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Fisheries Oceanography Acoustics Applications in Western Pacific

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External Independent Peer Review by the Center for Independent Experts

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1. EXECUTIVE SUMMARY:

The Pacific Islands Fishery Science Center (PIFSC) is conducting a broad range of fisheries applications using active acoustics that have generated two publications in the micronekton area. The center has only one person active in the program with others contributing on an ad hoc basis. The functioning of the equipment available on the large research boat *Oscar Elton Sette* to carry out the tasks has limited the science that could have been achieved. Despite this it was encouraging that good advances have been made and some great science embarked on in the field of micronekton research and connectivity with tuna populations. Applications of the acoustic method have also been done on measuring the abundance of tuna at a seamount, juvenile snapper biomass on a small outer shelf patch and bottom fishes at Penguin Banks. These examples have highlighted the difficult in applying the acoustic method in exposed waters on either large or small vessels in a heterogeneous environment with highly mobile species. However, these applications will require dedicated methods development before credible biomass estimates are realised. Nevertheless, significant advances have been made by the PIFSC and these should be written up and published.

This review is focused on how to further develop acoustic applications within the PIFSC. This will require some careful project planning of the overall science direction and the staff and equipment resources required. At the science direction level there are a wide range of applications available and there needs to be a critical assessment of what science will have the most impact over the long term. Acknowledging that the PIFSC has a unique position in the Pacific Ocean where it has responsibility for an ocean area the same size as the entire U.S. exclusive economic zone and in addition the high seas of the central and western pacific. This large ocean zone with its living resources will require some unique methods to be developed and applied. One such method being developed is the long term study and monitoring of the role of micronekton in the oceans ecosystem and its direct impact on tuna distribution and abundance. The science already carried out and resultant publications have highlighted PIFSC strengths in this area and its impact both nationally and internationally. This area is discussed in more detail below.

To resource acoustic research requires a team of people including a research scientist (acoustic/oceanography), acoustic technician and field ecologists. This team could then interact within and between programs in the divisions to meet PIFSC centre goals. Key to this success will be the linkage with expertise from acoustics and oceanographic and ecological modellers within NOAA the universities and internationally with other researchers. Within the field of acoustics it is recommended that regular attendance at the ICES Working Group on Fisheries Acoustic Science and Technology be facilitated. To implement an acoustic program requires well maintained and functioning equipment. Correcting the poor acoustic data collected from the *Oscar Elton Sette* needs to be addressed either with alternative placements of transducers or eliminating bubble sweep down. Fixing this problem should enable good quality acoustic data to be collected on all open ocean voyages. Biological sampling and species identification are key requirements of an acoustic micronekton program and the trawl facilities need to be operational and upgraded. Ideally multi-codend depth stratified trawls should be used in combination with lowered optical and acoustic devices. Interaction with NOAA's Advanced Technology Group to obtain this technology should be encouraged and/or projects facilitated with other national or international research agencies. Given the large EEZ region that PIFSC is responsible for facilitating novel acoustic monitoring methods including buoys, gliders and ships of opportunity should be investigated.

2. SUMMARY OF BACKGROUND PROVIDED:

The PIFSC is conducting a broad range of fisheries applications using active acoustics that have generated a good number of publications. The active acoustic program commenced in 2004 at the center and utilizes two Simrad EK60 systems. One system is installed on the NOAA ship *Oscar Elton Sette* with a home port in Pearl Harbor, while the other one is operated on a small (21-foot) boat, the *Kumu*. Acoustic data obtained by these systems are pre-processed using Echoview software then further processed and analyzed using Mathworks' Matlab software. IRD's Movies+ software has also been used occasionally for processing acoustic data.

Presently, there are two major foci of this work. One is the study of micronekton within the tropical and subtropical Pacific Ocean. Micronekton are smaller organisms that are forage for economically important fishes, such as tunas. Another focus of the active acoustic program is the development of a fisheries independent method to study commercially important fish with management issues. As for micronekton, both *in situ* and satellite data are used to examine the effects of the environment on these fish. One example of these organisms is bigeye tuna.

Future plans include obtaining more acoustic data on micronekton at different regions within the Pacific basin to develop an understanding of large-scale differences in biomass, composition, and movement patterns of micronekton. The development of fisheries independent methods to produce biomass time-series of economically important fish and the study of the effects of environmental factors is expected to continue. Acoustic data will be collected at various seamounts and their effects on micronekton and fish will be examined. With the development of new projects, the presently one-person "program" should also increase.

Due to the applied nature of this work, a thorough review of the approach would be justified. Further, this program would greatly benefit from a review because of the isolation it faces, as no one else is using this method in the state of Hawaii. A review would be additionally beneficial as this program faces special challenges due to the highly heterogeneous nature of tropical and subtropical environments, making acoustic identification of organisms difficult.

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

Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled at the Pacific Islands Science Center in Honolulu, Hawaii during 7-9 July, 2010.

The review consisted of three independent reviewers where my role was one of having broad interest in the application of acoustic methods for fish and micronekton. All three reviewers had similar expertise that covered the full spectrum of acoustic applications from plankton to fish and links to fisheries management. What appeared to be lacking in this review was specific oceanographic expertise and questions that were specifically targeted on this discipline area were not well addressed (Term of Reference 7, see Appendix B for a list of terms of reference).

4. SUMMARY OF FINDINGS FOR EACH TOR

4.1 *Evaluate whether the acoustic system is calibrated appropriately for high-quality data collection*

Two vessels were identified for calibration being the NOAA ship *Oscar Elton Sette* and portable equipment used on a small (21-foot) boat, the *Kum.*

It has been difficult to calibrate the *Oscar Elton Sette* vessel mounted acoustic systems due to the exposed coast and lack of sheltered water ways of suitable depths. Following the appropriate Simrad procedures requires a below hull depth of greater than 20 m. This is to ensure the calibration sphere is well outside the transducer near field and to reduce short range effects of time varied gain ramp in the sphere and time delays in the instruments electronics (Foote *et al*. 1987). Based on Foote et al. (1987) it should be possible to establish offsets for shallow water calibration methods. Calibrating in shallow water may make locations in sheltered waters such as Pearl Harbour viable increasing the frequency of calibration checks. Calibration of portable equipment could also be done in shallower waters if due care is observed with close range effects as discussed above.

The calibration procedures adopted by the PIFSC have followed the appropriate manufacturer recommendations. The procedure of mapping the entire beam pattern as part of the calibration for use in determining the echo integration gain constant whilst not used for the equivalent beam angle (EBA) has not been critically reviewed by the scientific community. Calibrations performed to date provide a system check but do not calculate the EBA of the transducer. The EBA of a transducer needed for absolute calibrations is provided by the manufacturer at a set temperature and a correction may be necessary if used in a very different temperature. To ensure the calibrations are at internationally accepted best practice engaging with the calibration study group within the ICES Fisheries Working Group on Acoustic Science and Technology (WGFAST) is recommended

It is pleasing to see that the systems used in this work have been regularly calibrated following a consistent methodology. Acoustic systems as used by the PIFSC have been shown to be stable over time although changes can occur due to transducer ageing/damage or due to the changing of software/hardware over the long term (Knudsen 2009). Therefore, regular checks on calibration are necessary and should be dictated by the science objectives. For critical stock assessment surveys calibrations at the start and end are recommended. For long term data collections of micronekton a calibration once a year may be suitable (Kloser *et al*. 2009). As other sources of error and bias including the poor data quality are well in excess of the potential calibration errors they deserve more attention as outlined below.

4.2 *Evaluate whether surveys are designed appropriately for estimating relative biomass of top predators, such as tuna from active acoustics data.*

To evaluate a survey design there needs to be clear objectives and reporting of the abundance estimate and its variance. Largely the work to date has been exploratory where the study has concentrated on understanding the dynamics of biota distribution and movement in relation to fine scale or large scale oceanographic features. These studies are important to develop an appropriate survey design that could be used to estimate biomass. If the objective is to measure the biomass of tuna over a small region this may be suited to a mapping exercise requiring the use of geostatistical methods. Simmonds et al. (1992) overviews the elements of survey design methodology where newer methods can be placed in context (Doray *et al*. 2008).

Both echo integration and echo counting methods have been suggested for estimating the abundance of fish stocks and each of these techniques have different needs in terms of reducing an error budget. In order to evaluate the best type of survey design all potential sources of error and bias need to be critically evaluated (Simmonds *et al*. 1992). A strategy to minimise survey sampling variance with a high number of transect without addressing other potential sources of bias or error such as species identification, target strength or detectability would not lead to a better estimate. An approach to determine the sources of error for a survey and an analytical approach to assess various strategies has been outline by Rose et al. (2000). To implement echo counting methods requires the user to identify all the sources of error and bias associated with this methodology, including variable sampling volumes with range and changing target threshold with range and angle off axis

Constraints on survey design strategies were discussed due to weather induced noise on the *Sette*'s transducers where transects can often only be carried out running with the sea. This places extra constraints on survey designs and highlights the need to rectify the noise problem on the *Sette*.

4.3 *Evaluate whether active acoustics data are pre-processed appropriately using Myriax Echoview Software for estimating relative biomass of top predators, such as tuna.*

To process acoustic data using commercial software products such as *Myriax Echoview Software* the user needs to have a good working knowledge of the principles of acoustics. In particular the influence of noise, changing absorption, platform motion, species target strength and single target detection criteria. In the data reviewed it was clear that more attention needs to be paid to these areas and in particular corrections of noise and absorption when comparing frequencies.

The general poor quality of the data due to inappropriate vessel hull characteristics has greatly increased the time required to quality assure and process data. Given the often poor quality of the data there is a high reliance on noise subtraction and bad ping rejection due to aeration. In many instances large portions of the data are rejected and the resultant data of dubious quantitative use.

Based on the data presented, some general points were discussed:

- Implement strategies that improve data quality at the time of collection.

- Implementing corrections for the absorption at each frequency and its depth and temperature related variability.

- When presenting acoustic data it is useful to demonstrate the amount of modifications that have been made to the data and the proportion of data it needed to be made on.

- Present pre and post noise corrected data to ensure artefacts have been correctly removed and do not bias multi-frequency comparisons.

- One application of the software was to use target tracking and single targets for estimates of biomass. To do this requires the user to identify all the sources of error and bias associated with this methodology including, variable sampling volumes with range and changing target threshold with range and angle off axis.

A major limitation on data quality was the transducer noise due to aeration. There is an urgent need to rectify this problem to ensure data is suitable for quantitative purposes. Some potential solutions were discussed being:

- Covering the open bow thruster hole that appeared to be in line with the transducers or relocation of the transducer blister.

- The possibilities of using a pole or towed body were discussed but solutions have extra maintenance issues and would require ongoing technical staff.

4.4 *Evaluate whether surveys are designed appropriately for estimating relative biomass of micronekton, forage for top predators, from active acoustics data.*

No work was presented on estimating biomass of micronekton whereas backscatter was presented as a surrogate for relative biomass. Voyages collected acoustic backscatter as a surrogate for relative biomass to test hypotheses of water mass influence on both micronekton and tuna distribution. A major problem with this approach is the assumption that the acoustic species/size groups are similar between regions. There was no conversion of the acoustic backscatter into appropriate acoustic functional groups aided by biological sampling which limits the approach used. Minimal biological sampling appeared to be due to a systematic problem with deploying a net on the research vessel with ongoing mechanical failures during voyages cited. There is an urgent need to review the biological collection capability of the research vessel. In particular, the following were discussed:

- Appropriate priority and personnel to ensure trawl equipment is functioning for a voyage.
- Need for a multiple opening and closing codend to sample distinct scattering layers.
- The need for lowered acoustic/optical sensing devices to complement species identification and target strength tasks.

A survey of relative or absolute micronekton biomass based on echo integration needs verification. It is recommended that acoustic data is collected with complementary collection of species identification or species mixture data. That these data are used to estimate the density of acoustic functional groups in g/m^2 or g/m^3 based on the best available target strength information. Using these data test assumptions that volume reverberation backscatter is linearly related to weight and test the hypothesis that variability of multi-frequency data could be used as a surrogate for changes in species composition in the region.

4.5 *Evaluate whether active acoustics data are re-processed appropriately using Myriax Echoview Software for estimating relative biomass and composition of micronekton.*

No estimates of biomass were provided but, as discussed in point 4.4, acoustic backscatter is used as a surrogate for relative biomass. No tests were carried out to verify this assumption but multi-frequency data with appropriate biological sampling could help to achieve this. A multi-frequency difference approach was used to infer that for similar frequency differences similar species composition were present and therefore relative volume backscatter would be a surrogate for relative biomass. This represents a first step in the process but must be complemented with more targeted fine scale biological/acoustic/optical sampling for verification.

The software was used to compare frequencies and given the high noise of the data large amounts (not quantified) of data needed to be corrected or rejected see point 3. When comparing frequencies over large depth ranges the influence of noise and absorption variability needs to be assessed and tested and limits to the depth of comparisons demonstrated.

Some particular issues were raised:

- When displaying frequency difference echograms appropriate colour scales need to be used to highlight differences appropriately, the currently used colour scale is not appropriate and an alternative was suggested.

- School detection algorithms were used to separate diffuse from concentrated scattering regions. There needs to be tests on the influence of algorithm sensitivity to school size and outcome

4.6 *Evaluate whether environmental data are applied appropriately to obtain information on environmental effects on the distribution and biomass of micronekton.*

A clear strength of the acoustic work undertaken at the PIFSC is the integration of acoustics and environmental data at large and fine scales. This work has and will advance the scientific knowledge of this locally and globally important area. Integration of micronekton with temperature, salinity, chlorophyll, oxygen currents and water masses will help initialise, and assimilate ecosystem and CPUE driven assessment models. So far the work has developed hypotheses about the sources of primary production relevant to estimating micronekton density the prey of tuna. This work was written up with two papers in the literature and testable hypotheses proposed (Domokos *et al.*, 2007; Domokos, 2009). It is highly recommended that these hypotheses be tested in future years to develop predictive capability for the distribution and abundance of micronekton and by inference the impact on the tuna CPUE series in the American Samoa region and elsewhere.

It is recommended that the observational and process understanding gained from this work is incorporated into oceanographic and ecosystem models and further developed.

4.7 *Evaluate whether the adequacy, appropriateness, and application of oceanographic data and analytical methods used represent the best available science to characterize the environment and give recommendations for improvements.*

This is outside my field of expertise but based on my knowledge this appears to be at the forefront of experimental science integrating oceanographic variables with micronekton distribution and abundance. This work can be used to initialise ecological models linking the physics to fish (e.g. Fulton *et al*. 2005, Lehodey *et al.* 2008). Although it seems that some independent modelling and further experimentation is required to test proposed hypotheses and linking with oceanographic and ecosystem modelers would be useful in the future. Linking the experimental work with models would be a good step in the program. Links with international researchers (CLIOTOP) have been established and this along with other modelling efforts should be encouraged and continued.

4.8 *Evaluate whether the adequacy, appropriateness, and application of bioacoustics data in combination of trawl samples to estimate relative biomass and composition of the scattering layers (micronekton) represents the best available science and give recommendations for improvements.*

This was a glaring inadequacy of the methods used and greater effort needs to be applied to bring the work up to international best practice. As mentioned in point 4 the lack of appropriate biological sampling and species identification sampling is severely limiting the work.

Repeated from point 4.4, there appeared to be a systematic problem with deploying a net on the research vessel with ongoing mechanical failures during voyages cited. There is an urgent need to review the biological collection capability of the research vessel. In particular the following were discussed:

- Appropriate priority and personnel to ensure trawl equipment is functioning for a voyage
- Need for an opening and closing codend to sample distinct scattering layers.
- The need for lowered acoustic/optical sensing devices to complement species identification tasks.

There was not a clear resourcing path for this activity either through NOAA funded or university programs. This area requires some immediate attention to ensure the biological sampling, species identification and interpretation is matched with other components of the program. As discussed in point 12, it is recommended that a biologist join the team to carry out the necessary biological sampling and ecological interpretations.

4.9 *Give recommendations on the application of Movies+ "Inversion algorithm" to multifrequency acoustic data to estimate absolute micronekton biomass and composition.*

An inversion program may be appropriate if acoustic functional groups are homogeneous which seemed to be rarely the case for the organisms and spatial structures presented. Inversion from models of scattering relies on homogeneous scattering types with minimal mixing and assumes that the targets are appropriately represented by the models and frequencies used. Micronekton represent a complex scattering group with gas, fluid, shell and gelatinous organisms. Often it is useful to group species into acoustic functional groups based on their scattering type and scattering dominance. A major complication is resonance scattering of an organism's gas-bladder that can change in resonance frequency depending on depth. Another complication is that an inversion may not be unique depending on the frequencies used and scattering types encountered. For the frequencies used here 38 kHz and 120 kHz the dominant scattering probably comes from gas filled swim bladders. Estimating the biomass of the gas-bladdered fish may be a good first step given their acoustic dominance at the frequencies used.

In the case of general micronekton biomass estimation, a mixed methodology approach is suggested using both inverse and forward solutions. For example, identify key scattering types based on school, scattering layers and frequency differences. Target these with depth stratified trawls, acoustic and optical samplers to identify the species (or functional groups) for both day/night samples. Develop models of the main species (functional groups) and how they are influenced due to depth orientation, size and when organisms are mixed. Test assumptions with targeted biological/acoustic/optical sampling in regions of like frequency differences or acoustic group structures (e.g. schools).

4.10 *Evaluate whether the adequacy, appropriateness, and application of data used to estimate fish abundance represents the best available science and give recommendations for improvements.*

No data were presented on estimating fish biomass although experiments have been conducted to significantly advance this objective. It would be necessary to move from the experimental stage and analyse the surveys to produce a biomass estimate identifying all the sources of uncertainty. This represents a major task and needs to be clearly funded and placed in priority of other work.

It was not clear how this objective fitted with other work or integrated with other divisions and the priority and resources that could be allocated. Some points to consider if the program of work was to look at estimating biomass of local tuna, snapper stocks and large bottom fishes in FRA's:

- Priority of the work and potential uptake of results
- Objectives of the survey and need for complementary data (e.g. proportion of stock sampled, species identification and biological sampling)
- Planning of the resources required to carry out the work and need for ancillary data.
- Biological sampling and or species identification (optical etc) is a key requirement and needs to be carried out as part of the program of works.
- How it integrates with other stock assessment advice or integrated within the stock assessment model.

- Checks on methods used and sensitivity to assumptions

A clear benefit of acoustic surveys is the potential for an absolute snapshot of fish abundance that can be used to test assumptions in the usually relative biomass estimates derived using stock assessment models.

4.11 *Evaluate whether the science reviewed is considered to be the best scientific information available.*

Two peer reviewed papers were provided for detailed analyse where the approach was original and overall findings appeared to be supported with the methods used and results obtained (Domokos *et al.* 2007 and Domokos 2009). A clear strength of the work was the linking of oceanography to ecology using multiple data sets and in particular the use of acoustic backscatter. Whilst a clear weakness was the limited biological sampling and the assumption that acoustic backscatter is a surrogate for biomass without verification.

Some specific issues noted in the papers that warrant further attention:

- Variable use of NASC without appropriate referencing to a depth layer was confusing throughout the paper and limits the utility of the information to other studies.

- The lack of biological sampling and untested assumption that acoustic backscatter was a surrogate for relative biomass change without verification.

4.12 *Recommend future direction and improvements to the science reviewed.*

Whilst the review has highlighted some issues with work to date this should not detract from the very good work that has been conducted with minimal resources. Significant advances have been made in understanding the application of acoustic methods in difficult (poor data quality) and challenging open ocean and multi-species environments. Improvement to the science methods are discussed in detail in the previous points and many of the issues would be assisted by a focus of the program with appropriate resourcing by staff, equipment and collaboration.

It is suggested that the program and division focus on the key aspects of the work required and develop project plans that factor all the resources required to complete the objectives. In developing future plans it should be considered what the impact and potential uptake of the work will be in 5, 10 to 15 year horizon. Past work areas have been spread between open ocean micronekton studies to more recent biomass assessments of tuna on a seamount, juvenile snapper and fish within a fisheries protected area.

- stock assessments of shallow shelf species (snapper and large fishes FRA banks)
- stock assessment of tuna – seamounts
- mid-trophic ecology and linkage with tuna CPUE standardisation – climate variability and potential adaptation strategies

From the work presented it is clear that the micronekton / oceanographic research and linkage with tuna has high profile within a clear ecosystem approach framework and takes advantage of the unique position of PIFCS in the region. Further, it is acknowledged that the PIFSC has responsibility for an ocean area the same size as the entire U.S. exclusive economic zone, as well as the high seas of the central and western pacific. This large ocean zone with its living resources will require some unique science methods to be developed and applied (Handegard *et al.*, 2010). A small team working in this area could make a large impact nationally and internationally. The micronekton studies appear to fit well with both national and international ecosystem based management objectives in the medium to long term.

To ensure a micronekton research focus can achieve its objectives there needs to be appropriate resourcing of science effort. As a minimum to perform work in this area covering oceanography- acoustics and biology subject to budgetary constraints would include as a minimum:

Staffing:

- Research scientist: (project leader acoustics/oceanography)
- Technical support (gear, electronics, acoustic processing)
- Biologist to be responsible for sampling and interpretation of species ecology life history and associated reporting.

Equipment and maintenance:
Acoustics:

- research vessel with vessel mounted multi-frequency acoustics
    - Need to fix aeration noise as top priority as it limits entire program and use of asset for any other work.
    - Unable to use platform for routine acoustic logging on other programs represents a significant missed opportunity.

- Investigate purchase of battery powered system to vertical lower through water column (with optics). Removes problems with variable sampling volume for TS investigations (e.g. Kloser *et al.,* 2009):

- Given the large EEZ territory of PIFSC mandate investigate novel methods for acoustic monitoring and interact with global initiatives (Handegard *et al.*, 2010).

Biological:

- for ecological, species identification and in situ TS measurements:

- Trawling on research vessel reported to be not functioning and poorly maintained over a number of years affecting the science missions.

- Need for multiple cod-end system to sample discrete depths or unique use of optics in the codend. (e.g. Kloser *et al.*, 2009)

- Profiling system of optics and acoustics “TS Probe” as above. (Ryan *et al.*, 2009)

Collaboration:

- Local collaboration between programs and within the University
- National collaboration with NOAA’s Advanced Technology Group and sourcing equipment identified above. Exchange of other acoustic experts within NOAA to be involved with experiments.
- Internationally exchange with other institutes by visiting science or post doc. funding schemes
- Maintain international best practice with regular attendance at the ICES WGFAST meetings.

- Interaction with relevant international meetings and in particular the MAAS working group within CLIOTOP IMBER (e.g. Handegard *et al.*, 2010).
- Facilitation of workshops in a specialist area such as micronekton fish density and biomass.

4.13 *Describe briefly the panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.*

The review was well facilitated and I thank Reka Domokos for her detailed preparation of material. I noted the following points that ensured all relevant material was obtained during the meeting:

- commenced with a good overview of program and drivers
- very open and well facilitated discussions
- access to all levels of management with important attendance of senior management at the end of the meeting
- well described need for the review and welcoming of feedback
- whilst not initially obvious it was important to attend a meeting to understand the local environment and the constraints that this imposes on application of methodologies; this would not be possible with a remote review of papers
- the detailed discussions with directors and research members highlighted how this review was targeted to help plan future directions with less emphasis on a detailed critic of past endeavours.
- in light of the previous point the review panel discussed how best to facilitate future directions and our discussions, reporting and recommendations be targeted to facilitate this.

5. CONCLUSIONS AND RECOMMENDATIONS IN ACCORDANCE WITH THE TORS

A clear strength of the acoustic program being conducted at the PIFSC was the study of micronekton integrating the acoustic and oceanographic data. This program has a clear linkage with the estimation of tuna availability at large and fine scales and takes advantage of the unique position and expertise of the PIFSC in the region. A small team working in this area could make a large impact nationally and internationally. Applications and uptake of biomass projects for snapper and tuna are also possible but should be well resourced with a clear path to uptake. The priority of this work and its potential impact should be carefully assessed and placed in context with other priorities.

To make an impact both nationally and internationally on the distribution and abundance of micronekton in relation to tuna fisheries and climate change requires planning and resourcing of both equipment and people.

There are clear problems with equipment when undertaking acoustic and biological sampling programs on the NOAA ship *Oscar Elton Sette*. A priority should be placed on fixing the acoustic interference that would greatly increase the data quality and reduce data processing time. It should be possible if the acoustic interference is fixed to collect acoustic data routinely on all trips to improve spatial and temporal coverage. Equally the ongoing problems experienced with operating trawl equipment on the vessel needs to be rectified. The lack of appropriate biological sampling in the program will be a major problem when proving up the methods and creating a time series. The type of biological sampling needed to cover a range of sizes and types from gelatinous to gas bladdered small fishes should also be reviewed where inclusion of acoustic and optical sensors need to be considered. Inclusion of depth stratified trawling methods and optical and acoustic sensors should be sought from NOAA's Advanced Technology Group or elsewhere.

Another clear need was for appropriate human resources to be placed on the tasks. It is a credit to Reka that she has been able to achieve some major advances in the applications but her resources appear to be spread very thinly. To appropriately tackle the micronekton studies will require adequate resources and it is suggested this would take:

- Research scientist: (project leader acoustics/oceanography)
- Technical support (gear, electronics, acoustic processing)
- Biologist to be responsible for sampling and interpretation of species ecology life history and associated reporting.

On the application of acoustics it is important that Reka engages with national and international expertise and mechanisms are found to support that. A clear first step is regular attendance at the ICES working group on Fisheries Acoustic Science and Technology. To support a bio-acoustic program, it will be important to link with other researchers and disciplines within NOAA and the University of Hawaii as well as internationally.

APPENDIX A: BACKGROUND DOCUMENTS PROVIDED:

Overview of active acoustic Work of Progress at the PIFSC, 13 pages (about half of them figures).

Domokos, R. (2009) Environmental effects on forage and longline fishery performance for albacore (Thunnus alalunga) in the American Samoa Exclusive Economic Zone. Fisheries Oceanography, 18, 419-38.

Domokos, R., Seki, M.P., Polovina, J.J., and Hawn, D.R. (2007) Oceanographic investigation of the American Samoa albacore (Thunnus alalunga) habitat and longline fishing grounds. Fisheries Oceanography, 16, 555-72.

Doray, M., Petitgas, P., and Josse, E. (2008) A geostatistical method for assessing biomassof tuna aggregations around moored fish aggregating devices with star acoustic surveys. Canadian Journal of Fisheries and Aquatic Sciences, 65, 1193-205.

Foote, K.G., Knudsen, H.P., Vestnes, G., MacLennan, D.N., and Simmonds, E.J. (1987) Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Cooperative Research Report, International Council for the Exploration of the Sea 144 1–69.

Fulton, E., Smith, A., and Punt, A. (2005) Which ecological indicators can robustly detect effects of fishing. ICES J. Mar. Sci, 62, 540-51.

Handegard, N.O., Demer, D.A., Kloser, R.J., Lehodey, P., Maury, O., and Simard, Y. (2010) Toward a Global Ocean Ecosystem Mid-Trophic Automatic Acoustic Sampler (MAAS). In Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society, 2.

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Knudsen, H.P. (2009) Long-term evaluation of scientific-echosounder performance. Ices Journal of Marine Science, 66, 1335-40.

Lehodey, P., Senina, I., and Murtugudde, R. (2008) A spatial ecosystem and populations dynamics model (SEAPODYM) - Modeling of tuna and tuna-like populations. Progress in Oceanography, 78, 304-18.

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APPENDIX B: STATEMENT OF WORK

Statement of Work for Dr. Rudy Kloser (CSIRO)

External Independent Peer Review by the Center for Independent Experts

Fisheries Oceanography Acoustics Applications in Western Pacific

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: PIFSC is conducting a broad range of fisheries applications using active acoustics that have generated a good number of publications. The active acoustic program commenced in 2004 at the center and utilizes two Simrad EK60 systems. One system is installed on the NOAA ship *Oscar Elton Sette* with a home port in Pearl Harbor, while the other one is operated on a small (21-foot) boat, the *Kumu*. The *Sette* is equipped with hull-mounted, split-beam, 7° beam-width transducers, originally operating at the 38 and 120 kHz frequencies. During the FY08 drydock period, an additional 70 kHz transducer was installed, bringing the number of frequencies to three. The Sette is slated to receive the full suite of the split, narrow-beam frequencies available from Simrad with the installation of an 18 and a 200 kHz transducer during the next drydock period, scheduled for FY11. The small boat, *Kumu,* is equipped with a portable split-beam system, operating at 38 and 120 kHz frequencies. Acoustic data obtained by these systems are pre-processed using Echoview software then further processed and analyzed using Mathworks' Matlab software. IRD's Movies+ software has also been used occasionally for processing acoustic data. The Movies+ software will be utilized more in the future as the availability of more frequencies will make identification of organisms and absolute biomass estimates possible by Movies+ "inversion algorithm", not available in Echoview.

Presently, there are two major foci of this work. One is the study of micronekton within the tropical and subtropical Pacific Ocean. Micronekton are smaller organisms that are forage for our economically important fishes, such as tunas. To characterize micronekton biomass, composition, and spatiotemporal distribution, acoustic data is collected on board the *Sette*, typically 24-34 days per year. To ground-truth the acoustics data thus allowing for better interpretation, micronekton samples are collected via a large trawl. Work has been conducted at American Samoa, within the Hawaiian archipelago, in the north central Pacific, with the Mariana Islands scheduled for FY10. During all cruises, the physical environment is monitored via CTD casts (temperature, salinity, oxygen, and chloropigments) and an Acoustic Doppler Current Profiler (ADCP) down to 1000 and 700-800 m, respectively. Using *in situ* environmental data in combination with remotely sensed data, such as satellite altimetry and ocean color, the effects of the changing environment on micronekton are investigated.

Another focus of the active acoustic program is the development of a fisheries independent method to study commercially important fish with management issues. As for micronekton, both *in situ* and satellite data are used to examine the effects of the environment on these fish. One example of these organisms is bigeye tuna. A relatively homogeneous area occupied with mostly bigeye was selected for this study: Cross seamount, located in the Hawaiian archipelago and exploited by the local fishery. As the acoustic characteristics of bigeye tuna are well known, this effort focuses on the *in situ* acoustic identification of bigeye tuna and the development of a study design to convert the 2D data collected along transects to a 3D map. The results of this study are so far very promising as determined by acoustics data collection and simultaneous handline fishing. Another example of this type of work is the development of a time-series of bottom fish in Hawaii, heavily targeted by the local fisheries. For this work, both the *Kumu* with the portable acoustics system and the *Sette* are utilized. Using the *Kumu*, *in situ* acoustic target strength measurements with simultaneous video camera recordings were conducted on juvenile pink snappers in an insular nursing area, as well as a time-series is being developed of their biomass along transect lines In the nursery grounds. In addition, a time-series is being developed on the biomass of adult bottom fish with the aid of simultaneous "Botcam" video recordings.

Future plans include obtaining more acoustic data on micronekton at different regions within the Pacific basin to develop an understanding of large-scale differences in biomass, composition, and movement patterns of micronekton. The development of fisheries independent methods to produce biomass time-series of economically important fish and the study of the effects of environmental factors is expected to continue. Acoustic data will be collected at various seamounts and their effects on micronekton and fish will be examined. This work will enable us to have a better understanding of the processes affecting micronekton and fish at seamounts, as seamount environments are known to aggregate these organisms. With the development of new projects, the presently one-person "program" should also increase.

Due to the applied nature of this work, a thorough review of the approach would be justified. Further, this program would greatly benefit from a review because of the isolation it faces, as no one else is using this method in the state of Hawaii. A review would be additionally beneficial as this program faces special challenges due to the highly heterogeneous nature of tropical and subtropical environments, making acoustic identification of organisms difficult.

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 CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have working knowledge and recent experience in the application of active fisheries acoustics, and it is desirable to have experience with the acoustic processing software including Echoview and Movies+ and the application of acoustics to sampling subtropical micronekton and tuna. At least one reviewer should have expertise in the application of acoustic fish surveys in stock assessment. 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 at the Pacific Islands Science Center in Honolulu, Hawaii during 7-9 July, 2010.

Statement of Tasks: Each CIE reviewers 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/sponsor.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.

Tentative list of background documents:

1.) R Domokos, M.P. Seki, J.J. Polovina, and D.R. Hawn. Oceanographic investigation of the American Samoa albacore (Thunnus alalunga) habitat and longline fishing habitat. Fisheries Oceanography, 16:555-572. 18 pages.
2.) R. Domokos. Environmental effects on forage and longline fishery performance for albacore (Thunnus alalunga) in the American Samoa Exclusive Economic Zone. Fisheries Oceanography, 18:419-438. 20 pages.
3.) Overview of active acoustic Work of Progress at the PIFSC, 13 pages (about half of them figures).

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.

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.

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 at the Pacific Islands Science Center in Honolulu, Hawaii during 7-9 July 2010.
3) At the Pacific Islands Science Center in Honolulu, Hawaii during 7-9 July 2010 as specified herein, and conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than 23 July 2010, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, David Die, 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.

4 June 2010	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
18 June 2010	NMFS Project Contact sends the CIE Reviewers the pre-review documents
7-9 July 2010	Each reviewer participates and conducts an independent peer review during the panel review meeting
23 July 2010	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
6 August 2010	CIE submits CIE independent peer review reports to the COTR
13 August 2010	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

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 COTR within 10 working days after receipt of all required information of the decision on substitutions. 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) Each CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) Each 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:

William Michaels, Contracting Officer's Technical Representative (COTR)
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1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
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Key Personnel - NMFS Project Contact:

Jeffrey Polovina, Jeffrey.Polovina@noaa.gov
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Phone:808-983-5390

Dr. Reka Domokos, Reka.Domokos@noaa.gov,
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Phone: 808-983-5368

Annex 1: 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 shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

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.

Annex 2: Terms of Reference for the Peer Review Fisheries Oceanography Acoustics Applications in Western Pacific

1) Evaluate whether the acoustic system is calibrated appropriately for high-quality data collection.

2) Evaluate whether surveys are designed appropriately for estimating relative biomass of top predators, such as tuna from active acoustics data.

3) Evaluate whether active acoustics data are pre-processed appropriately using Myriax Echoview Software for estimating relative biomass of top predators, such as tuna.

4) Evaluate whether surveys are designed appropriately for estimating relative biomass of micronekton, forage for top predators, from active acoustics data.

5) Evaluate whether active acoustics data are re-processed appropriately using Myriax Echoview Software for estimating relative biomass and composition of micronekton.

6) Evaluate whether environmental data are applied appropriately to obtain information on environmental effects on the distribution and biomass of micronekton.

7) Evaluate whether the adequacy, appropriateness, and application of oceanographic data and analytical methods used represent the best available science to characterize the environment and give recommendations for improvements.

8) Evaluate whether the adequacy, appropriateness, and application of bioacoustics data in combination of trawl samples to estimate relative biomass and composition of the scattering layers (micronekton) represents the best available science and give recommendations for improvements.

9) Give recommendations on the application of Movies+ "Inversion algorithm" to multifrequency acoustic data to estimate absolute micronekton biomass and composition.

10) Evaluate whether the adequacy, appropriateness, and application of data used to estimate fish abundance represents the best available science and give recommendations for improvements.

11) Evaluate whether the science reviewed is considered to be the best scientific information available.

12) Recommend future direction and improvements to the science reviewed.

13) Describe briefly the panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

Annex 3: Tentative Agenda

Fisheries Oceanography Acoustics Applications in Western Pacific

Pacific Islands Fisheries Science Center, Honolulu, Hawaii

7-9 July 2010

Presentations:
Overview of center's objectives and challenges using active acoustic data.

Acoustics data to filter out micronekton, estimation of relative density and biomass, and usage of multifrequency for relative composition estimates.

Use of oceanographic data in combination of acoustics

Give example: American Samoa work (present both papers) and Cross Seamount work. Also, present short results from SE 09-02 (TZCF)

Present forward/backward method to estimate micronekton biomass using trawl samples. Discuss problems with trawl samples (biases).

Present Waianae study for intercomparisons of acoustics and gear as example of biases and problems with trawl samples.

Acoustic data to filer out fish schools based on their characteristics (examples Penguin Banks and Cross)

Acoustic data to identify bigeye tuna based on prior knowledge and estimation of biomass of a school.

Present Cross Seamount work

Acoustic data to identify bottom fish (Penguin Banks) based on general knowledge of expected TS and size of fish

Present preliminary results

Survey design to estimate biomass – limitations of Sette (noise problem)

Give theory and how to apply but we'd need to fix the noise problem to cover larger area in a shorter time.

Simultaneous use of acoustics and video recordings: Kaneohe Bay (Kumu) work

Present results of Kumu work

Simultaneous use of acoustics and Botcam work (Penguin Banks)

Present Penguin Banks work

Point of contact for reviewer security & check-in: Dr. Reka Domokos, Pacific Islands Science Center, Reka.Domokos@noaa.gov

APPENDIX C: PANEL MEMBERSHIP

Dr Rudy Kloser
Dr Gary Melvin
Dr Yvan Simard

Management staff

The science director Dr Pooley opened the meeting and provided an overview of the context of the work within the PIFSC. Dr Jeffrey Polovina head of the Ecosystem and Oceanography Division outlined the fit of the acoustics program within the divisions. At the end of the meeting Dr Jeffrey Polovina and Dr Michael Seki were available to discuss and clarify the program fit and future needs based on issues identified during the previous two day meeting.

During the two days of meetings Dr Reka Domokos overviewed the work conducted within the acoustics program through 7 projects.

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