Center for Independent Experts

Review of 2015 Pacific Hake/Whiting Assessment and Management Strategy Evaluation

Scope of Work and CIE Process: 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 Technical Representative (COTR), 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 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.

Project Description: The Pacific hake (or whiting, *Merluccius productus*) benchmark stock assessment will provide the basis for the management of the largest groundfish fisheries off the West Coast of the U.S. and British Columbia. In 2013, Pacific whiting fishery accounted for 90% of the landed catch and 56% of the ex-vessel revenue of the U.S. Pacific coast groundfish fishery. The technical review will take place during a formal, public, multiple-day meeting of fishery stock assessment experts.

The requested CIE reviewer will participate as a member of the Scientific Review Group, which was established under the U.S. –Canada Pacific Whiting Treaty to provide independent peer review of the Joint Technical Committee's work, including the 2015 stock assessment for Pacific hake / whiting, the associated Management Strategy Evaluation (MSE), as well as the acoustic survey for whiting. Specifically, the review group is charged with:

- Establishing Scientific Review Group terms of reference for approval by the Joint Management Committee.
- Reviewing the stock assessment criteria and methods and survey methodologies used by the Joint Technical Committee.

- Providing annually, by March 1, unless otherwise specified by the Joint Management Committee, a written technical report of the stock assessment and its scientific advice on annual potential yield.
- Performing other duties and functions as directed by the Joint Management Committee.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for the CIE Reviewer: One CIE reviewer shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein.

The CIE reviewer shall have expertise in acoustic survey design, particularly optimization of sampling design (eg. optimizing spatial structure of transect design and sampling needed to obtain representative information on the biological characteristics of the targeted fish stocks). The CIE reviewer shall also have expertise in geostatistical analyses such as variogram analysis, kriging, and/or stochastic simulation of spatial variability. In addition, the CIE reviewer shall have experience using acoustic survey data in to develop estimates of total biomass for use in stock assessments. Experience with pelagic and benthic fish species is desirable to complete the primary task of providing peer-review advice in compliance with the Scientific Review Group's Terms of Reference.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Vancouver, BC during 24-27 February 2015.

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

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also 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 COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) 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/

http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Draft and Background materials are likely to include the following:

- Terms of Reference for 2015 SRG (~2 pgs);
- 2015 draft Pacific hake stock assessment and management strategy evaluation document (~170 pg);
- 2014 Pacific hake stock assessment and management strategy evaluation document (168 pg;)
- 2013 SRG report (10 pg)
- 2014 SRG report (10 pg);
- CIE reports of the Review of the NWFSC and SWFSC Joint survey of Pacific sardine and Pacific hake survey (SaKe survey review) (159 pgs. Total);
- Pacific Hake Integrated Acoustic and Trawl Survey Methods (~46 pgs);
- Stock Synthesis Technical Description and User Manual (178 pgs total);
- Other materials as determined necessary and appropriate

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** 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.

The CIE reviewer will participate on the review panel as an external independent reviewer. The current Terms of Reference for the SRG review are available online (URL below), however, may be revised prior to the 2015 SRG meeting.

TOR:http://www.westcoast.fisheries.noaa.gov/publications/fishery_management/groundfish/whiting/srg-tor.pdf.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for the CIE Reviewer: The following chronological list of tasks shall be completed by the 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 at Vancouver BC from 24-27 February 2015 and conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than 9 March 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@ntvifederal.com, and Dr. David Die, CIE Regional Coordinator, via email to *ddie@rsmas.miami.edu*. Each CIE report shall be written using the format and content requirements specified in **Annex 1**, and address each ToR in **Annex 2**.

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

12 January 2015	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
2 February 2015	NMFS Project Contact sends the CIE Reviewers the pre-review documents
24-27 February 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
9 March 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
13 March 2015	CIE submits CIE independent peer review reports to the COTR
16 March 2015	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR 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 CIE 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: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:

(1) The CIE report shall completed with the format and content in accordance with **Annex 1**,

(2) The CIE report shall address each ToR as specified in **Annex 2**,

(3) The CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

Allen Shimada
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
Allen Shimada@noaa.gov Phone: 301-427-8174

William Michaels
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-427-8155

Manoj Shivlani, CIE Lead Coordinator
NTVI Communications, Inc.
10600 SW 131st Court, Miami, FL 33186
MShivlani@ntvifederal.com Phone: 305-968-7136

Key Personnel:

NMFS Project Contact:

Stacey Miller
Email: Stacey.Miller@noaa.gov
Phone: 978-281-9203

Michelle McClure
Email: Michelle.McClure@noaa.gov
Phone: 206-860-3402

Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   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 Summary Report that they feel might require further clarification.

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

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review

   Appendix 2: A copy of the CIE Statement of Work

   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Terms of Reference for the Peer Review

1. Become familiar with the draft Pacific hake/Whiting stock assessment(s) and background materials.
2. Participate in the multiple-day meeting in a manner specifically agreed upon by the Scientific Review Group (SRG). It is anticipated that the CIE reviewers will participate in the review panel meeting as "officially invited members" of the SRG rather than "formally appointed members", as outlined in the U.S. Canada Pacific Whiting Treaty. CIE participation in official SRG discussions and decisions will be at the discretion of the SRG co-chairs. However, it is hoped that their roles will be no less than discussants, seated at the SRG table, if not de facto, fully functioning SRG members.
3. Review the current systematic transect design for acoustic sampling of hake utilized by the joint Pacific sardine and Pacific hake survey and the geostatistical approach used to estimate biomass to provide recommendations in the following areas:
    - Data collection, including target verification and biological data, and survey protocols to assess whether or not the level of sampling is sufficient (i.e., is there evidence that the survey is oversampling or undersampling the stock).
    - The effects of reduced transect coverage with existing data or novel techniques
    - The impact of a change in survey direction and developing appropriate calibration if direction were changed.
    - Geostatistical methods used to estimate biomass as well as data processing approaches
    - Survey variance estimates;
    - Viable alternative transect sampling designs;
4. Provide recommendations on the relative priority of previously recommended acoustic and associated research, including, but not limited to: calibration efforts, migration behavior, target strength and oceanographic or ecosystem associations.
5. Evaluate assessment model structure, assumptions, estimates, and major sources of uncertainty and provide constructive suggestions for improvements if technical deficiencies or additional major sources of uncertainty are identified.
6. Provide specific suggestions for future improvement in any relevant aspects of data collection and treatment, survey approaches and technical issues including assumptions in the survey methodology and the impact of uncertainty in acoustics estimates on stock dynamics and management quantities (e.g. reference points).
7. Evaluate whether the science reviewed provides the best available scientific information (BASI) for the Pacific hake assessment.

Note – CIE reviewers typically address scientific subjects, hence ToRs usually do not involve CIE reviewers with regulatory and management issues unless this expertise is specifically requested in the SoW.

Meeting Agenda
Joint US-Canada Scientific Review Group for Pacific Whiting

Room 320
Morris J. Wosk Centre for
Dialogue Simon Fraser
University
580 West Hastings Street
Vancouver, B.C., Canada, V6B
1L6
February 24 – 27 2015

Tuesday, February 24, 2015

9:00 AM	Welcome and Introductions
9:15 AM	Review and Approve Meeting Agenda (Chair)
	Review Terms of Reference for Assessments and Review Meeting
	Assignment of reporting duties
10:00 AM	General Overview of the Pacific Whiting Acoustic Survey (survey team & JTC)
10:30 AM	Presentation of the 2014 research and survey efforts (JTC & survey team)
11:30 AM	Presentation of survey methodology and biomass estimation methods (SRG, JTC and survey team)
12:00 AM	Lunch (on your own)
1:30 PM	Continue presentation of survey methodology and biomass estimation methods (SRG, JTC and survey team)
2:30 PM	Discussion of survey methodology and biomass estimation methods (SRG, JTC and survey team). 4:30 PM Public comment on acoustic survey and research
5:00 PM	SRG develops list of request for additional information from JTC and survey team
5:30 PM	Adjourn for the day

Wednesday, February 25, 2015

8:00 AM Review of topics/questions from previous day (survey related) 9:00 AM Overview of the 2014 Whiting Fisheries

- Canadian Waters
- U.S. Waters

10:00 AM Presentation of draft 2015 update assessment

(JTC) 12:00 PM Lunch (on your own)

1:00 PM	Discussion of update assessment with the STATs
2:00 PM	Presentation of MSE progress
(JTC) 3:00 PM STATs	Discussion of MSE with the
4:30 PM	Public comment on assessment and MSE
5:00 PM	SRG develops list of requests for additional information from the JTC
5:30 PM	Adjourn for day

Thursday, February 26, 2015

8:00 AM	Discussion – MSE and JTC presentation(s) of response to SRG requests
10:00 AM	Survey design and planning for the Joint Hake/Sardine survey in 2015
11:00 AM	Distribute and review status of notes and draft SRG Report
12:00 PM	Lunch (on your own)
1:30 PM	SRG discussion - Evaluation of base model and primary sources of uncertainty - Compile a list of catch levels to consider in a decision table - Evaluate MSE methodology and approaches - Develop list of additional requests to the JTC
4:00 PM	Public comment period
4:15 PM	Initial SRG discussion of research needs for 2015, 2016 and longer-term
5:30 PM	Adjourn for day

Friday, February 27, 2015

8:00 AM	Distribute and review status of notes and draft SRG Report
8:15 AM	JTC presentations and comments on SRG advice
10:00 AM	SRG discussion on research needs for 2015, 2016 and longer-term
11:00 AM	SRG statement of findings and finalization of report
1:00 PM	Panel adjourns

Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Authored by Scientific Review Group (SRG) Members

John Holmes, Co-chair, PBS, DFO, Canadian appointee
Michelle McClure, Co-chair, NOAA, NMFS, NWFSC, U.S. appointee
Trevor Branch, UW, independent member
Kendra Holt, PBS, DFO, Canadian appointee
Michael Prager, NMFS, NOAA, retired, U.S. appointee
David Sampson, OSU, independent member
Mike Buston, Advisory Panel - Canada, AP Advisor to the SRG
Rod Moore, Advisory Panel - USA, AP Advisor to the SRG

Independent Reviewer

François Gerlotto, Center for Independent Experts