External Independent Peer Review by the Center for Independent Experts

Fisheries Oceanography Acoustics Applications in Western Pacific

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Executive summary

The fisheries acoustic research conducted at Pacific Islands Fishery Science Center (PIFSC) in the last six years to explore the possibilities of this technology for obtaining fishery independent estimates of relative biomass of top predators such as tuna, and studying their forage micronekton and the relation with their environment was reviewed. This research included seven projects with various objectives that were conducted in different parts of the Pacific Ocean.

A considerable amount of work was accomplished by the research scientist in charge. Some results were published in peer-reviewed papers. The analysis of the rest of the results is ongoing. The clear strength of this research is to always integrate the oceanographic context in analyzing the observations on fish and micronekton distribution and biomass, in an effort to get a comprehensive understanding of the functioning of the ecosystem in relation with environmental forcing. Difficulties in acquiring high-quality acoustic data with the research vessel were encountered, which significantly complicated and lengthened the data processing while degrading the quality of the results. The required ground-truthing of the acoustic data with direct sampling of the diverse fish community with trawls and other gears was very limited. Several acoustic processing techniques were explored, and the present review highlights some of their limitations for achieving the targeted objectives. Recommendations for improvements and future directions are provided. The general recommendations are summarized below.

1) **Research direction focus**: A research direction should be chosen to focus the limited efforts and support towards a research theme where a small PIFSC team could develop the needed skills and expertise to make a significant contribution in the next 10-20 years by exploiting the advantages PIFSC location in the middle of a large ocean ecosystem and the strength of the local expertise. A research program focusing on the oceanography and ecology of the forage micronekton targeted by top predators appears an obvious theme which could have a large scale impact.

2) **Staffing for a minimal research team**: It is unlikely that all the work and expertise required for performing in this complex and multidisciplinary research field can be covered by a single person. The minimal operational unit is three trained persons, one technician, one biologist, and one acoustics and oceanography research scientist. It is therefore recommended to add complementary permanent staff of two persons, one technician and one biologist/ecologist to the present single-person team.

3) **Isolation:** Fisheries acoustics is a rapidly developing science involving several levels of technical difficulties. The ICES WGFAST is an international group of experts which meets annually to discuss the current developments in this field and coordinate

collaborative efforts to address common issues. It is therefore strongly recommended that the PIFSC acoustic research scientist join the WGFAST community and receive adequate support to participate to its annual meetings.

4) **Collaboration:** To further break the isolation, and widen the resources and expertise pool for progressing more rapidly, it is suggested to enhance the collaboration with complementary research teams at national and international levels, possibly by a visiting scientist program.

5) **Equipment:** Several problems were encountered with the equipments, and additional equipments are needed to cover data gaps required to adequately apply recommended standard protocols and to complement the data sets for a more complete characterization of the ecosystem. It is therefore recommended to make all efforts to solve the equipment problems encountered and to take advantage of all opportunities to acquire additional equipments.

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Background

This review of Fisheries Oceanography Acoustics Applications in Western Pacific of the Pacific Islands Fisheries Science Center (PIFSC) of National Marine Fisheries Service (NMFS) was conducted at the request of the Center for Independent Expert (CIE) for NMFS Office of Science and Technology. The statement of work (SoW) and terms of references (ToR) for this review are given in Appendix 2.

Description of the individual reviewer's role in the review activities

The reviewer's role for this independent review was to act as an expert in fisheries oceanography acoustic application to evaluate the documents presented for the review as listed in appendix 1. The reviewer cumulates 25 years of experience in this research field after his PhD degree in biological oceanography from Laval University, Qc, Canada. He authored 46 papers peer-reviewed Journals, 67 other publications and reports, 4 software and R&D tools, and he presented more than 250 communications in this general research field. He also trained 16 graduate students and Postdocs.

Summary of findings for each term of references

This section summarizes the findings as requested for each term of references, highlighting the strengths and the weakness of the research conducted and providing recommendations when appropriate.

1. Acoustic system calibration

ToR: "Evaluate whether the acoustic system is calibrated appropriately for high-quality data collection".

The calibration of the Simrad EK60 multifrequency split-beam system was performed with a calibration sphere with known TS as recommended in fisheries acoustic protocols (Simmonds and MacLennan 2005)[1], using the Simrad ER60 single target/calibration software. The calibration sphere was deployed at a range of about 20 m or more and the sound speed and absorption coefficient of the environment were properly set from CTD (conductivity, temperature and depth) profiles. The calibration was performed for the power and pulse duration settings used for each during the surveys. The beam was uniformly scanned with the sphere with more than

[1] Cited references are given in the final section of this report

200 data points, using their rms deviation from beam models as good fit criteria. The objective was to determine the Sv gain and Sa correction required by the Simrad ER60 data acquisition software. The beam angle parameters were kept at the factory values provided by Simrad. The calibration of the 200 kHz frequency of the EK60 system used aboard the *Kumu* allowed the operators to detect a problem in its functioning. Calibration was done about once a year.

There was some questioning during the review concerning the adequacy of the estimated equivalent beam angle given that the calibration temperature is quite different from that used in Norway at Simrad factory to provide the transducer properties. Such calibration details are presently under review by the SGCal study group of the Fisheries acoustics Science and Technology Working Group (WGFAST) of the International Council for the Exploration of the Sea (ICES). It is therefore recommended to refer to the ongoing work and guidelines of this expert group for these questions. SGCal reports to the WGFAST at its annual meeting and its reports of activities are posted on ICES web site (ICES 2009).

In conclusion, ***the acoustic system appears to have been calibrated appropriately for high-quality data collection***, using recommended standard protocols in fisheries acoustics, and following the procedure and software tools offered by the equipment manufacturer. Ideally, a calibration should be done for each survey, but consistency of the calibration over time showed that the calibration results were replicable, indicating some stability over time as expected from properly working systems.

2. Survey design for estimating relative biomass of top predators

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

Six different research projects were carried on since 2004. They were conducted in different areas: the American Samoa, for which two review papers were provided, the CNMI & Guam, the Transition Zone Chlorophyll Front (TZCF), the Penguin Banks, Kaneohe Bay and Cross Seamount of the Hawaiian Archipelago, which were summarized by PowerPoint presentations to the review panel. These projects pursued different objectives. All were more exploratory oceanographic and ecosystem research rather than routine application of fisheries acoustic methodology for specific fish stock biomass assessment. The protocols for fish stock assessment and fisheries acoustics methods for achieving this latter goal are well described in literature (Simmonds and MacLennan 2005 and ref. therein) and include dedicated sampling strategies (e.g. Cochran 1977, Thompson 1992) to estimate the target density and its confidence interval over a given area. None of the two review papers provided pursued this objective. The three Hawaiian Island Archipelago projects partly tracked such objectives of relative density estimation. They include some aspects of sampling design, but none adopted the required protocols for accurate relative biomass assessment of top predators, as interpreted for stock assessment. Therefore, ***we can say that the surveys were not designed appropriately for estimating relative biomass of top predators***. However, efforts along this direction were notable in the Kanehole Bay juvenile opakapaka, Cross seamount bigeye tuna, and Penguin bank bottom fish projects.

If estimating the relative biomass of top predators in a given area is an expected outcome of a survey, it is recommended to fully implement the fisheries acoustic methodology developed for this task (Simmonds and MacLennan 2005, and ref. therein). For the survey design, different degrees of difficulty are encountered depending on the targeted estimate, the complexity of the local acoustic backscatterer community and environment, the sampling constraints and conditions of realization. The requirements include:

1) the definition the estimated quantity looked for: type of estimate[2], metrics, species, boundaries of the 2D or 3D estimation domain;
2) the determination of the proportion of the available effort to allocate to (a) the acoustic sampling and (b) to the ground-truthing of the targeted and non-targeted species by direct sampling (e.g. Massé and Retière 1995) ;
3) the selection of a survey design strategy for the acoustic sampling that is adapted to the targeted estimate and sampling constraints among design-based, model-based or adaptive sampling strategies (e.g. Petitgas 1993, Simmonds and Fryer 1996, Thompson and Seber 1996, Rivoirard et al. 2000, Doray et al. 2008);
4) the selection of a strategy to minimize the effects of main sources of variability and error for both the acoustic and ground truth samples (e.g. Simard and Sourisseau, 2009) such as fish identification, diel changes in composition, distribution, tilt angle and TS, or migrations in/out of the estimation domain during the survey.

If the estimate must include a map of the quantity looked for, the design chosen in above point (3) must accommodate this constraint. Uniform sampling with parallel line transects crossing the direction of maximum variance (e.g. across bathymetric contours, flow directions), with effort allocated according to a stratified scheme when needed, is then the appropriate design. When the quantity is strongly correlated with external variables available over the estimation domain, for instance bathymetry or synoptic satellite imagery, it might be advantageous to incorporate them in the estimation and mapping models, such as multivariate geostatistical models like kriging with external drifts and co-kriging, including conditional simulations (cf. Chiles and Delfiner) or other multivariate spatial estimation models.

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[2] E.g. estimate of total biomass estimate, estimate of partial biomass exceeding a given density threshold, representativeness of the estimate (local or constant fraction of a larger regional stock)

From the research projects presented, it appears that the above four points were not sufficiently considered for designing the surveys, if estimating top predator biomass was there objectives, which does not appear to be the case as multiple objectives were tracked simultaneously, with a strong emphasis to understand the relationship between the distributions of the acoustic backscatterer with the environment. Nevertheless, it was clear that a large diversity of backscattering sources was present in all study areas, and the ***effort allocated to ground-truthing the acoustic data was insufficient***. It is therefore recommended to allocate more effort to validate the acoustic data using various gears (see ToR 4). The survey designs adopted for acoustic transects for the three Hawaiian Islands Archipelago projects were to conform to common systematic estimation design with parallel or zigzag transects uniformly covering the study areas. A star sampling design was used for Cross seamount. These sampling designs allow unbiased estimation of acoustic quantities over the study areas using model-based estimation schemes. In addition, they allow optimal mapping over the study areas. They, therefore, appeared well adapted to comply with the multiple objectives of the survey, assuming all other of variability mentioned in above point (4) are controlled. This was not necessarily always the case, notably for 24 h/day surveys, because of the diel changes in several characteristics of the backscatter community in response to diel vertical migrations (DVM), which are convoluted with the ship track over the study area.

The acoustic transect design for the other projects were more opportunistic or adaptive with the oceanographic objectives of the survey, such as chasing the effect of eddies and frontal boundaries on the distributions of the acoustic backscattering community. The main advantage of this oceanographic sampling strategy is the detailed overlay of the acoustic data with the environment characteristics, providing the fundamental information required to adequately feed ecosystem functioning models linked with climatic information. The design seemed therefore appropriate for this objective, when the convoluted spatial/temporal variabilities are properly taken into account in data processing and interpretation.

3. Pre-processing for estimating relative biomass of top predators

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

First, it must be mentioned that the review document and the presentation of the research projects clearly pointed out the poor quality of the acoustic data acquired from the *Sette*. Strong interferences from transducers aeration by air bubble flows along the ship hull and background noise were systematic at operational survey speeds under the particularly rough sea states of the survey areas. The need to first filter out these interferences before using the data has considerably increased the data processing requirements. Several algorithms implemented in Echoview were used for that filtration. All require the tuning of a set of parameters to get optimal results for the ranges of conditions encountered during the survey. The result is that gaps of missing data, of variable lengths and locations, are common along the acoustic transects, which could eventually lead to estimation biases, besides cancelling a substantial portion the effort and investment in the survey. The cumulative effect of these filters is also to alter the original acoustic data, which can impact the results of further processing steps. For example, the noise subtraction algorithm sometimes appeared to have significantly affected the signal strength in different proportions at different frequencies. The application of multifrequency classifiers may then be affected, notably in areas of low signal-to-noise ratios (SNRs). Since SNR is range dependent, a classification bias can occur with range. Similarly, the noise filtration may affect the performance of the single target tracking algorithm and the accuracy of the in situ TS estimation (cf. Ona 1999).

Fisheries acoustics processing software such as Echoview, Movies+ and others are commonly used by scientists in this research field, notably to provide relative estimates of fish biomass. They offer several algorithms to process acoustic data for different purposes. However, for adequate interpretation of the results, none can be used without a thorough understanding of their effects on the end results of the processing chains.

The two peer-reviewed papers did not involve estimation of top predator relative biomass. The research projects involving relative estimates of top predator densities were based on tracked echo-trace densities in a depth stratum based on the TS range of the target species. Although the Echoview tracking algorithm was fed with parameters supported by the knowledge of the target fish distribution on the vertical and their expected TS range, ***this echo-counting like approach suffers from the limitations of in situ TS detection and tracking***. Among the interferences to consider we have the effects of thresholding, variable SNR with range, single and multiple target distributions, fish tilt angles and behavior. There is also no guarantee that the species classification from a range of TS values excludes other possible species, especially in an ecosystem otherwise characterized by a high diversity. Possibilities of biases are therefore non negligible.

As a first recommendation for this ToR, ***it is strongly recommended that the ship noise problem is first corrected*** in order to bring the acoustic data to the standard quality level expected from fisheries research vessels. This will reduce need for the data filtration and their adverse impact on further processing steps for fish biomass estimation. It is not recommended to envisage the alternative of mounting the transducers on a towed body, because of the additional operation and maintenance difficulties relative to a hull mounted system, and the usual need to exclude the towed platform during trawling for ground-truthing samples. The effect of the bow thruster tunnel on the generation of the air bubbles flowing at the transducer faces should be investigated and solutions developed to correct the problem eventually. The possibility of extending the transducer pod to deeper distances from the hull to clear the bubble flow should be envisaged, notably at the occasion of installing the coming new 18 and 200 kHz transducers, which will require a modification of the pod. Second, if biomass estimation of top predators is a survey objective, it is recommended that the methods for acoustically estimating rare top predators from diverse co-occurring backscattering sources in the same environment (e.g. Doray et al. 2008, 2009) are reviewed for comparing their relative advantage and drawbacks. This difficult task could eventually be submitted to the ICES WGFAST as a research topic.

4. Survey design for estimating relative biomass of micronekton forage for top predators

ToR: “Evaluate whether surveys are designed appropriately for estimating relative biomass of micronekton, forage for top predators, from active acoustics data.”

The general comments and recommendations on survey design made for ToR 2 also apply to estimating the relative biomass of micronekton.

Because of the large diversity of scattering layers observed over the insonified water column and the strong diel pattern in distribution and aggregations, it ***appears essential to allocate more effort to validate the acoustic data for an eventual estimation of the relative biomass of micronekton***. Recognizing that efficient micronekton sampling represents a challenge for nets and trawls, various advanced optical and acoustic technologies could be explored as alternatives or in complement, keeping in mind that all sampling tools have their own efficiency and selectivity. Using opening/closing mechanisms in trawl cod-ends would improve the sampling efficiency and the sample resolution for better comparisons with the acoustic data. Optical or acoustic cameras (e.g. Didson imaging sonar) could be mounted on the CTD/Rosette to get validation samples of the scattering layers when profiling for environmental properties along the acoustic transects. Autonomous or cabled multifrequency echosounders are also used to get high-resolution data with constant sampling volumes throughout the water column, for a better identification of the composition of the scattering layers (e.g. Kloser et al. 2009). The deployments of moored or drifting autonomous acoustic systems could be advantageous to get more high-resolution information on the scattering layers and track their temporal changes, notably the DVMs, during surveys or on more permanent observatory systems in studied areas.

The sampling strategy for ground-truthing the scattering layers could take advantage of their DVM pattern, for identifying the composition of the different layers that were shown to migrate to and from the upper layer at different times, either by targeting the migrant layer or by tracking the changes in the composition of the surface layer at their respective arrivals and departures. Likewise, the allocation of the ground-truthing effort could take advantage of the observed multifrequency patterns in the surveyed area, to partition the effort between the scattering layers showing different multifrequency signatures (cf. ToR 9).

5. Pre-processing for estimating micronekton relative biomass and composition

ToR: "Evaluate whether active acoustics data are pre-processed appropriately using Myriax Echoview Software for estimating relative biomass and composition of micronekton."

If "estimating relative biomass and composition of micronekton" is interpreted as it usually is, in terms of weight per species/taxa per unit of volume or area, clearly, ***none of the projects presented achieved this task***. This would require knowing the contribution of the different groups to the estimated Sv or Sa, which implies that their TS vs. length relationships and their proportions are known, according to fisheries acoustic protocols as mentioned in ToR 2 (Simmonds and MacLennan 2005). When the problem can be simplified to single species/taxa with constant length-frequency and behavior, then the Sv or Sa metrics can be used as representing relative biomass. Ground-truth samples might reveal that this is possible for particular scattering layers.

As used in the reviewed projects, Sv or Sa are implicitly assumed to be proportional to biomass, and differences in multifrequency signatures to changes in the composition. This may be the case for some homogeneous scattering layers or on average for all the mesopelagic micronekton community, but this needs to be thoroughly documented. This represents substantial task, which can only be accomplished by investing substantial efforts to document the taxonomic composition, acoustic characteristics and distributional ecology of these mesopelagic micronektonic species. ***Since this cannot be done by a single person, it is recommended to add at least one biologist/ecologist to the team and foster collaborations with additional specialist to fill this information gap.***

The cautions raised in ToR 3 in applying the different algorithms provided by acoustic processing software tools as Echoview are still relevant here. The performance of the school/aggregate detection algorithm as function of several parameters such as the setting of the algorithm parameters, signal thresholding, SNRs, missed pings due to noisy data, variable pinging rates, range dependences of the volume sampled by the acoustic beams, their overlaps and the continuity of the echogram image, etc., must be evaluated. Some schools/aggregate seemed to have been missed or truncated in some cases. The interpretation of the aggregated Sv patches is not clear in a multispecies and strong environmental forcing context.

6. Environmental data analysis for effects on micronekton distribution and biomass

ToR: "Evaluate whether environmental data are applied appropriately to obtain information on environmental effects on the distribution and biomass of micronekton."

This is the strength and originality of the reviewed research. Understanding the links between the environmental characteristics and the distribution of micronekton was an evident preoccupation in all projects. Information from satellite imagery was properly used to get the regional environmental context, explore the applicability of physical models and the effects of particular persistent structures such as eddies, fronts and topographic interactions, to adequately interpret the finer scale measurements along the acoustic transects from multi-sensor CTD profiles and continuous current profiling from an Acoustic Doppler Current Profiler (ADCP). Additional sensors could be used to complete the description of the main characteristics of the environment that micronekton is responding to. These especially include the *in situ* light level in the wavelength band micronekton is sensitive to (as well as their visual predators) and which controls their DVMs. The zooplankton concentrations constituting their principal preys should also be targeted with additional sensors. The acoustic backscatter from the four beams of the ADCP could also be analyzed to get additional information on micronekton distribution and behavior, and the degree of homogeneity and patchiness of the scattering layers from tilted view angles.

This general physical-biological coupling approach to micronekton distribution and biomass is the type of information presently needed to feed basin-scale ecosystem models and document the links with climate variability and trends. ***It is therefore strongly encouraged to pursue this heuristic approach for a comprehensive understanding of the structuring role of micronekton in the functioning of the pelagic ecosystem up to top predators in future work***.

7. Environmental data adequacy and analytical methods to characterize the environment

ToR: “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.”

The term “best” is troubling here, and hopefully the answer is “no”, otherwise it would not be possible to improve the characterization and understanding of the processes. As mentioned in ToR 6, it is recognized that substantial effort has been put to this comprehensive characterization of the environment and relevant processes for micronekton and top predator distributions in all research projects. Some technical details concerning the construction and presentation of the figures were discussed during the review. The advantage of overlapping the physical and biological results on same maps to illustrate their coupling was highlighted.

Improvements for a comprehensive understanding and a validation of the interpretation would include some mesoscale modeling of the transport and aggregation of the micronekton using a ground-truthed 3D circulation model coupled with DVM biological models representative of the behaviors of the different scattering layers as observed in the field. Eventually, the strength of the links between the physical processes, the primary and secondary productions, micronekton and top predators could be tested by bringing additional information, notably on zooplankton abundance and distribution, and on micronekton diets. Small- and meso-scale studies at frontal boundaries and eddies should include some efforts to investigate the responses of micronekton to the gradients in the environmental characteristics.

8. Adequacy of bioacoustics data and trawl samples for estimating biomass and composition of micronekton

ToR: "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."

See responses to ToRs 4 and 5.

9. Recommendations for applying multifrequency inversion algorithms to estimate micronekton biomass and composition

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

The reviewed research did not include any application Movies+ inversion algorithm to multifrequency acoustic data to estimate absolute micronekton biomass and composition. The difficulty of using this software and its documentation was mentioned during the review. The software uses the best fits between the observed and modeled multifrequency acoustic signatures to propose a model for interpreting the acoustic data. The same cautions raised in ToR 3 and 5 for carefully understanding the principles and conditions of applications of the processing algorithms before using them are reiterated here, especially for such sophisticated classification approaches. They are strongly dependent on: accurate Sv measures at all ranges for all frequencies (taking into account the actual the sound speed and absorption profiles over the water column); SNRs; a homogeneous composition with a single scatterer type and size; and several other input parameters for the scattering models such as scatterers sound speed and density contrasts and tilt angles. This is also true for the forward problem, where the composition obtained from ground-truth samples, -which includes several sources of biases and errors-, is used as input to the scattering models to estimate the expected multifrequency signature of the community.

In a first step, it is suggested to use false color imaging and unsupervised clustering methods to partition the multifrequency acoustic data into a few groups sharing similar signatures for selected time periods in the diel cycle, to look at the most evident patterns and try to interpret and question them with the help of adequate ground-truth samples, as suggested in

ToR 4, and build a comprehensive understanding of the effects of all processing steps taking into account the inherent errors.

10. Adequacy of data and methods to estimate fish abundance

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

See responses to ToRs 1 to 5.

11. Contribution of the science reviewed

ToR: "Evaluate whether the science reviewed is considered to be the best scientific information available."

Only the two peer-reviewed papers provided can be evaluated for this ToR. The other research projects were ongoing activities for which preliminary results were presented during the review. As mentioned in ToR 6, the strength of the research is the integration of the acoustic observations in the global picture connecting to the basic physical oceanographic forcing processes related to water mass circulation and climate. These two contributions add to the knowledge on the functioning of the ecosystem of the American Samoa EEZ and provide the physical-biological context likely contributing to the distribution and aggregation of top predators such as tuna. This research will contribute to structure future work in this area as well as on oceanic top predator ecosystem.

The two published papers contained some errors and misuses even if they were peer-reviewed, notably for the labeling of some figure axes and units, power and pulse settings for the 120 kHz in 2007, the use of large sample volumes for analyzing the multifrequency signatures, interpretation of zooplankton exclusion from thresholding, equation for dSv, and typos. The separation of the day, night and twilight periods for the analysis was a proper choice to account for large variability in several acoustic and biological characteristics over the diel cycle due to DVMs.

12. Recommendation of future directions and improvements

ToR "Recommend future direction and improvements to the science reviewed."

Specific recommendations were presented within the responses to the above ToRs. This section now focuses on global recommendations for future directions and improvements of the research program in the context of the activities conducted in this research field in the world.

General recommendations:

1) **Research direction focus**: The reviewed research included several projects conducted over a short period of time by a single scientist. They were presenting different objectives comprising the estimation of distribution, composition and biomass of top predator and micronekton and their relation with the environmental characteristics. This allowed exploring the possibilities of present fisheries acoustics methodology to address a wide range of fisheries and ecosystem questions. The accomplishment is enormous considering the size of the team and the inherent difficulties associated with the technique and its implementation at sea. However this has stretched the efforts over the capacity limit of a small team to realized high-quality contributions in this specialized field requiring multidisciplinary expertise and adequate support. It appears important to ***move from this exploratory approach to a dedicated mid- or long-term research program that can make significant differences to fill the knowledge gaps in the next 10 or 20 years from now***, by choosing a research focus where the PIFSC can provide adequate and stable support to a small research team to develop and master the methodology and to pilot significant research projects. Because of the particular location of the PIFSC, the expertise of the research scientist, the international interest in oceanic top predators, the ecosystem approach to fisheries, and the impact of global climate change and adaptation, a research program focusing on the oceanography and ecology of forage micronekton appears an obvious theme which could have a large scale impact. Other themes incorporating physical and biological coupling, such as seamount dynamics, critical habitat descriptions, could also be interesting but would likely have a lesser international impact. In all cases, it appears crucial to choose a strong research direction where to focus the limited available effort given the operational constraints at PIFSC.

2) **Staffing for a minimal research team**: Performing in this multidisciplinary research field requires expertise and support in equipment installation and maintenance, in biology/ecology for sampling the diverse community of sound scatterers, and processing the samples and contributing biological information to the analyses, and in acoustic, oceanography and data processing, integration and interpretation. It is unlikely that all these tasks can be accomplished by a single person. Most institutions carrying on research in this field have dedicated supports involving teams composed of several trained technicians, professional staff and research scientists. To develop skills in this research field, improve the quality of the data, the completeness of the multidisciplinary results, and to be efficient in doing the research and publishing the results, ***it is recommended to provide more steady support to the acoustic and oceanography research scientist by adding one technician to care for the technical aspects of the equipment and data acquisition, and one marine biologist/ecologist to take in charge the deficient but needed biological sampling and the life history, biology and ecology of the micronekton and fish community and to contribute to the data processing***. This is viewed as a minimal operational unit for efficient fisheries acoustics

applications for ecosystem studies. Non-dedicated temporary support is inefficient because of the high learning curve in all three main disciplines involved in this specialized and complex research field and because of costly training.

3) **Isolation:** Fisheries acoustics is a rapidly developing science where improvements and innovations in equipments, data processing algorithms and application methodology are constant. This field has been developed by the cooperative efforts of an international community of scientists regrouped within the ICES WGFAST community. To benefit from this collective expertise for adequate application of the methodology, efficiently keep up with the regular advances and be inserted within a network of peer experts, it is important to participate and contribute to the activities of this international working group and attend its regular annual meetings. ***It is therefore strongly recommended that the PIFSC acoustic research scientist join the WGFAST community and receive adequate support to participate to its annual meetings.***

4) **Collaboration:** To further break the isolation, and widen the resources and the pool of expertise for progressing more rapidly, ***it is suggested to enhance the collaboration with complementary research teams at national and international levels,*** for example with NOAA advanced technology group for improving the ground-truthing of the acoustic data, with experts in micronekton taxonomy, life history and behavior, and with other acoustic experts pursuing similar research with complementary skills. This might be done by supporting training stages in external laboratories and by putting in place a visiting scientist program to collaborate with the PIFSC team on particular research aspects. The integration of the research efforts and collaboration with larger international research programs on top predators and their ecosystem is also strongly encouraged.

5) **Equipment:** Several problems were encountered with the equipment, the more severe one being related to the mounting of the acoustic system on the research vessel, whose trawling capacity for ground-truthing the acoustic data was often absent due to winch malfunctions. For improving the data quality and completeness for a comprehensive ecosystem research, the acquisition of additional equipments is necessary. Among the suggested acquisitions suggestions are: a multiple-codend micronekton trawl and other ground-truthing gears, complementary environmental sensors, autonomous acoustic equipments to deploy in particular habitats to get high-resolution eulerian or lagrangian time-series of the fish community patterns and environmental characteristics. ***It is therefore recommended to make all efforts to solve the equipment problems encountered with acoustic and trawling equipments on the research vessel and to take advantage of all opportunities to acquire spare parts and to complement the instrumentation*** with additional sensors and gears to improve the quality of the acquired data set for present and future ecosystem research.

13. Description of panel review proceedings

ToR: "Describe briefly the panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations."

According to the agenda, the panel review met the PIFSC personnel at the PIFSC center in Honolulu on 7-9 July 2010. General background information on the PIFSC research activities and mandate was presented by Dr Sam Pooley, the Science Director, and Dr Jeffery J. Polovina, the Director of the Ecosystem and Oceanography Division. It was recalled that the fisheries acoustic research started six years ago, with Dr Réka Domokos as research scientist, to explore the possibilities of this technology for obtaining fishery independent estimates of relative biomass of top predators such as tuna, and initiate research projects on their forage micronekton and the relationship with the characteristics of their environment. Several projects were conducted in different areas. Some were specifically designed for particular research objectives and other were taking advantages of opportunities of ship time to explore the possibilities of the methodology. Difficulties were encountered, especially with the equipment and the data processing. Results were published in two peer-reviewed papers in Fisheries Oceanography for the American Samoa Islands EEZ, and the analyses were at an advanced stage for the projects. An application was presented to the NOAA fisheries review program to proceed with CIE for a review of this fisheries acoustic and oceanographic work, in order to evaluate the results accomplished so far and to get recommendations for improvements and future directions.

Dr Domokos then presented the different projects and methods employed to the three members of the review panel, and several points were freely discussed during the 2-day presentation. Dr Polovina and Dr Michael P. Seki, Deputy Science Director of PIFSC, joined the panel on the second day to respond to the questions raised by the members of the review panel after the presentation of the projects. These questions concerned the research directions expected for the acoustic research program at PIFSC and its support possibilities. From the discussion with the managers and research scientist, the review objective was more to improve future work and get advise for future directions than to examine past analyses.

On the third day the three members of the review panel met to discuss and share advises on the 13 ToRs of the SoW. There was a large consensus among the three members on the general evaluation. Some specialized technical points were also discussed. The panel decided to present the same main recommendations in their reports to evidence this clear consensus.

The review was well organized by the CIE and was realized as planned. The welcome by PIFSC personnel in Honolulu was excellent and the facilities offered for the review were fine. The access to high-level PIFSC managers greatly helped the review panel to understand the particular research context at PIFSC and to adapt their comments accordingly. The ToR list could have been simplified by merging ToR 2 and 3, and 4, 5 and 8, to facilitate a more ordered response in the review report. The terms “relative biomass” and “composition” could be interpreted differently depending of on the considered points of views; their definition for this review would have helped to ensure a common understanding.

Appendix 1: Bibliography of materials provided for the review

Overview of Active Acoustic Work at the Pacific Island Fisheries Science Center (PIFSC) Honolulu, July 7-9, 2010 Review doc. 14p.

Domokos, R., Seki, M.P., Polovina, J.J., and Hawn, D.R. Oceanographic investigation of the American Samoa albacore (*Thunnus alalunga*) habitat and longline fishing grounds. Fish. Oceanogr. 16:6, 555–572.

Domokos, R. 2009. Environmental effects on forage and longline fishery performance for albacore (*Thunnus alalunga*) in the American Samoa Exclusive Economic Zone. Fish. Oceanogr. 18:6, 419–438.

Seven PowerPoint presentations on research conducted by Reka Domokos that were presented during the site visit on July 7-9.

Appendix 2: Copy of the CIE Statement of Work

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 microneckton 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.

<u>Prior to the Peer Review</u>: 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.

<u>Foreign National Security Clearance</u>: 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**.

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.
Participate during the panel review meeting at the Pacific Islands Science Center in Honolulu, Hawaii during 7-9 July 2010.
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**).
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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Key Personnel - NMFS Project Contact:

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Pacific Islands Science Center, 2570 Dole Street, Honolulu, Hawaii
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, Phone: 808-983-5368

Appendix 3:

Panel membership or other pertinent information from the panel review meeting

Panel membership:

Review panel:

Dr Rudy Kloser, Hobart, Australia
Dr Gary Melvin, St. John, NB, Canada
Dr Yvan Simard, Rimouski, Qc, Canada

Contributors:

Dr Réka Domokos, research scientist, Ecosystem and Oceanography Division, PIFSC, Honolulu, Hawaii
Dr Jeffery, J. Polovina, Ecosystem and Oceanography Division Director, PIFSC, Honolulu, Hawaii
Dr Sam Pooley, Science Director, PIFSC, Honolulu, Hawaii
Dr Michael P. Seki, Deputy Science Director, PIFSC, Honolulu, Hawaii

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