Chair's Executive Summary of Program Review of Ecosystem Science
Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

July 12 – 14, 2016

General Observations and Recommendations

Scientists at the NWFSC are doing the right kind of Ecosystem Science and Research (ESR), doing it at a very high level, and having important impacts on management. ESR at the NWFSC ranges from physical drivers to the analysis of ecological systems to the human dimensions and an enormous amount of very high quality work has been accomplished with limited funding. NWFSC scientists have lead the development of EBFM towards EBM and the Integrated Ecosystem Assessment (IEA) work is at an international level. Work in the Puget Sound provides a local test-bed for many important ideas and a local application of EBM.

This is a critical moment, with senior leadership (Dr. John Stein and Dr. Phil Levin) leaving, but the current success can be maintained with appropriate support from NOAA Fisheries.

It is clear that everyone understands the toll that loss of permanent staff over the last decade has taken. Consequently, this report will not harp on that point (although it is mentioned).

Theme 1 – Management Context and Strategic Planning

The vision for ESR, and how funds are prioritized needs to be carefully and publically articulated before Dr. Stein leaves. The Integrated Marine Ecology and Nearshore Ecology teams, which are responsible for much for the IEA work, need assurance that their work and structure will continue after Dr. Levin's exit. The next Director must understand the culture of the NWFSC, the importance of writing proposals, and the importance of seed funding through the internal grants program.

Because of a decline in permanent FTE and flat or declining NOAA budgets, post-doctoral colleagues and temporary funding will continue to play an important role in ESR in the short-term and mid-term (in the long-term, more permanent FTE are needed). A general culture of proposal writing that will include formal training (many scientists still do not receive such training in graduate school) and ensuring that barriers to successful funding are reduced (which differ according to the source of funding) is thus essential.

Theme 2 – Ecosystem Data

A broad range of ecosystem data are collected in support of ESR at the NWFSC and in most cases the hypotheses that underlay the collection of data are clear. The

NWFSC's expertise with qualitative methods and MSE simulation testing should be used to explore questions of sample size and frequency of sampling to ensure that neither too little nor too much data is collected. Modern statistical methods are being applied and developed for the analysis of these data, and this requires computational power that must be supported.

Theme 3 – Ecosystem modeling and analysis

ESR modeling at the NWFSC is at an international level of excellence, although there are a few gaps. The combination of retrospective analysis, new data, and statistical modeling as the nexus for prediction and understanding is at a very high level and the next step is to develop more process-based models and then confront the models with the data. Integration of modeling efforts across divisions (e.g. by using a process based model in stock assessments or having the IEA team write the ecosystem portion of stock assessments) will increase the overall effect of the modeling efforts.

Theme 4 – Incorporation into Management

Stakeholders consider that NWFSC is doing superb job of providing ecosystem advice to them. The California Current IEA is an excellent tool and participation in the Puget Sound Partnership (PSP) ensures that local managers will benefit from the most current scientific advice. The NWFSC is well on the road to its aspiration of EBM.

Theme 5 – Communication and Peer Review

ESR is effectively communicated to the PFMC, PSP, and other clients and other stakeholders. Although many scientists working at the center are gifted communicators, formal training in communication (as with proposal writing) will improve communications. The peer-reviewed publications are stellar in number, quality, and publication outlet.

Other

The level of collaboration across divisions is impressive, but such collaborations are always threatened in a time of poor budgets. One relatively costless way of ensuring collaboration across divisions is not to silo people, but to mix them up according to general research interests rather than division. Similarly, the internal grants program, which is essential, can be used to foster inter-divisional collaboration.

Conclusions

The NWFSC has achieved great things on limited federal resources that are supplemented by external funding in Ecosystem Science and Research and the slope of the trajectory is very positive. Additional attention and support from NOAA Fisheries can ensure continued greatness and achievement even at this moment of transition.

Chair's Summary of Program Review of Ecosystem Science
Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

July 12 – 14, 2016

Review Panel Members

- Marc Mangel, University of California, Santa Cruz, CA (Chair)
- Doug Demaster, Alaska Fisheries Science Center (Reviewer)
- David Fluharty, University of Washington (Reviewer)
- Beth Fulton, CSIRO, Hobart, Tasmania, Australia (Reviewer)
- Sarah Gaicas, Northeast Fisheries Science Center (Reviewer)
- Ian Perry, Pacific Biological Station, Nanaimo, BC, Canada (Reviewer)
- Ellen Pikitch, Stonybrook University, Stonybrook, NY (Reviewer)

Per the template provided to the panel, the individual reports that follow this Chair's summary are anonymous and appended to this summary in random order.

Background and Overview of Meeting

The panel met 12-14 July 2016 to evaluate the quality, relevance, and performance of Ecosystem Science and Research (ESR) conducted at the Northwest Fisheries Science Center (NWFSC) and to aid NMFS in positioning the NWFSC to be the national leader in ESR.

The formal presentations in which staff provided information that described ESR in a regional context lasted 2.5 days; all panel members heard all talks. The panel met for an hour with the Division Directors without the Center director and with NMFS senior leadership for 1.5 hours. Panel members attended a poster session and chatted informally with NMFS scientists.

Although the panel had substantial discussion, each panel member wrote hers or his report with no review by other panel members. When writing the reports, panel members were guided by these questions, provided by the NWFSC:

1. Does the NWFSC have clear goals and objectives for an ESR? Is ESR integrated with the other science activities across Divisions within the NWFSC? Are the ESR activities appropriately prioritized and evaluated as part of an overall strategic plan?

2. Does ESR at the NWFSC focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management

Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?

3. Has the NWFSC appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy?

4. What is the status of oceanographic, habitat, climate and ecological data required to fulfill needs of ESR? Has the NWFSC developed strategies to obtain and manage such data?

5. Is the NWFSC appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?

6. Is the NWFSC oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?

7. Is the ESR at the NWFSC adequately peer-reviewed relative to their purpose and use? If not, has the NSWFSC developed a strategy for peer-review?

8. Does the NWFSC appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?

ESR at the NWFSC ranges from physical drivers to the ecological analysis to human dimensions. The consideration of trade-offs and generating science to support EBFM and EBM are central to ESR activities. Effective EBFM and EBM require working in Pasteur's Quadrant[1] in which the search for fundamental understanding (in both the natural and social sciences) is motivated by an important applied problem. They also require interdisciplinary work and one cannot force people to be interdisciplinary. The NWFSC has excelled at achieving interdisciplinary collaborations in which terrific science is done in the service of the mission of NOAA Fisheries.

[1] D Stokes (1997) *Pasteur's Quadrant*. Brookings Institution, Washington, DC

General Observations and Recommendations

The NWFSC provided a well-organized overview of ESR with excellent presentations that showed the commitment to ESR. Comments from the members of the Pacific Fishery Management Council (PFMC), NOAA Regional office, local NGOs and industry were strongly positive. The last two presentations by NWFSC leadership were inspirational. In contrast, Center's Strategic Plan is comprehensive but it is not motivational.

NWFSC staff were helpful and responsive to panel requests for additional information throughout the review. The evening poster session allowed panel members to interact directly with staff. It is clear the NWFSC staff is committed to doing useful and important applied work and NWFSC scientists are worldwide leaders in the development of EBM. Much of the work is driven by the enthusiasm and innovation of the staff, who are self-motivated and have been successful in obtaining competitive funding for this work.

The morale of the investigators appears high even though recent years have had financial and personnel cuts and that this is a time of transition, with two key leaders departing soon (Drs. Phil Levin and John Stein).

In summary, across the NWFSC there is a commitment and genuine enthusiasm for ESR and a sense of mission to develop and communicate top quality scientific understanding in support of EBFM and EBM. Work in the Puget Sound is especially valuable, because of its proximity, the importance of EBM there, and that it can serve as a test-bed for EBM in the California Current.

ESR at the NWFSC is highly productive, with more than 16 papers per FTE since 2010 that span technical, theoretical, disciplinary specific, and policy journals with at least 7 in the high profile journals (*Nature, Science* and *PNAS*). The vast majority of these papers are from collaborations rather than single authored work.

Furthermore, the NWFSC is one of the few places globally that has really begun to do interdisciplinary work between the natural and social sciences, although it is heavily biased towards the natural scientists. Center leadership is cognizant that social science is integral for EBFM and EBM and that there remains a mismatch between the recognized need to include human dimensions and the requisite data to address those needs.

The internal grants program, which provides seed money, is a terrific way to spur interdisciplinary research and should be high priority.

The period since 2008 lead to a decline in permanent FTE at the NWFSC and much of the ESR is done with temporary funds, which concerned the panel because the continual search for temporary funding may distract from focus on

key questions of ESR. Because of staff reduction over the last decade, post-docs have become essential for the Center overall and for ESR; the NOAA Fisheries QUEST Program appears to be an untapped source of support for post-doctoral colleagues doing ESR.

The Integrated Marine Ecology and Nearshore Ecology teams are remarkable. They embody applied community ecology in Pasteur's Quadrant, including human behavioral ecology, field work (particularly near shore diving), and connections to academic ecology. They are a cohesive and collaborative group showing creativity and flexibility in their work, collaboration across divisions, and the ability to learn new methods.

In summary, NWFSC is definitely doing the right science, doing it very well, and providing ecosystem advice for management.

General Recommendations

Take the leadership turnover as an opportunity to formally review the NWFSC ecosystem science strategy and to codify the underlying principles and strategy that guide ecosystem science at the NWFSC in a stand alone document.

(For example, the current Director could assemble a team of scientists to meet weekly for 1-2 hours for about 3 months to develop a strategic plan, asking "what should Ecosystem Science and Research look like here in 5, 10, and 15 years". This plan should be linked to the current IEA work, the WRAP, and the ecosystem goals of the PFMC.)

Ensure that the next Director of the Center understands the culture of the NWFSC, the importance of writing proposals (also see below) and the importance of internal seed funding.

The Integrated Marine Ecology and Nearshore Ecology teams should be kept together even though Dr. Levin is leaving. In the same way that the panel recommends planning by the current Director, these teams should determine a collective vision for their own work. Dr. Levin's FTE and associated funds be returned to these teams (it should be possible to support both a new FTE and a post-doc).

Increase the number of post-docs doing ESR; some of these may end up with permanent positions but that is not requisite. A QUEST post-doc, funded by S&T, and working with Dr. Levin and the Integrated Marine Ecology and Nearshore Ecology teams is a natural way to ease the transition of Levin leaving for UW.

Make the budget planning process more transparent and explicit.

Continue the internal grant scheme as a means of supporting new scientific directions and facilitating collaboration across and within divisions.

Maintain an environment that supports and encourages collaboration and the engagement (hiring) of the next generation of science leaders.

Provide training in grant writing.

Recognize the value of the IEA by prioritizing it to receive at least 1 FTE (rather than the current partial FTE).

Panel Members' Major Recurrent Observations and Recommendations

Theme 1 – Management Context and Strategic Planning

Observations

ESR at the NWFSC is very broad, including

- Impacts of climate change on living marine resources;
- Impacts of climate change on local communities;
- Impacts of commercial fishing on the California Current Large Marine Ecosystem (CC LME);
- Harmful Algal Blooms (HABs);
- Ecosystem function within the CC LME and Puget Sound marine ecosystem;
- Integrated Ecosystem Assessment (IEA);
- Incorporating environmental and ecological information in traditional stock assessment; and
- The development of various indices and metrics to assess and monitor the status of the CC LME and Puget Sound marine ecosystem.

There is generally good integration across divisions and groups doing ESR.

It is not clear how budget priorities are set, other than that there are inevitable tradeoffs. With the breadth of work and stakeholders, an objective protocol for ranking research activities and then allocating funding according to known priorities is essential.

The Center's ESR received high praise from NOAA Regional staff and PFMC staff. Center staff are clearly integrated into the production of key management-related documents, such as Fishery Management Plans and Fishery Ecosystem Plans. Presentations reflected a similar effort to incorporate the priorities of the Puget Sound Partnership (PSP), which is important because the Puget Sound can be an important test-bed for EBM.

The Center's leadership in ESR depends to a fairly large degree on opportunistic funding opportunities seized by motivated individuals, several of whom are on temporary appointments. The process for organizing research under reimbursable or non-permanent sources of funding was not clearly outlined; the panel was concerned that this type of funding supports a disproportionate amount of ESR.

A number of panel members commented on some topics notable by their omission. These included marine spatial planning, benthic invertebrates, and physical oceanographic work and it was not clear if they are not being done or simply not presented.

The NWFSC has a variety of formal documents about ESR. What appears to be missing (or at least the panel did not see it) is something that goes beyond the standard formal NOAA Fisheries documents to provide the staff with the vision, inspiration and clarity of what is so clearly in the minds of the leaders. Such a document, even if informal, would likely provide a clearer direction to those interested and engaged in the future science than the agency standard planning documents.

ESR at the NWFSC has good integration across divisions. This degree of collaboration is clearly a mixture of top-down willingness to facilitate the organic growth of collaborations and a bottom-up collaboration of co-located individuals exploring important new questions. The internal grant scheme is a very popular and extremely important means of delivering seed funding for such collaborations.

Recommendations to address issues

Produce a written and clear document laying out the Center's current ecosystem science activities and goals. The current Center Director should do this. It will be an important legacy.

Select a new center director who is supportive of the vision and ground breaking direction set by the NWFSC.

Maintain and strengthen the internal grant scheme and provide formal training in grant writing.

Continue the focus on EBFM from the Headquarters levels, but include more recognition of the importance of non-fisheries related issues and pressures, with EBM as an aspiration.

Continue to support and enhance human dimensions work, by providing more consistent support for social scientists.

Ensure that there is an effective minimum critical mass of social scientists.

Raise the profile of marine spatial planning among the tools for ESR.

Include benthic invertebrates as integral parts of marine ecosystems and incorporate their interactions with vertebrate species (if not already done).

Theme 2 – Ecosystem Data

Observations.

The NWFSC has established monitoring surveys for multiple trophic levels in both the CC and Puget Sound; some of these are conducted without base fund support. Time series are maturing and useful for some applications, but still too short for others. All monitoring requires hypotheses, since there are simply too many things to measure otherwise. In general, the hypothesis-driven nature of data collection was clear.

The NWFSC opportunistically collects information when possible, and is making efforts to synthesize information from multiple sources using innovative spatial and statistical modeling approaches. Length (number of years) and breadth (variables observed) of time series are very impressive. Surveys of non-trawlable grounds is a gap, but one that is recognized and in the process of being addressed by alternative methods. However, the small size of the teams conducting these observations (e.g. plankton, which currently is one FTE surveying one line off Oregon) and the ephemeral nature of funding for these activities (i.e. via outside grants and proposals) is a concern. It is unclear how critical these programs and their data are to the Center's ESR. Similar comments and concerns apply to studies of Harmful Algal Blooms (HABs).

It appears that data are not shared as widely as possible, with some siloing within division, and this needs to be overcome. Discovery and use of existing data is being made easier via the use of centralized data discovery and storage tools, although some duplication remains and further efficiencies around data centralization surely exist.

Modern statistical methods for ESR are being both developed and used; this allows old information to be used in new ways and gaps for new information to be identified. It also requires powerful computing facilities and the NWFSC has been successful in creating bioinformatics clusters, where internal and external scientists have access to comprehensive data sets at a single data portal (e.g., FRAM database). However, IT constraints in data acquisition and management exist.

It appears that "core" (e.g. as related to direct stock assessment and endangered and threatened species requirements) and "peripheral" (e.g., studies that inform about broader ecosystem conditions but for which, at least at present, impacts to assessments and endangered and threatened species are indirect) are treated differently.

Peripheral studies include plankton and small pelagic surveys, and harmful algal blooms. Information on these issues is crucial for detecting changes in

marine ecosystems due to natural processes, but in general they are not input into assessments. Research teams on these issues are small, and research funding appears to be largely via outside proposals, or by collaborations with outside groups (e.g. reliance on community observers for HAB sample collections). This places these programs at significant funding risk and collapse if key researchers leave.

It was not clear if the current protocol for collecting fish stomach samples from research vessel surveys and at sea observers is supported by a proper experimental design (i.e., hypothesis-drive, where pre-specified targets for statistical power or precision are included in the experimental design). Thus it is not possible to determine if the current sampling regime results in a sample size that is appropriate, over-sampled, or under-sampled. A similar argument can be made regarding harbor seal scat samples.

MSE can be used to elucidate the susceptibility of existing time series to breaks in data collection, associated with loss of funding or logistical problems. With such an analysis in hand, the modeling efforts most likely to fail in meeting management needs because of a break in time series data can be identified and protected as much as possible.

The biophysical surveys are world renowned for their longevity, coverage and frequency. Nevertheless, they are expensive and new technologies can likely ease the load or allow for new data streams to come on line that address some of the additional needs that arise when moving form stock considerations to ecosystem process and function in the context of global change.

Concerns about data security restrict access for collaborations with colleagues outside NOAA.

<u>Recommendations to address the issues</u>

Develop a plan for increasing or shifting funding for obtaining data critical for ecosystem-level analysis and assessment.

Ensure that sample size for surveys is hypothesis driven (which will as a corollary ensure that one knows how the diet data are integrated into other ecosystem work). This would also allow – in a time of constrained resources -- optimization of survey design.

Conduct a NWFSC-wide examination of how information on feeding relationships (gut contents, etc.) are obtained and used to ensure that these data are used as optimally as possible. Combine the two databases for diet samples.

Continue to encourage the development of new statistical methods and the use of modern Bayesian and likelihood methods. In particular, formally investigate

tradeoffs in monitoring (yearly, bi-yearly) using MSE and methods for filling in missing data.

Incorporate "peripheral" data collection programs more fully into assessment and the endangered and threatened species programs to make them essential information.

Investigate and support new means for cost effectively supplementing, extending or improving the efficiency of data collection (e.g. to cover the currently "missing" parts of the ecosystem such as mesopelagics, benthic invertebrates, aspects of the human dimensions etc.).

Use MSE to explore the costs, benefits, value and efficacy of alternative monitoring schemes.

Investigate how the standard groundfish, ocean salmon surveys, and other monitoring programs can be harmonized/coordinated for full ecosystem work.

Investigate the feasibility of increased diet collections aboard different platforms, including collection by fishing industry partners, recreational fishermen, or other methods.

Continued to support for NWFSC-wide data accessibility.

Work with DOC and NOAA IT programs and scientists at all Centers to address and mitigate IT constraints on science while ensuring the level of necessary security for IT systems.

Theme 3 – Ecosystem modeling and analysis

Observations.

ESR modeling at the NWFSC is at an international level of excellence in which state of the art methods for analyzing and modeling ecosystem-level processes are developed and applied. Cumulative and integrative analyses are being conducted. A good balance between data collection and analysis exists. Incorporating social and natural sciences within ecosystem analyses and models has been pioneered by the NWFSC.

Even so there are a few missing pieces. For example, although the panel heard many talks about temperature, there was no talk about applying ideas from the thermal ecology to the data; many of the social science questions require answers from a human behavioral ecologist; and ensemble modeling is done outside of the NWFSC.

The combination of retrospective analysis, new data, and modeling as the nexus for prediction and understanding is at a very high level. Additional process level modeling will allow the science to move forward in a number of instances, such as

- What underlies the human impacts forecasts;
- Forecasting Harmful Algal Blooms (HABs); and
- Linkages between the PDO and salmon returns.

The NWFSC is a world leading in developing innovative modeling methods. These include

- Qualitative network analysis that provides a powerful tool to address data poor systems and the nexus of natural and social systems;
- Conceptual models developed by the IEA program that are particularly useful for collaborating across disciplines (natural and social sciences) and for communicating relevant ecosystem interactions to stakeholders;
- Food web models that have been developed and applied in Puget Sound and in the NCC include extensions of the typical Ecosim with Ecopath (EwE)EwE framework and incorporate uncertainty into food web model analyses; and
- The Atlantis model at NWFSC, which is well developed and continually evolving to address management relevant questions. This is a monumental task achieved by a very small but clearly capable staff.

Key modeling done outside of NWFSC but involving collaborations with it includes MICE models that are very powerful, but can be challenged because they do not fit all of the data and ensemble modeling.

At least some of these tools have intentionally been developed to have capacity to address cumulative impacts required for EBM.

As with data, IT constraints on analysis and modeling relate to computing constraints, and the inability to use tools (e.g. GitHub, DropBox) that foster transparency and collaboration on tool development.

The true potential of MSE is yet to be realized (both in terms of monitoring design and for informing management decision making); although Center staff are lauded for the effort they have already put into advancing that work and the engagement with the many relevant management bodies.

The expansion of the toolbox for ecosystem assessment and forecasting is directly responding to management requests. However, NWFSC leadership needs to be cognizant of the resourcing needed to maintain and refine the toolbox, as well as extend it in future. Grants and postdocs are an effective means of doing development but they are a risky strategy for maintaining capability in the long-term.

As with the more general issues described above, planning for model development has been project-specific rather than strategic.

<u>Recommendations to address the issues</u>

Encourage the development of process-based modeling (as in the MARSS software). A natural starting point, which would also link across divisions, would be to develop process based models for size at age and the stock recruitment relationship (rather than treating them as statistical objects) for stock assessments, which may require additional funding for FRAM to conduct process-based studies.

Develop process based trophic models to link across the trophic levels from primary or secondary producers to salmon.

Continue the development of the methods of qualitative network analysis.

Conduct a formal analysis of the set of models as a package relative to ecosystem science strategic planning. What is working, what needs more development, what is missing?

Have empiricists and modelers develop together the data that needs to be explained by a MICE model and ensemble models for them to be considered appropriate for management use.

Find cyber secure methods of engaging with modern data and software sharing platforms (e.g. GitHub, DropBox), develop internal clusters for the Atlantis work, and provide dedicated support for the IEA website.

Conduct analyses to determine the weight and importance of these time series to the various integrating/model studies. For example, how reliant/vulnerable are the ecosystem models to loss of any of these time series given the ephemeral nature of their funding?

Establish formal modeling connections with AFSC and to share the investment developing and maintaining a toolbox of approaches.

Conduct targeting hiring of individuals working in the metabolic theory of ecology; human behavioral ecology (or perhaps a psychologist who works on fisheries issues); and ensemble modeling.

Theme 4 – Incorporation into Management

Observations

The incorporation of NWFSC science into management is enviable.
Based on the comments from the WCR, Council, and other stakeholders, the NWFSC is doing an excellent job providing ecosystem advice to resource managers. As with all ecosystem work, there is a long road to get this information into management (particularly Council processes). The IEA is openly acknowledged as framing decisions made by the PFMC.

Important ecosystem science is being conducted by the NWFSC in Puget Sound, in collaboration with other agencies and organizations. These studies provide opportunities for learning and demonstrating how to move towards EBM, with Puget Sound as a laboratory for building an ecosystem approach to management and as a case study for comparisons with the California Current System.

The CC IEA is an excellent vehicle for providing ecosystem advice to managers. Similarly, participation by Center staff in the PSP provides an important means for informing managers regarding a host of environmental concerns. Finally, NWFSC staff involvement in the PFMC CC Fishery Ecosystem Plan indicates a successful partnership between managers and ecosystem-related scientific practitioners.

However, application of the IEA is at a disadvantage because of a lack of clear objectives on the part of management clients. The IEAs have gone through many phases, but are not quite mature because of this.

Major accomplishments have been to provide important contextual and background information on ocean and ecosystem conditions. The importance of this is hard to demonstrate quantitatively, but it appears to have significant qualitative impact. The importance of ESR to the business of the PFMC has been enhanced by the very unusual conditions in 2015 (the warm "blob").

The work on tipping points, although in preliminary stages, has great potential for management since a clear management concern is advance warning of significant changes of state and their potential impacts, or at least rapid identification post-event that significant changes have occurred. Impacts of ecosystem changes to human communities that depend on marine systems are also clear management concerns.

Thus, the capacity of the NWFSC to maintain sufficient scientific flexibility to provide help with topics as they arise (so management can react quickly) is also important.

Engagement with stakeholder and management groups is essential as more sectors are included with the move from EBFM to EBM – the shift will not be an easy one in terms of resources or philosophy, since fisheries are typically far ahead of other sectors in terms of their readiness around the principles of decision support and adaptive management.

Stock assessment scientists already appreciate the time commitment needed to deliver on management needs. As their remit has expanded into reporting on ecosystem considerations they have become more and more time and resource pressured. This is where resource sharing (e.g. IEA team providing the ecosystem considerations and indicators for assessment reports) could free up time for the assessment group to pursue new options (e.g. using ecosystem indicators to inform short term projections), explore hypotheses that stock assessments have raised, or to help secure funds to do the sampling required to achieve greater process understanding and thereby reduce uncertainty in management advice. An example is the progress is being made with sablefish assessments.

Recommendations to address issues

Work with the PFMC, PSP, and Regional Planning Body to clearly identify objectives for EBM. Then prioritize data collection programs, analysis, modeling, assessment and advice based on those objectives. Ensure that staff have adequate time for this interaction.

Formally conduct a lessons-learned from the Harmful Algal Bloom to provide ecosystem science advice to management.

Provide support to scientists to facilitate the transition from scientific surveys to management relevant monitoring schemes (e.g. for HABs, the warm blob) – or at the very least to provide them with the resources to see if such a transition is feasible.

Take advantage of other strong unusual ecosystem conditions and events in the environment to underline their importance and potential impacts to the PFMC decision process.

Continue the work on tipping points, with communication to PFMC and stakeholders.

Use the expertise of the IEA team to write the ecosystem considerations component of stock assessments.

Fill the MSE position with ecosystem level MSE (e.g, protected species, habitat) as well as stock assessment level MSE in mind.

Theme 5 – Communication and Peer Review

Observations.

The PFMC is a (perhaps the) primary client for ESR work at the NWFSC. All indications are that the research results obtained and communicated exceed PFMC expectations. In part this is because the ESR at the NWFSC has anticipated future needs of the PFMC, and thus the NWFSC is able to meet current information needs.

A second client group is the scientific community, as one would expect of scientists working in Pasteur's Quadrant, since publication in professional journals is essential.

Communication

The NWFSC has excellent communication with its primary constituents in the fishery management community and the PSP. Modelers have been involved in direct communication with managers, in particular with the CCIEA.
Some concerns were expressed about the need for capacity building internally and with external partners to be able to effectively use products of more sophisticated scientific assessments and models [e.g., risk assessments, and trade-off analysis].

Condensing and presenting complex ecosystem information into succinct and useful formats for decision-makers or the public is difficult.
The polished look of key IEA and EBFM graphics indicates that the NWFSC takes communications seriously. Many of the scientists working at the center are already gifted communicators. Even so, communication effectiveness can be improved through dedicated training programs.

Communication directly with stakeholders both informs ecosystem analysis and strengthens relationships with them. However, relying on NGOs to "interpret" the science (even unintentionally) comes with some benefits (their engagement and understanding) but also risks (control of messaging).

Projects such as the Ocean Tipping Points (and the IEA more generally) highlight the collaborative nature of the NWFSC's work and show it at its best: multi-institutional, multi-disciplinary with value academically and for management. The impressive advances highlight how the small internal grant process (and the long history of supporting inter-collation of modeling and data) can see enormous returns. This work shows the way forward on the national and global stage, as it fully recognizes the importance of a socio-ecological perspective, going beyond economics to consider social end points, and provides information relevant to the operationalization of EBM.

The Center has developed and is expanding its website on ecosystem science with the goal of providing real-time detailed information to stakeholders. This is an essential project and a vital communication tool that will need additional and sustained funding in order to meet its objectives.

Peer Review

The peer reviewed publications are stellar in number, quality, and outlet. Per ESR FTE, the publication of first authored or co-authored papers is on the order of 3 papers per year. Seven publications since 2010 were published high profile journals. This output would be considered outstanding anywhere in the world.

The Atlantis model has been reviewed by CIE/SSC and the CC-IEA has been reviewed by national IEA program and received considerable accolades from the WCR, Council, and other constituents

It was unclear to the panel whether the important work with Councils/other managers is given the same credit as peer reviewed journal publications.

The NWFSC has many close partnerships – particularly with the SWFSC, UW and other universities and the Puget Sound Partnership. This level of collaboration has been effective in supporting the delivery of integrated ecosystem science. This world-class reputation comes with the pressure of expectation and maintaining it is tied to maintaining the collaborative spirit.

<u>Recommendations to address issues</u>

Ensure that engagement with the public and the council has rewards comparable to peer-reviewed publication. At the same time, continue to encourage the outstanding level of peer-review journal publications.

Provide formal training in communication.

Formally study how to present and summarize the ecosystem science information and model outputs, especially for a lay audience.

Continue and expand collaborations with social scientists and further develop stakeholder processes to improve two-way communication.

Broaden the view of who the clients are and increase communication efforts to reach this broader constituency.

Other

Observations**.**

The level of collaboration across divisions is impressive, but such collaborations are always threatened in a time of poor budgets. In general, external funding is required to maintain ESR.

Although there are no federally managed fisheries in Puget Sound, it is the ideal place to test and ground-truth EBM, to collect ecosystem-level data, analysis, and implementation of EBM. NWFSC has an important history and role; continued involvement in Puget Sound will have enormous payoffs.

The research collaboration between the NWFSC and SWFSC was abundantly evident. This is commendable and no doubt contributes to the overall success of the science mission at both Centers.

There appears to be on-going collaboration between staff at the NWFSC and the AFSC. Nonetheless, greater collaboration would strengthen the ESR at both Centers. For example, the nature and magnitude of the degree to which the CC LME and Gulf of Alaska LME interconnect should be more thoroughly investigated, especially given the emergence of the warm blob.

Funding to support a comprehensive IEA for the CC is inadequate. Current funding provides for reasonable coverage of the lower trophic level, and parts of the upper trophic level of the CC (e.g., commercially important fish species). However, the middle trophic level and certain marine mammal (e.g., harbor seals) and seabird elements of the upper trophic level have had relatively little support in the past and currently. Without better information on these species, the reliability of the ecosystem model output is open to question.

Recommendations to address issues

Since collaboration is more often than not established by physical proximity, consider putting ecosystem scientists from different divisions physically together.

Ask IEA staff to write the ecosystems effects of stock assessments, and – as described above – to develop process based models for size at age and the SRR.

Develop a general culture of proposal writing that will include formal training (many scientists still do not receive such training in graduate school) and ensure that barriers (which differ according to the source of funding) are as low as possible.

Have leadership from the NWFSC and AFSC schedule a workshop/meeting for the

purpose of identifying best practices at each Center and ways in which scientific partnerships and collaborations could be enhanced.

NWFSC's involvement in Puget Sound should be encouraged and facilitated since Puget Sound is an excellent test bed for ecosystem-level data collection, analysis, and implementation of EBM. NWFSC has an important history and role in this.

Assess the costs and benefits of enhancing citizen science to include restoration activities.

Evaluate the merits of reprogramming funding, as current appropriate rules allow, to better support these underfunded elements of the CC IEA.

Conclusions

This review began with Dr. Merrick asking 1) is the NWFSC doing the right ecosystem science, 2) doing it well, and 3) translating it into management advice?

As this summary and the individual reports appended to this summary show, the answers to these questions are yes, yes, and deeply engaged in the process.

First, ecosystem science and research at the NWFSC is focused on the absolutely correct suite of questions, although there are some gaps such as middle trophic levels species. There is also a lack in an over-arching vision.

Second, the quality of the work presented during the review, and the accompanying papers, is at a very high level – the science is indeed being done very well. Again, there are some instances in which the science can be improved, most particularly in sampling programs that will benefit from clear articulation of hypotheses and careful assessment of appropriate sample size.

Maintaining this high level of ESR, both in quality and quantity, would be a challenge in any environment, but is more so with changes in leadership and decline in permanent funding for the NWFSC. A number of the recommendations listed above are a response to this challenge and many of them can be done with little additional funding but with attention.

Perhaps the most important of the transitional activities is the development and sharing of a unified vision for ESR at the NWFSC and then and allowing it to develop in a new generation of leaders.

Third, the NWFSC provides management support to multiple agencies and is a national and international leader in translating ESR into management. Research at the NWFSC is clearly great as the Center's scientists create tools that can be used to address current and future management questions. The Center is on the right path and as long as it is not diverted, many stellar successes lie ahead.

Reviewer Report on Program Review of Ecosystem Science

Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

July 12 – 14, 2016

Background

General Observations and Recommendations

The NWFSC has developed and implemented an impressive array of ecosystem-related science activities. It is a leading institution in ecosystem science and its applications, as evidenced, in part, by publications in leading journals. The accomplishments in this arena are particularly impressive given the relatively small number of staff and small base budget available for these activities. Much of the work is driven by the enthusiasm and innovation of the staff, who are self-motivated and have been successful in obtaining competitive funding for this work. The leadership of NWC facilitates and encourages this work by providing a very supportive, positive, open, environment, and through seed grant programs. I am impressed that the morale of the investigators appears high despite the fact that there has been a recent period of financial and personnel contraction due to budget cuts in recent years. It is also impressive given that this is a time of transition, with two key leaders departing soon (Phil Levin and John Stein).

Key (Specific) Findings and Recommendations (as reviewer has comments on)

- **Theme 1 – Management Context and Strategic Planning**
  - Observations
- **The Centers programs clearly address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission. In addition, the Center shows leadership by ANTICIPATING and providing information for needs that may not have been recognized in advance by client groups.**

- **There is a fair amount of integration of ecosystem science and other science activities across divisions within the center. The level of integration varies among programs. There are many excellent projects and programs and each of these has clear goals and objectives.**

- **Many program activities are opportunistic and investigator driven. The need to obtain external funding is one driver of this tendency. The enthusiasm and special insights of the excellent staff is also an important driver.**

- **An *overarching* vision and plan for ecosystem science at the center appears**

to be lacking. This is understandable, given the high proportion of center funding derived from external sources and the relatively immature state of the field.

- Recommendations to address issue

- **The need for a comprehensive, coordinated vision and transition plan is clear and I recommend that this be developed very quickly, especially given the forthcoming leadership personnel transitions.**

- **Theme 2 – Ecosystem Data**

  Observations

  The Center has developed and implemented innovative strategies to obtain oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs. Where funds are lacking to implement routine quantitative survey data – staff have developed ways to supplement data through citizen science programs and qualitative surveys – for example of scuba diver and recreational communities. Moreover – the center recognizes the importance of considering people as part of ecosystems, and therefore the requirement to obtain social science data to implement an ecosystem approach. The NWFSC has gotten ahead of the curve in this respect.

  Much of the collection of ecosystem-level data including social science data, and some ecological data, is not supported by base funding.

  - Recommendations to address issue

A plan for increasing or shifting funding to obtaining critical data for ecosystem-level analysis and assessment is needed. If this does not occur, some essential data bases risk termination with the departure of key individuals.

- **Theme 3 – Ecosystem modeling and analysis**
  - Observations

  The Center is using state of the art methods for analyzing and modeling ecosystem-level processes, and has contributed novel methods in this arena. Cumulative and integrative analyses are being conducted.

  - Recommendations to address issue

A coordinated strategic plan for ecosystem science would strengthen an already excellent program.

- **Theme 4 – Incorporation into Management**
    - Observations
      The incorporation of NWFSC science into management is excellent
    - Recommendations to address issue
      none

- **Theme 5 – Communication and Peer Review**

    - Observations

Communication -

- **The Center sees the Pacific Fishery Management Council as its primary client. All indications are that the research results and resource needs are communicated appropriately and adequately to this client. The research results obtained and communicated probably exceed PFMC expectations. In part this is because the work done here has anticipated future needs, and thus it is able to meet current information needs.**

- **A second "client" group is the scientific community. In many of the presentations we heard, the scientists described their primary communication efforts as publishing papers and speaking at scientific meetings.**

- **The Center has developed and is expanding its website on ecosystem science. There is a goal of providing real-time detailed information to stakeholders. This is an essential project and a vital communication tool that will need additional and sustained funding in order to meet its objectives.**

Peer Review:

Internal peer review appears adequate and the high publication rate in quality journals of the Centers work provides yet another level of peer review. I don't see any need to beef this up.

    - Recommendations to address issue
      Communication Recommendations –

- **Given that the Center aspires to inform EBFM and EBM, I recommend that it broaden it's view of who its stakeholders are and increase its communication efforts to reach its broader constituency. It's clear that many of the scientists working at the center are already gifted communicators. Communication effectiveness can be improved through dedicated training programs.**

- **I recommend that Center staff put greater emphasis on outside communication to the broader public – beyond the "traditional"**

management authorities and the scientific community.

- **I recommend adequate and sustained funding for the website sufficient to achieve the goal of providing real time tailored information for stakeholders.**

Peer Review Recommendations –
None.

- **Other – Puget Sound Investigations**
  - **Observations**
    Puget Sound is an excellent test bed for ecosystem-level data collection, analysis, and implementation of Ecosystem Based Management. NWFSC has an important history and role in this. The expertise of Center staff and the close proximity of the Center to Puget Sound make continued involvement highly desireable.

  - **Recommendations to address issue**

    NWFSC's involvement in Puget Sound should be encouraged and facilitated.

    Consider enhancing citizen science to include restoration activities.

- **Other – Institutionalizing key positions/roles vs. opportunistic, individual-dependent roles**

  - **Observations**

  The Center's leadership in Ecosystem Science depends to a fairly large degree on opportunistic funding opportunities seized by motivated individuals, several of which are on temporary appointments.

  - **Recommendations to address issue**

    To ensure continued leadership in this area of great and growing import, key positions/roles should be identified and made "permanent"

- **Other – Future leadership considerations**
-
  - **Observations**

  The Center has exhibited leadership in Ecosystem-based science and maintained excellence, and a positive, open culture in an era of declining budgets and staffing.

  - **Recommendations to address issue**

    Future leadership decisions should consider the unique, positive culture of the Center. Emphasis should also be placed on selecting

leaders who fully embrace and will further encourage and facilitate the Centers excellence in Ecosystem Based Science and Management.

Conclusions

The Center is a leading institution in ecosystem-based science and management. Given upcoming staff transitions and an era of level or declining funding, maintaining excellence will be a challenge. Development of a clear and coordinated vision, and firming up support for key personnel roles and activities will help ensure continued success. Upcoming leadership decisions are key. A broadened view of the constituency of the center, and enhanced communication with stakeholders is recommended.

Reviewer Report on Program Review of Ecosystem Science

Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

July 12 – 14, 2016

Background

NWFSC staff provided information that describes their relevant ecosystem-related programs in a regional context. The reviewers used this information (and ensuing discussion) to provide advice on the direction of the research programs conducted to meet management needs in the region. In doing this, the reviewers considered 8 overarching questions, which have been organized under 5 themes in the review below. (Other reviewers may allocate questions to themes differently.)

General Observations and Recommendations

The NWFSC provided a well-organized overview of ecosystem related work during the Program Review. It was particularly helpful that reviewers were provided with clear context regarding programs and topics that could have been considered in more depth here, but have either already been extensively reviewed (ecosystem work related to salmon and protected species) or will be fully reviewed in the coming year (human dimensions and social sciences). Similarly, the organization of presentations with common information on the number of employees involved in the work, funding sources, lists of related projects that could not be covered due to time constraints, and "knowledge to action" sections was very helpful in understanding and organizing the large amount of information covered in the review. The evening poster session was a good opportunity for reviewers to interact directly with staff. The organizers and presenters clearly put a lot of effort into this review and it is greatly appreciated. NWFSC participants were helpful and responsive to review panel requests for more or different information throughout the review.

Overall, the NWFSC has an extremely strong ecosystem science program that spans multiple Center divisions and programs, and addresses multiple needs from diverse partners. It is apparent that the NWFSC Directorate sees ecosystem science as a high priority and provides an environment where highly talented and dedicated staff are able to innovate and to collaborate across disciplines. NWFSC scientists have led efforts to develop EBM frameworks, to address interactions between managed (including protected/endangered) species, to address habitat quality, and to develop analytical tools (including software and models) that are generally applicable within and beyond the region. Peer-reviewed publication of results is impressively high and diverse. Many products are feeding directly into management mandates for protected and endangered species and fisheries management.

The work is particularly impressive given the recent history reduced budgets and staff losses (although it was noted that the California Current IEA work has received the bulk of national IEA funding since its inception, which clearly facilitated the development of an exemplary

product). Because much of the funding for ecosystem science at NWFSC is reimbursable or otherwise non-permanent, and because the currently expressed core mandates of NOAA Fisheries do not explicitly include some of this work, there is some risk that the progress made in this region could be slowed or stalled under more constrained budgets combined with leadership changes that place less value on integrative ecosystem research and advice.

The overall recommendations in this review are intended to institutionalize the conditions that have facilitated the highly productive ecosystem science in this region to ensure that progress and innovation continue, surviving changing leadership and uncertain budget conditions.

Key (Specific) Findings and Recommendations (as reviewer has comments on)

- **Theme 1 – Management Context and Strategic Planning**
  Q1. Does the NWFSC have clear goals and objectives for an ecosystem-related science program? Is ecosystem-related science integrated with the other science activities across Divisions within the NWFSC? Are the Center's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?

  - Observations
- There is not "an" ecosystem-related science program at NWFSC; rather there is ecosystem science happening across multiple divisions to address multiple mandates. Therefore, goals and objectives of individual projects are tailored to specific mandates (e.g. endangered species Biological Opinions, HABs forecasting, CCIEA).
- Ecosystem science presented at the review originates in all Center divisions, although one division is less involved in ecosystem science than the other three. Collaborations across those three divisions are generally strong. This type of cross-divisional collaboration is critical for successful ecosystem science.
- The NWFSC clearly identifies an "Ecosystem approach to improve management of marine resources" as one of 4 major themes within its strategic plan. Aspects of the other 3 themes (Sustainable and safe seafood, Species recovery, Habitats) also involve ecosystem science. Foci within themes outline more specific attributes of ecosystem science planned by the Center. These can be considered overarching goals and objectives (although they are not operational objectives for specific projects).
- The Annual Guidance Memo (AGM) identifies several programs reviewed here (CC ecosystem monitoring, Newport line, and Climate Regional Action Plan as "Focus areas" for FY2016. The CCIEA product is identified as a "Core" activity, given highest priority for funding (along with surveys, stock assessment, BiOPs, MSEs, etc).
- The current Science Director stated that he envisions contributions to synthetic IEA products and websites as "business as usual" for the Center in the future.
- The AGM does not clearly prioritize how tradeoffs between the many activities listed as "core research" would be achieved under reduced budgets.
- The annual process for allocating funds between core and focus areas of research is not clear.
- The process for organizing research under reimbursable or non-permanent sources of funding is not clearly outlined, and this type of funding supports a disproportionate amount of ecosystem science.

- While support for ecosystem science is clearly expressed in the NWFSC Strategic Plan and most recent AGM (as well as by current Center leadership both verbally and practically), the above conditions suggest that continued funding and staffing support for the diversity of ecosystem science programs is at the discretion of Center leadership, and that decisions regarding priorities and tradeoffs among priorities may not be transparent, especially with a change in leadership.

    - Recommendations to address issue
- Institutional structures that encourage continued cross-division collaboration (e.g., the internal grants program, physical co-location of scientists across disciplines) should be maintained and expanded where possible.
- Focused strategic planning efforts should take place prior to the departure of current leadership to communicate the vision for making ecosystem science and products "business as usual" at NWFSC. How can this be achieved? What collaborations and partners are required? What efficiencies can be gained within the Center, and what resources could reasonably be redirected to address this vision? How will tradeoffs between the many core areas be addressed if not all needs can be met?

- **Theme 2 – Ecosystem Data**
  Q4. What is the status of oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs? Has the Center developed strategies to obtain and manage such data?

    - Observations
- The NWFSC has established monitoring surveys for multiple trophic levels in both the CC and Puget Sound. Time series are maturing and useful for some applications, but still too short for others.
- Efforts are underway to expand types of data collection on existing surveys to make the most of expensive ship time.
- Advanced technology is being explored and deployed for some applications.
- The NWFSC opportunistically collects information when possible, and is making efforts to synthesize information from multiple sources using innovative spatial and statistical modeling approaches.
- Maintenance of some ecological time series has been done without "base" funds
- Diet data collection requires improvement to address Council needs for forage fish initiatives.
- A "Data warehouse" has been established as a central location to manage data and for researchers to access different ecosystem data types.
- Citizen science is used by HAB and other programs as a means to improve data collection.
- Some IT constraints were noted in data acquisition and management (computing for bioinformatics, firewall issues for transmitting data from AUVs)

    - Recommendations to address issue
- It is assumed that standard groundfish and ocean salmon surveys would continue, but NEFSC should investigate how these and other standard monitoring programs could be harmonized/coordinated for full ecosystem work. A more systematic approach to

strategic planning for monitoring across Center priorities, including ecosystem science, stock assessment, protected species, and habitat should investigate whether increased monitoring efficiency is possible.

- As suggested by NWFSC scientist at the review, data streams could be evaluated by MSE to determine the relative value of expanding or reducing sampling across multiple monitoring surveys. However, the diverse mandates served by the monitoring and climate-driven ecosystem changes suggest that it would be difficult to reduce sampling for ecological data from its current level. MSE could identify which time series are essential and possibly which are not currently available that would improve ecosystem science and advice.
- Feasibility of increased diet collections aboard different platforms should be investigated, and collection by fishing industry partners, recreational fishermen, or other methods should be considered.
- Continued support for Center-wide data accessibility is necessary. The data warehouse seems likely to facilitate much ecosystem science simply because analysts will not need to spent time searching for an organizing data, but it is new. A user survey once the system is established could further improve data management for ecosystem and all Center science.
- IT and computing constraints come from levels above the Center and are common across NMFS Centers. Improved efforts are necessary to work between DOC and NOAA IT programs and scientists at Centers to address and mitigate IT constraints on science while ensuring the level of necessary security for IT systems.

- **Theme 3 – Ecosystem modeling and analysis**
  Q5. Is the Center appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?

    - Observations
- A good balance between data collection and analysis was apparent during the review. Many synthetic and general purpose tools were presented to analyze data, in addition to models developed to address specific questions.
- The NWFSC has impressive analytical and modeling resources for single species, multispecies, habitat, and full ecosystem levels.
- Conceptual models developed by the IEA program are particularly useful for collaborating across disciplines (natural and social sciences) and for communicating relevant ecosystem interactions to stakeholders. Qualitative models based on these conceptual models are a promising tool for identifying key ecosystem sensitivities to perturbations in a fairly complex network.
- Food web models have been developed and applied in Puget Sound and in the NCC. Extensions to the typical EwE framework have been developed and used to incorporate uncertainty into food web model analyses.
- The Atlantis model at NWFSC is well developed and continually evolving to address management relevant questions. This is a monumental task achieved by a very small but clearly capable staff (1 FTE and many collaborations).
- Partnerships with academic institutions have expanded the range of available tools (e.g. a MICE model).

- Multimodel inference is under consideration for ecosystem modeling applications.
- Incorporating social and natural sciences within ecosystem analyses and models has been pioneered here.
- There is a tradeoff between model development and model maintenance, and it is unclear to what extent current (relatively small) ecosystem modeling staff is able to keep up with both demands.
- Planning for model development has been project-specific rather than strategic (similar to many ecosystem programs), although national workshops (NEMoW) have guided ecosystem model development to be consistent with the toolbox in other regions.
- IT constraints on analysis and modeling relate to computing constraints, as well as the inability to use the "tools of the trade" (e.g. GitHub) that foster transparency and collaboration on tool development.

    - Recommendations to address issue
- Evaluate the set of models as a package relative to ecosystem science strategic planning. What is working, what needs more development, what is missing?
- Continue and expand collaboration between social and natural sciences.
- Continue to work with managers to elucidate potential ecosystem level objectives, risk profiles, and acceptable and unacceptable tradeoffs between objectives to further refine modeling and analysis (see below).
- See recommendation above for evaluating the necessity of IT barriers, in particular for GitHub.

- **Theme 4 – Incorporation into Management**

  Q2. Do the Center's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?

  Q3. Has the Center appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy1?

  Q6. Is the Center's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?

    - Observations
- There is a good start on all of these questions. But as with all ecosystem work, there is a long road to get this information into management processes (in particular Council processes) due to a lack of articulated ecosystem based management objectives.
- Direct input to Puget Sound Partnership, PFMC FEP, multiple BiOPs and other management processes was apparent.
- A draft WRAP exists, and is based on the existing CCIEA. A great start that takes

advantage of the IEA framework.

- Mechanisms to determine when inclusion is warranted require further development, in concert with stock assessment specialists and managers and other stakeholders.
- Closed loop management strategy evaluation would be useful to inform management processes and define which ecosystem information is needed for decision making, but ithas not yet been attempted in the ecosystem program.

    - Recommendations to address issue

- Keep it up. Work with the Council, Partnership, and eventually Regional Planning Body to clearly identify objectives for ecosystem based management. Then prioritize data collection programs, analysis, modeling, assessment and advice based on those. Ensure that staff have adequate time in performance plans for this interaction.
- Expanded social science partnerships can facilitate further increases in relevance of science to managers and stakeholders.
- The Center's MSE position should be filled with ecosystem level MSE (including protected species, habitat, etc) as well as stock assessment level MSE in mind.

- **Theme 5 – Communication and Peer Review**

Q7. Are the Centers' ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the Center developed a strategy for peer-review?

Q8. Does the Center appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?

    - Observations

- Peer reviewed publication output is impressive
- Modelers have been involved in direct communication with managers, in particular with the CCIEA
- Atlantis model has been reviewed by CIE/SSC
- CCIEA has been reviewed by national IEA program
- Regional Office involvement in FEP development and ecosystem science has facilitated improved use of ecosystem science at the Pacific Fishery Management Council.
- Communication directly with stakeholders is happening via social science partial employees and partnerships. This both informs ecosystem analysis and strengthens relationships with stakeholders.
- Unclear whether work with Councils/other managers is given the same credit as peer reviewed publication?

    - Recommendations to address issue

- Continue current work, facilitate current partnerships.
- Allocating resources to improve communication of complex information and analyses.
- Ensure that communication with stakeholders and managers is as valued as peer reviewed publication for evaluating staff productivity.
- Continue and expand collaborations with social scientists and further develop stakeholder processes to improve two-way communication.

- **Other**
    - Observations
    - Recommendations to address issue

Conclusions

The NWFSC Ecosystem Science enterprise is a world leader in many respects. The overall recommendations in this review are intended to institutionalize the conditions that have facilitated the highly productive ecosystem science in this region to ensure that progress and innovation continue, surviving changing leadership and uncertain budget conditions.

1. Develop a strategic plan that clearly prioritizes ecosystem science and products within the range of Center products (stock assessments, etc.)
2. Articulate the steps that make IEA and other synthetic products "business as usual"
3. Align and evaluate data collection programs and analytical development to "feed" the envisioned suite of operational models.
4. Invest in more social science connections to ecosystems
5. Invest in stakeholder communication processes

Reviewer Report on Program Review of Ecosystem Science

Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

July 12 – 14, 2016

Background

The NWFSC has a total funding of approximately $60 million USD. The less than $0.5 million spent on the IEA undersells the broad contribution to ecosystem science across the majority of divisions and programs within the NWFSC. It is understandable that in an era of flat or declining budgets that the impost of the additional scope of ecosystem science, ecosystem based fisheries management (EBFM) and ecosystem based management (EBM) may be seen as overwhelming. However, the NWFSC has tackled the challenge head on; using a brave but effective combinations of research collaborations to deliver across a broad range of disciplines.

The science program considers the full gamut from physical drivers and climate change through to the ecological system components and from there to the human dimensions and the drivers of behavior. The consideration of trade-offs and generating science to inform decision making (making EBFM/EBM decisions) is central to the stated work objectives of the NWFSC ecosystem science program.

The IEA framework drawn up by researchers at the NWFSC thoughtfully and systematically includes all aspects of the science needed to deliver to adaptive management; not just in the limited sense of tactical short term decision making, but also the monitoring and evaluation for long term strategic decision making that is often lost. Whether by intent or geographic accident, the combination of the LME scale California Current work and the sub-regional scale Puget Sound work has proven to be a great testbed for quickly coming to grips with what is needed for EBFM and EBM both in terms of the full demands of socioecological cycles (including multi-jurisdictional governance) but also in terms of handling issues of scale. The issues tackled are far from trivial, including multiple use management of highly anthropogenically structured environments through to the delicate issue of multiple interacting endangered species. The NWFSC work has also made significant advances in the integration of local and indigenous knowledge into the broader understanding of system dynamics and desirable states, something that has been put forward by IPBES as both desirable but, as yet, rarely achieved.

General Observations and Recommendations

The work presented during the review is only a small percentage of what is done at the NWFSC. Like the tip of an iceberg it was not only impressive in its own right but hinted at the volume of high quality science done at the NWFSC. Since 2010 the ecosystem science program has produced more than 16 papers per FTE, across both technical, theoretical, disciplinary specific and policy journals; with at least 7 in the highest journals (Nature, Science and PNAS). The vast majority of this work has come from productive collaborations, with less than 1.5% of the articles single authored. This represents an amazing and awe inspiring breadth of work that has definitely taken one of the most tangible steps globally towards real ecosystem

science, going from the theory to practice. This is one of the few places globally that has really begun (in earnest) to do socioecological work rather than simply pay the concept lip service. The work presented was from all the NWFSC divisions (conservation, fish ecology, environmental and fisheries sciences, and fishery resource analysis and monitoring). A network diagram presented during the review illustrated the breadth and depth of that degree of collaboration – although it also showed that the collaboration network is patchy in nature and relies on a facilitative leadership to see it grow and prosper. While the work is truly interdisciplinary (form oceanographers to ecologists, economists, anthropologists etc.) it is still heavily biased towards the natural scientists, despite the IEA team and leadership's acknowledgement that social science is key to delivering both system understanding and management needs.

This work is a testament to the many dedicated and gifted people who work for the NWFSC and their partners. The commitment to being useful and applied scientists was repeated and appeared genuinely heartfelt. It is also good to see the efforts supported by some agency (or at least sub-agency) initiatives, such as the project database shared across the NWFSC, AFSC and SWFSC.

The NW as a region (and the NWFSC as part of that) stands out as an area that has accepted the reality of change and is making the most of opportunities presented to it. The uncertainty of funding that is the increasing reality of modern science is often seen as threatening and off putting and in many nations is seeing scientists turn away to other pursuits. However, while it probably was not joyously embraced at the NWFSC they have done an admirable job of using it to their advantage, to provide flexibility to shape the science as needed – hiring on postdoc's and specialists as needed to grow areas of specific interest. Similarly, the climate anomalies and harmful algal bloom (HAB) events of recent years have not seen people give up or wail about the end of the world, but instead it has seen the regional bodies and communities come to appreciate the needs science can fill. Something that the NWFSC was well set up to respectfully deliver on, in stark contrast to other locations around the world where similar events, or the leap-frogging of scientific capacity by policy, has seen initially positive EBM efforts flounder as the tools were not in place.

The presentations and discussions with Center staff suggest that some thought has been put into how to deliver EBFM (at least by some people). Management uptake has begun, if somewhat informally, and the process has begun to crystallize. However, it is less clear how much of that organic process is sufficiently solid to truly survive additional pressures (and reporting to additional sectors) on shrinking/flat budgets and the leadership turnover. Society more broadly is at a potential bifurcation point between the entrenchment of existing sector based management and more integrated cross sector thinking and governance. It is not clear which valley the ball will roll down, but it is likely that integrated science will be required in both instances to ensure sustainable ecosystems, even if the exact nature and communication of that science would be different in those alternative futures. With that in mind the NWFSC's positioning to deliver in a feasible way to EBM considerations seems a wise one.

The value of this science and the NWFSC's ability to juggle the balance of "must do" surveys with the newer or more aspiration research needs is reflected in the all-round positive endorsement from the public and stakeholder representatives. However, as is always the case the work is not yet done and there are areas for the NWFSC and its next generation of science leaders to refine, expand and lead. The remainder of this report attempts to highlight

existing strengths as well as make suggestions as to the gaps that may be addressed.

General Recommendations

- **The leadership turnover should be taken as an opportunity to more formally review the NWFSC ecosystem science strategy to leave a legacy to support and guide the program** under the new Director and new scientific champions. The loss of thought leaders can be a nervous time for those left in their wake, but the quality of the scientist at NWFSC is such that they should not fear the event, there is plenty of talent who will blossom. Nevertheless, I do not doubt that those same scientists would appreciate the opportunity to reflect on what the big picture is, what holes remain, what directions need to be taken and to generally benefit from discussions around the vision that the departing scientists may have been consciously (or unconsciously) following over the last decade and more. The process of doing this reflection and planning will likely prove far more beneficial than any document it produces, but it would likely prove to be the best means of ensuring that opportunistic engagements, the exploitation of funding streams and the many collaborations deliver most effectively on that ecosystem science vision. Without such guidance it is quite possible that the funding cycle could see the science diverge from the intent.

- Similarly, the changed nature of the marine ecosystems the NWFSC is charged with overseeing have potentially changed the fundamental structure and function of the systems (or at least subsystems). Thus it **would be prudent to take a step back to look at what ecosystem components are delivered on**. The **work is focused on economically valuable species and charismatics; that may be mandated but is it ultimately delivering on what is needed?** What may be needed into the future, given the value of long-term time series that begin ahead of when major change occurs?

- **NWFSC leadership is encouraged to maintain an environment that supports and encourages collaboration and the engagement (hiring) of the next generation of science leaders.** Existing tools such as cross housing of disciplines (i.e. avoiding program specific seating arrangements), internal grants and partnering to hire key capacity (social science) is critical to the ongoing success of the ecosystem science program. There should be no fear that the with the current leadership stepping away that there will be an immediate hole, but wise hiring is required to make sure the generation after that is in place to make sure succession does not falter.

- **The use of the internal grant scheme should continue to be used as a means of supporting new scientific directions and facilitating collaboration.** The program seems an excellent means of getting a great return for very little extra investment. Based on what was presented through the course of the review the grant program has led to some major outcomes (for the world not just the NWFSC).

- **Continue to support the wise use of alternative income streams.** The external grants can be an excellent means of embracing uncertainty and allowing for science capability to be flexibility trialed and targeted at new areas. Partnerships already

appear to have been an effective means for the NWFSC to meet gaps in funding needs and of providing flexibility around tailoring science to the long list of needs, while also allowing for creative development that will ultimately deliver to the core of future needs. This obviously needs to be done with a careful eye so as not to create undesirable vulnerabilities. Where it is well directed it should also be well supported, with barriers kept to a minimum (as much as possible in an agency such as NOAA). The productivity and imaginative science provided by postdocs can be substantial. This has already been used effectively by the NWFSC but further opportunities remain. Although, as all would acknowledge, it needs to be done with a mind to the researchers involved – being clear on potential long term employment options, for instance, and making sure those involved feel the benefits of the situation rather than feeling exploited. (I hasten to add that no current postdoc said they felt that way!).

- **NOAA is encouraged to make the most of existing partnerships, particularly those within the agency.** There was a lot of talk of inter-center collaboration, particularly between the NWFSC and SWFSC and to a lesser degree the AFSC. This should not only be supported, but extended where possible – for example by **strengthening ties** (where sensible) **between the NWFSC and AFSC**. It seems a missed opportunity for the two centers to be so geographically closely positioned but not to be more closely intellectually linked. This may be one means of tackling some of the resourcing issues, if some of the more general needs can become a shared load, making the individual contributions lighter. The project data center seems to be a great first step in that process, but there is equal potential in the scientific realm (e.g. around modelling and MSE technical exchanges).

- Given the importance of ecosystem science and the IEA to the delivery of management relevant science and plans, such as the WRAP, having a small signature FTE wise seems a little strange. **The NWFSC should clearly recognize the value of the IEA and ecosystem science area, prioritizing it to receive at least 1 FTE** (rather than 0.5 FTE). This would telegraph the importance of the work and provide the incumbent the time to do the job well. The team does a stellar job now, but the feeling of continually being asked to do more with no more resources will eventually undermine the excellent morale currently pervading the center. It may well be that this has already been accounted for and it is an intentional strategy to co-fund through a partnership, in which case that needs to be communicated to those involved in a more transparent manner.

- **Careful consideration should be given to how the current toolbox will be maintained long term.** Postdocs are an excellent means of gaining access to new ideas and new scientific disciplines and of extending existing models or tools and developing new approaches. However, the maintenance of tools is a more onerous task that is ill suited to the transient nature of postdocs due to the intellectual and financial commitment involved, the need for continuity and the risk of institutional memory loss.

- **The NWFSC faces the monumental task of trying to bring EBM and EBFM to an enormous coastline**. This seems an insurmountable task. However, **using a hierarchical triage approach and making best use of existing tools may well**

make it more tractable. For example, using qualitative methods to do a first pass assessment and to vet those systems where that is sufficient versus those where more quantitative approaches are required. This approach has been done elsewhere at a national scale and the NWFSC IEA teams is already familiar with the basic methodological approaches (having adapted some of them for specific case studies in the US previously). This is an opportunity for the NWFSC to do what it does best – taking a constraint and making it an opportunity to do things differently; the big data approach of surveys (etc.) will not work everywhere or for everything and this is one way of looking for other options and making best use of the huge intellectual capacity to hand.

Key (Specific) Findings and Recommendations

Theme 1 – Management Context and Strategic Planning

Relevant review questions:

1. *Do the Centers/ST have clear goals and objectives for an ecosystem-related science program? Is ecosystem-related science integrated with the other science activities across Divisions within the Center/ST? Are the NWFSC's/ST's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?*

3. *Has the Center/ST appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy1?*

Observations

There is a long list of PFMC research needs and there has been an obvious attempt by the NWFSC to prioritize it to some degree, as servicing the entire list all in the short term is infeasible. The strategic plan for the NWFSC does have some clearly defined foci for the ecosystem science area. Similarly, there is a regional climate action plan (WRAP) spanning the west coast. The center is clearly addressing its science to the NFMS roadmap, something recognized by the PFMC and others.

Between the various publically available planning documents, the center has a sufficient array of formal documents that address the science needs. However, what appears to be missing (perhaps just not available to the panel) is something that goes beyond the standard agency formal documents to provide the staff with the vision, inspiration and clarity of what is so clearly in some of the minds of key thought leaders. This needn't be a public document, but such a document would likely provide a clearer direction to those interested and engaged in the future science than the more comprehensive "outward facing" agency standard planning documents.

In terms of individual personnel, as with any organization, some members have taken the time to think about what is needed, what presents exciting opportunities (or even just helps more easily deliver on existing goals) and to make connections across groups and disciplines. This has by no means been universal, however.

It is unclear whether the strengths of the NWFSC (development of the tools, level of collaboration etc.) has been done under the guidance of direct strategic thought or under a more organic evolution. Attempting to read between the lines it appears to have been a combination of the two (though with the guidance sitting more informally in a few key minds rather than necessarily transparently laid out). For example, the process whereby the IEA combines multiple products to get maximum information gain seems to have been intentional in some spots and opportunistic in others. This is not a bad model, particularly if it is working. The one risk however is that conditions change and the organic growth withers. Fortunately, discussion with staff indicated that there been at least some brainstorming on what was needed (e.g. around climate change effects) and in some areas (e.g. for sardine work) formal gap or SWAT analyses had also been performed. The evolution of other areas has been more organic – the development of IEA being a case in point, where a need was recognized and the tools delivered to address that before it became a broader agency requirement. This evolution from ad hoc to purposeful seems to have been a useful way of seeing whether it was worth engaging in an area (or feasible) before there was reputation pressure to deliver to a hard deadline and high expectations.

Nevertheless, such organic growth does mean that some potential cross fertilization is missed. For example, a diversity of modelling approaches is to be applauded (and supported, there is no single platform that will deliver in all instances), but there does seem to be the risk of missed technical opportunities given the three different modelling groups (HAB, salmon forecasts, ecosystem wide) have all had their own individual motivations and model development trajectories. There may be some technical lessons that can be shared and (potentially) open up new opportunities or make some savings (if a method typically used with one model type eases requirements for another model type).

It is worth repeating that the NWFSC ecosystem science is of the highest quality with exceptionally good integration across divisions. When pressed on what supports this degree of collaboration it was clear it was a mix of top-down willingness to facilitate the organic growth of collaborations and a bottom-up desire of co-located individuals to see how their joint capability could be gainfully employed on new questions. The internal grant scheme seems to be a very popular and extremely important means of delivering on this.

The final contextual aspect is that it is clear that the NWFSC is cognizant that it delivers to 4 mandates, not just the MSA, and that this is seen as clear motivation to move to EBM (rather than simply aiming to achieve EBFM as the next rung in the policy aspirational ladder). This mindset has perhaps been facilitated by their ability to shape their thinking around Puget Sound case studies. This scientific arena has been a hot house of the globally pressing issues of multiple anthropogenic use of coastal and nearshore marine zones, but is on a tractable geographic scale with engaged and open minded interest and governance groups. The potential of this location has been used to great effect, but is also reflected in the degree of development of the NWFSC's work on HABs and the human dimensions.

Recommendations to address issue

- Sufficient formal planning documents appear to exist, however **the center should take the opportunity presented by this point of renewal to review the vision and**

to more transparently document current thinking, providing guidance for future direction setting decisions. The intellectual legacy of those departing the organization will be greatest for all involved if they can take the time to engage with those remaining to transmit that vision and use it as a leverage point for the new leaders to build from. If this is not done there is the risk that the advances may be slowed or lost.

- **NMFS should be careful to select a new center director with a background (or psychology) that sees them sympathetic to the vision and ground breaking direction set by the NWFSC.**

- **The use of grants should not be seen as a threat**, as it reflects the NWFSC's entrepreneurial approach to doing science. **However, grants must be used wisely** and under guidance from the vision, so (i) key science areas are not unintentionally put at risk and (ii) so that the vision is not accidentally lost be the contingencies of the grant topics. In addition, **given the importance of grants to the center, support for junior staff to increase their chances of success seems a wise investment**.

- The **on-going use of the internal grant scheme is strongly encouraged** as it appears to be an extremely productive means of facilitating novel science and close collaborations to the benefit of the center, science and (ultimately) society more generally.

Theme 2 – Ecosystem Data

Relevant review questions:

4. *What is the status of oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs? Has the Center developed strategies to obtain and manage such data?*

Observations

The center undertakes an impressively broad array of surveys and other data collections that cover some oceanographic properties, key fish species and even some aspects of the human dimensions (e.g. some economic and social statistics). The biophysical surveys are world renowned for their longevity, coverage and frequency. Nevertheless, they are expensive and new technologies may need to be used to ease the load or to allow for new data streams to come on line that address some of the additional needs that arise when moving form stock considerations to ecosystem process and function in the context of global change. Effective engagement of industries, NGOs and society in delivering alternative knowledge and "citizen science" data streams may also be an effective means of expanding the available data (and achieving management outcomes, such as restoration or incentivized changes in behavior).

Partnerships have already been used to good effect to collaboratively deliver on science needs. For example, the center relies on the NOAA Pacific Marine Environmental Laboratory (PMEL) to deliver information on physical oceanography. Similarly, the low

number of social scientists on the permanent staff has been compensated for (to some degree) by collaborations with leading experts in other institutions. This has been productive, but care needs to be taken that there is still true "ground-up" integration of the social scientists into the IEA and other ecosystem work rather than seeing it as the (eventual) "cherry on the top" supplied at some later date. True integration is required to best meet management needs, where social and economic concerns can equal (or exceed) ecological ones. A good number of center staff have made the attitudinal transition – recognizing the diversity, inherent value and equal reputational standing of the social sciences and economics – but it is not yet a universal appreciation.

This is good recognition amongst center staff of the value and limitations of the data available to them. For instance, there is recognition that there is a strong seasonal bias to existing data and that there is insufficient process understanding to provide mechanistic explanations for some key processes, especially in the context of global change. Focusing entirely on what can be garnered from old data is likely insufficient when anomalous events of the kind witnessed over the past few years in the California Current occur or become more common. At present there is a strong reliance on correlations as proxies (e.g. for recruitment drivers), which in more stable conditions may have been a very logical means of making the most of scarce resources. Unfortunately, such relationships are known to become unreliable as conditions change. Similarly, much of the human dimensions' work is currently descriptive and not yet process oriented. While a suitable place to start on such complex topics it needs to advance if IEA and ecosystem science more generally is to mature. If the benefits of EBFM and EBM are to be realized (i.e. in terms of avoided opportunity costs) then both the management and science need to go beyond target species status and commercially oriented community-ecosystem links.

The center staff's interest in the ecosystem and its dynamics has naturally lead to concomitant interest in understanding shifting processes, such as phenology, feeding and the effects of range shifts. Given the importance of habitat and the need to supply information on essential fish habitat there is a clear (and acknowledged gap) around having a ground-truthed seabed map of even moderate resolution along the entire coast. Identifying trawlable and untrawlable ground, for example, is not simply important scientifically, but also in terms of management needs and understanding of implicit refugia.

There is (justifiable) concern amongst many of the researchers that the volume of historical data and the maturing of models will lead to a relaxation of the perceived need to fund monitoring. Indeed, it was clear that monitoring and even a broadening of the samples that can be taken (e.g. via new methods) is desired as the system changes have highlighted new data needs. For example, center staff, the regional office and other stakeholders all identified the need for modern food habits information so that up-to-date conceptual models could be drawn of the key sub-systems. Moreover, while management imperatives may shift once a species is de-listed, management information needs about status, trends and the interaction of those species with other ecosystem components remains (e.g. amongst the complex of threatened, endangered or protected species that compete with, or predate upon, each other). In addition, empirical data is needed to verify risk analyses or hypotheses generated from models.

Discovery and use of existing data is being made easier via the use of centralized data discovery and storage tools (though some duplication remains and further efficiencies around data centralization may exist).

Recommendations to address issue

- **The center is strongly encouraged to continue to make the most of collaborations and partnerships to deliver on data needs and new science areas** (e.g. in the social sciences).

- Further to the recommendation immediately above, **where possible the value of the social scientists** (beyond economists) **should be directly acknowledged** (e.g. by providing for a full FTE funding) **so that full integration can be achieved more readily**.

- **Support should be provided to explore the utility of new methods/technology for cost effectively supplementing, extending or improving the efficiency of data collection** (e.g. to cover the "missing" parts of the ecosystem such as mesopelagics, benthic invertebrates, aspects of the human dimensions etc.). This is already happening in some areas (e.g. HABs, some diet data sources, data for historical reconstructions), but additional opportunities (e.g. around citizen or industry based data streams) could be explored.

- **The NWFSC's use of historical environmental variability and space-for-time substitutions to help inform forecasts should continue to be supported** as a cost effective means of making advances in the face of uncertainty and without full system wide information.

- **The NWFSC's expertise with qualitative methods and MSE simulation testing should be used to explore the their own operational options**. For example, the costs, benefits, value and efficacy of alternative monitoring schemes could be MSE tested; and qualitative modelling could be used to identify the key points of collaboration across divisions to deliver on EBM and the broader NWFSC vision for ecosystem science.

Theme 3 – Ecosystem modeling and analysis

Relevant review questions:

5. *Is the Center appropriately analyzing and modeling ecosystem-level processes?*

Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?

Observations

The NWFSC has put a significant investment into a range of modelling tools – e.g. single species, qualitative system approaches, MICE, Ecopath with Ecosim and Atlantis. At least some of these tools have intentionally been developed to have the capacity to address

cumulative impacts. That investment is reaching maturity and the diversity of approaches maintained is to be applauded, as is the participation in the modelling forum and ensemble work. That is the future of ecosystem modelling science.

The toolbox is beginning is to see broader use, but many opportunities remain – such as the use of qualitative models (i) to explore (triage) EBM options, (ii) as a basis for performing rapid screening of indicators and (iii) as a means of undertaking structural sensitivity analysis that can inform quantitative modelling efforts. Similarly, the true potential of MSE is yet to be realized (both in terms of monitoring design and for informing management decision making); although center staff should be lauded for the effort they have already put into advancing that work and the engagement with the many relevant management bodies. It is a long and sometimes seemingly thankless task.

The expansion of the toolbox to ecosystem assessment tools and forecast models is an exciting extension that seems to be directly responding to management requests. However, there needs to be a stocktake of the true resourcing needed to maintain and refine the toolbox, as well as extend it in future. Grants and postdocs are an effective means of doing development but they are a risky strategy when it comes to longevity of approaches (due to the nature of that work and the potential for institutional memory loss).

Recommendations to address issue

- The investment required in developing and maintaining a toolbox of approaches is high, but so are the benefits of using a diversity of approaches. Thus **effort should be made to formally connect with AFSC, both have strong modelling teams with lessons to share**.

- **Given the maturity of the modelling toolbox it should now be used in novel ways** (as noted already for triaging EBM and MSE or sensitivity testing options).

- **Cross fertilization of technical modelling methods** (e.g. in joining biophysical and human dimensions) **is currently largely organic and may benefit from more explicit support** – particularly when venturing into ecosystem aspects that are not regularly modelled in a management context (such as cultural aspects). **On-going agency level support for the technical workshop series** (e.g. ecosystem modelling, extension of stock assessment methods to EBFM/EBM considerations) **is strongly encouraged**.

- **Cyber secure methods of engaging with modern data and software sharing platforms (e.g. Github) need to be found as they are the principle means of sharing in that scientific community globally** and to simply ban their use blocks the researchers from that broader intellectual community (frustrating their progress and efficiency) or leads to behaviors that ultimately undermine security.

Theme 4 – Incorporation into Management

Relevant review questions:

2. *Do the NWFSC's/ST's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem- related information to achieve their mission?*

6. *Is the NWFSC's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?*

Observations

While the input of ecosystem science into fisheries management remains largely informal, or ad hoc, significant progress has been made and the IEA is openly acknowledged as framing other decisions made by the council. Credit for this level of success must be laid squarely at the feet of the science leadership and IEA teams who have taken the time to build the relationships and take the journey with all involved. This is clear from the high level of praise given by the regional office, NGOs, council and other stakeholders: "Marvelous foundation and high quality ecosystem science… if they can do more then they should definitely continue and expand into cross-disciplinary cross-cutting work"; "The Council is very glad to have had the scientific input into the FEP". Furthermore, all center staff seem themselves as directly delivering to management in one way or another (a great testament to their commitment).

The IEAs have gone through many phases already, but are not quite mature as yet – there is an on-going evolution of understanding of prioritization and capability required (both within the science and management uptake). There is still a long journey ahead to EBM however, as there is no formal EBM agency (reporting remains sectoral) and even the operational form of EBFM is not yet clear. This has led to concern (by stakeholders and scientists alike) that in pursuing EBM either more and more expectations will be laid upon a static pool of resources or that the extension to new areas will put existing core science delivery at risk. Neither is the intent of the NWFSC, but they are legitimate concerns and again tools like MSE could have useful input here as to where the greatest benefits and costs lie. At present it is clear to all (a point made by the PFMC representative) that the traditional stock assessment base remains core, but there is a realized need for the ecosystem work and the balance is changing (this shift has likely been accelerated by recent anomalous environmental events).

The positive benefits of a responsive attitude of science to management is reflected in the development of forecast models, in addition to the long term scenario oriented end-to-end models. This recognizes the need for management relevant information on the 3-5 yr scale alongside the pressure to deliver insights on longer climate change scales.

From a management and stakeholder perspective, the socioecologically relevant priorities lie around: updating foodweb understanding, habitats, climate aspects (variability, vulnerability, and tipping points), bioregionalisation and social indices (e.g. vulnerability and dependency of fisher communities and the impacts of management

decisions on that). MSE testing is considered a particularly important tool (it was the top agenda topic in cross council meetings) and support from the center is sort in support of advancing that. The capacity of the NWFSC to maintain sufficient scientific flexibility to provide help with hot topics as they arise (so management can react quickly) is also desired and appreciated.

More strategically, the stakeholder community would like the NFWSC to keep working on the effects of fishing on the NW socioecological systems and to assist in finding sustainable options for management. The EBM roadmap is seen as a useful document for laying out the process and the potential for IEA to grow beyond fisheries (e.g. into habitats and protected) species is recognized. However, management will still need to deliver on their responsibilities as the transition to EBM happens and they encouraged the scientists to continue to deliver true engagement and clearer lines for immediate uptake rather than become mired in theoretical efforts. Nonetheless, they are grateful that NWFSC scientists helped shift their thinking from retrospective to forward looking (something that deserves praise and credit as such exercises are not easy).

Engagement with stakeholder and management groups requires significant time commitments (on both sides) and the regional liaison in the NW is a unique position nationally (initially personality driven). This level of engagement will only grow as more sectors need to be included with the move from EBFM to EBM – the shift will not be an easy one in terms of resources or philosophy, as fisheries are typically far ahead of other sectors in terms of their readiness around the principles of decision support and adaptive management. Nevertheless, there is a tangible benefit to increased ecosystem literacy in terms of more educated end point decisions.

Stock assessment scientists are a group who appreciate the time commitment needed to deliver on management needs. As their remit has expanded into reporting on ecosystem considerations they have become more and more time and resource pressured. This is where smart resource sharing (e.g. IEA team providing the ecosystem considerations and indicators for assessment reports) could free up time for the assessment group to pursue new options (e.g. using ecosystem indicators to inform short term projections), explore hypotheses stock assessments have raised, or to help secure funds to do the sampling required to achieve greater process understanding and thereby reduce uncertainty in management advice.

Recommendations to address issue

- **The NWFSC is encouraged to provide support to scientists to facilitate the transition from scientific surveys to management relevant monitoring schemes** (e.g. for HABs) – or at the very least to provide them with the resources to see if such a transition is feasible.

- **The expertise of the IEA team members should be used to deliver on the ecosystem considerations component of stock assessments, with the goal of better using resources, freeing up time and providing information to help deliver process understanding so that assessment uncertainty is reduced.**

Theme 5 – Communication and Peer Review

Relevant review questions:

7. *Are the Centers'/ST's ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the Center/ST developed a strategy for peer-review?*

8. *Does the Center/ST appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?*

Observations

The polished look of key IEA and EBFM graphics indicates that the NWFSC takes communications seriously. While they are still navigating around agency imposed constraints on website functionality they expressed good intentions on what and how information should be delivered.

The scientific standards around peer reviewed publications are also exceptionally high – not just in quantity but quality, with many publications appearing in the highest rated technical and cross cutting journals. The center appears to be one of the leaders nationally (and potentially globally) in its contributions to EBFM, EBM and applied marine socioecology.

However, a few comments by the NGOs indicated that perhaps there is some ways to go before the NWFSC's communication with the broader public is considered to have hit the mark in terms of accessibility. Relying on NGOs to "interpret" the science (even unintentionally) comes with some benefits (around their engagement and understanding) but also risks (around the control of messaging).

Recommendations to address issue

- **Good communication is not cheap and resources must be set aside to do it well as it is a value amplifying exercise** that is at the heart of the uptake of science and successful EBM.

- **The true cost of maintaining relationships needs to be recognized and appreciated** (and supported).

- Not everyone is a natural communicator and **staff training around effective communications would likely be highly beneficial**.

Other

Partnerships

Observations

The NWFSC has many close partnerships – particularly with the SWFSC, UW and other universities and the Puget Sound Partnership. This level of collaboration has been effective in supporting the delivery of integrated ecosystem science. This world class reputation comes with the pressure of expectation and maintaining it is tied to maintaining the collaborative spirit.

Recommendations to address issue

- **The center is strongly encouraged to maintain, support and facilitate their collaborative partnerships** – the productivity of these partnerships is why the center is seen as an exciting and world class place to work.

The Whole Enchilada

Observations

Projects such as the Ocean Tipping Points work (and the IEA more generally) highlight the collaborative nature of the NWFSC's work and show it at its best - multi-institutional, multi-disciplinary with value academically and for management. The impressive advances in this project highlight how the small internal grant process (and the long history of supporting science and data) can see enormous returns. This kind of works shows the way forward on the national and global stage, as it fully recognizes the importance of a socioecological perspective, going beyond economics to consider social end points, and provides information relevant to the operationalization of EBM.

Recommendations to address issue

- The center should be **encouraged to continue supporting such cross cutting work** as it is leading the way on how ecosystem work needs to be done and the benefits of doing it well.

Conclusions

The quality of the work presented during the review was outstanding. However, with high achievement comes high expectation and the pressure is now on not to slip as staff turnover occurs. This should be possible, however, via transitional activities including: sharing the vision and allowing it to flower and evolve amongst a new generation of thought leaders; and hiring in support of succession planning (ensuring the legacy continues and prospers for many intellectual generations to come).

The NWFSC recognizes it serves multiple mandates and has already used that as justification for moving to EBM. Servicing that decision has not been trivial and has involved a funding model that is not seen in any other center. This comes with increased flexibility but also some risks. Communicating this balance to the next leadership group will be important for the NWFSC's ongoing success.

The advances into integrated methods, human dimensions, effective communications and engaged uptake of IEA are all benchmark setting. However, they are also all resource hungry. There is an opportunity to help keep EBM tractable by using the existing investment and partnerships to the fullest and by exploring new technological initiatives as they arise. By its very nature ecosystem science involves non-stationary processes and components from (effectively) every field of science. Rather than being overwhelmed by piling all of this one on top of the other it is a matter of becoming the integrating conductor that draws it all together. The NWFSC has taken some giant strides down that path and I for one am excited about where it leads.

Reviewer Report on Program Review of Ecosystem Science

Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

July 12 – 14, 2016

Background

This review began with Dr. Merrick asking 1) is the NWFSC doing the right ecosystem science, 2) doing it well, and 3) translating it into management advice. The answer to these questions is yes, yes, and in process of becoming the regular situation.

EBM requires interdisciplinary work and one cannot force people to be interdisciplinary. Effective EBM will also require working in Pasteur's Quadrant (see Stokes (1997) *Pasteur's Quadrant*. Brookings Institution, Washington, DC) in which the search for fundamental understanding (whether it is in the natural or social sciences) is motivated by an important applied problem.

The Ecosystem Science work at the Center has the goal of informing decisions by the Pacific Fisheries Management Council, which can be viewed as the client for work (both stock assessments and advice). The Council priorities as given to us by their representatives and interpreted by me are

- An updated California Current (CC) food web (current one circa 1960-1990 data);
- Preparing for climate change (OA, Temperature, Hypoxia, Precipitation, changing biotic communities);
- Exploring how interacting management programs affecting fisheries/people/non-target species and ground truth the models in coastal communities; and
- Preparing to manage for tipping points, which are hard to predict, but it is possible to manage to avoid them.

However, until I asked about them, there was no clear articulation of the priorities.

A minor point: I suggest providing badges for the panelists, especially if there is going to be a poster session.

General Observations and Recommendations

The Center has done a remarkable job in the development of interdisciplinary ecosystem science, especially in times of lean budgets. This has been achieved by having highly motivated individuals, including post-doctoral colleagues, and by leveraging the Center funding with external grants.

But this is a critical moment for the Center's ecosystem research because of the exit of Drs. Stein and Levin. With appropriate attention from NOAA Fisheries, and increase in moral and financial support, the stellar trajectory in ecosystem research can be maintained.

Key (Specific) Findings and Recommendations (as reviewer has comments on)

• Theme 1 – Management Context and Strategic Planning

Observations The vision of the Center and of the Council for Ecosystem Science is not nearly as clear as it could be (especially for the NOAA scientists doing the work).

The Integrated Marine Ecology and Nearshore Ecology teams are remarkable. They embody applied community ecology in Pasteur's Quadrant, including human behavioral ecology, field work (particular near shore diving), and connections to academic ecology. They are a cohesive and collaborative group who show creativity and flexibility in their work, collaboration across division and the ability to learn new methods.

Post-docs remain essential for the Center overall and for Ecosystem Science. The work of Dr. Shelton Ole on eDNA is an example of what a post-doc with modern skills and the ability to conduct intellectual exploration can achieve.

Recommendations to address issues

Before leaving, the current Center director should develop an Ecosystem Science Strategic Plan (see below) and the new director needs to understand the culture of both NWFSC and the Ecosystem Scientists. The current Director should assemble a team of scientists to meet weekly for 1-2 hours for about 3 months to develop a strategic plan, asking "what should Ecosystem Science look like here in 5, 10, and 15 years". This plan should be linked to the current IEA work, the WRAP, and the ecosystem goals of the PFMC.

When selecting the next Director of the Center, he or she must understand the culture of the NWFSC, the importance of writing proposals (also see below) and the importance of seed funding.

The Integrated Marine Ecology and Nearshore Ecology teams should be kept together even though Dr. Levin is leaving. I recommend that the current Director ask them to hold a retreat and determine a collective vision for their own work. I also recommend that Dr. Levin's FTE and associated funds be returned to the group (my guess is that it should be possible to support both a new FTE and a post-doc). I note that the demography of these groups could be improved by the hiring of women, scientists of color, and young scientists.

Efforts should be made to increase the number of post-docs in the Ecosystem Science program; some of these may end up with permanent positions but that is not requisite. A young and enthusiastic person who spends 2-4 years at the NWFSC can have effects long after leaving.

In this regard, the QUEST program in the Office of Science and Technology is an ideal source of potential additional postdoctoral funding, which I recommend be directed to Dr. Levin at UW with specification to work with the Integrated Marine Ecology and Nearshore Ecology teams .

Theme 2 – Ecosystem Data

Observations

All monitoring requires hypotheses (since there are simply too many things to measure otherwise) and it is easy NOT to do this with large field programs. In general, many of the talks that we heard made the hypothesis-driven nature of the data collection clear, but some did not. There are two databases for diet samples.

Modern statistical methods are being both developed and used by the Ecosystem Science researchers; this allows old information to be used in new ways and gaps for new information to be identified

Recommendations to address issues

Ensure that sample size for surveys is hypothesis driven (which will ensure, for example, that one knows how the diet data are integrated into other ecosystem work). This would also allow – in a time of constrained resources -- optimization of survey design. These could change how we think about un-surveyed locations – as well as being used for designing surveys.

Combine the two databases for diet samples.

Continue to encourage the development of new statistical methods and the use of modern Bayesian and likelihood statistical methods**.** In particular, formally investigate tradeoffs in monitoring (yearly, biyearly) using MSE and methods for filling in missing data.

Theme 3 – Ecosystem modeling and analysis

Observations

Ecosystem modeling at the NWFSC is at an international level of excellence. Even so, I note a few missing pieces. For example, although we heard many talks about temperature, we heard no talk about applying ideas from the thermal ecology to the data; many of the social science questions require answers from a human behavioral ecologist, not just an anthropologist; and ensemble modeling appears to be done outside of the NWFSC.

The combination of retrospective analysis, new data, and modeling as the nexus for prediction and understanding is at a very high level. Even so, additional process level modeling will allow the science to move forward in a number of instances**,** such as

- What underlies the human impacts forecasts;
- Forecasting Harmful Algal Blooms (HABs)
- Understanding the links between the PDO and salmon returns.

Predicting the northward migration of fish will require more than understanding their thermal preferences, one needs to understand the life history tradeoffs between predation, food finding, and energetic costs.

Qualitative network analysis provides a powerful tool to address data poor systems and the nexus of natural and social systems.

MICE models are very powerful, but can be challenged because they do not fit all of the data.

Computing can be improved through access to Dropbox and GitHub, clusters for the Atlantis work, and dedicated support for the IEA website.

Recommendations to address issues

The solution to many of these issues is targeting hiring: an individual working in thermal ecology; a human behavioral ecologist (or perhaps a psychologist who works on fisheries issues); an individual who is skilled in a variety of modeling methods to do ensemble modeling; and a life history modeler.

Process based or state space modeling (as in the MARSS software, which has a very specific structure) needs to be further developed at the NWFSC. A natural starting point, which would also link across divisions, is to develop process based models for size at age and the stock recruitment relationship (rather than treating them as solely statistical objects) for stock recruitments. This may require additional funding for FRAM to conduct process based studies.

Similarly, process based trophic models can be used to link across the trophic levels from primary or secondary producers to salmon and process based behavioral models will allow us to understand how light limitation in the northern latitudes will affect the northward migration of species (as they trade off higher metabolic costs with decreased food finding).

Continue the development of the methods of qualitative network analysis.

Empiricists and modelers together should develop the data that needs to be explained by a MICE model or ensemble models for them to be considered appropriate for management use.

Figure out a way for scientists to have access to Dropbox and GitHub, develop internal clusters for the Atlantis work, and provide dedicated support for the IEA website.

Theme 4 – Incorporation into Management

Observations

Integrated Ecosystem Assessment is both a process and a product and as such, can feed into management both indirectly and directly.

We heard a very interesting 'pre-review' process (outside of NS 2) for the Atlantis model, and some critical comments from Dr. Merrick.

The work on tipping points, although in preliminary stages, has great potential for management.

Recommendations to address issues

Encourage the kind of pre-review that was used for the Atlantis model to continue, so that by the time a model reaches the SSC formally, at least some of the members understand what is going on with it.

Continue the work on tipping points, with communication to PFMC and stakeholders.

Theme 5 – Communication and Peer Review

Observations

It is clear that the communication with the client (PFMC) and stakeholders is excellent but it is also challenging. The peer-reviewed publications are astounding in both number and quality and at an international level of excellence.

Recommendations to address issues

Ensure that engagement with the public and the council has rewards comparable to peer-reviewed publication. At the same time, continue to encourage the outstanding level of peer-review journal publications.

Other: Crossing Divisions, Funding, and EBM in the Puget Sound

Observations

I am impressed by the level of collaboration across divisions, but such collaborations are always threatened in a time of poor budgets. In general, external funding is required to maintain Ecosystem Science. Although there are no federal fisheries in Puget Sound, it is the ideal place to test and ground-truth EBM.

Recommendations to address issues

Since collaboration is more often than not established by physical proximity, consider putting ecosystem scientists from different divisions physically together.

In addition, it is appropriate to ask the IEA staff to write the ecosystems effects of stock assessments, and – as described above – to develop process based models for size at age and the SRR.

The internal grants program is essential and must be maintained; it can also be used to encourage cross-divisional collaboration.

Since in the short term at least, proposal writing will become more and more important. More than just tolerating proposal writing, develop a general culture of proposal writing that will include formal training (many scientists still do not receive such training in graduate school) and ensuring that barriers (which differ according to the source of funding) are as low as possible.

Conclusions

Wayne Gretzky said "A good hockey player plays where the puck is. A great hockey player plays where the puck is going to be". Ecosystem Science at the NWFSC is great. The scientists there are creating tools that are flexible and can address future questions thus providing crucial and timely ecosystem science input to managers.

Reviewer Report. Program Review of Ecosystem Science

North West Fisheries Science Center
Seattle, WA
12-14 July 2016

Background

General observations and recommendations

- Overall, the North West Fisheries Science Center (NWFSC) is definitely doing great science, and in general doing the right science, in regards to ecosystem issues and marine management
- World-leading activities on ecosystem based marine management science, in particular statistical and modelling studies;
- Multi-model approaches are crucial and do not represent duplication of modelling efforts
- Harmful algal studies are hugely important and 'first class', in particular considering current trends of increasing frequency and severity of events.
- Puget Sound ecosystem science activities are important as a case study to develop ecosystem approaches for management
- I had expected to hear more about spatial management approaches as tools for ecosystem-based management.

Key (specific) findings and recommendations

Theme 1 – Management context and strategic planning

Observations:

- In the overview from Headquarters, there is a clear focus on Ecosystem-based Fisheries Management (EBFM). In my view, the (aspirational) goal should be broader, i.e. to Ecosystem-based marine management (EBM). There are many other human pressures on marine ecosystems in addition to fisheries. Too strong a focus on fisheries issues risks ignoring or downplaying impacts on marine systems that are within NOAA's mandate and which can have significant effects, at both local and regional scales. These other pressures were presented during this Program Review, demonstrating that ecosystem science activities by the NWFSC are broader than 'just' fisheries. Examples include the excellent work being done on Harmful Algal Blooms (observations, identification of ecosystem and human health impacts, and forecasting), the effects of large urban areas

on marine ecosystems, and the activities in Puget Sound which provide a very nice case study to develop ecosystem-based management at 'tractable' scales.

- The 'human dimensions' work is exceptional, and clearly related to the 'aspirational' goal of moving towards ecosystem-based management
- The Center is entering a period of significant transition of leadership. This creates both opportunities and challenges for the continuation and elaboration of ecosystem science.
- What was missing from the presentations? I had expected greater discussion of marine spatial planning issues, both as an important management tool but also as a driver for important scientific studies. Marine spatial planning and identification of "hot spot" areas (however that may be defined) were not totally absent from the work presented, but they were definitely not highlighted. Similarly, I had expected greater mention of benthic invertebrates, both of commercial and ecosystem importance. The presentation from the NOAA Regional Office listed specific numbers of fish, mammals, turtle species for which they are responsible, but "many marine invertebrates". I realise many of these may be managed by the State, but they do play important roles in the marine ecosystems of this Region (not to mention the important habitat roles of corals, sponges, etc.). There was almost no mention or presentation of physical oceanographic work or activities. These may be conducted collaboratively with Universities or the Pacific Marine Environmental Laboratory, but then how are the NWFSC needs for physical oceanographic information prioritised among the many competing needs of these other institutions? The example of the warm water anomaly (the "Blob") in 2015, and its importance at focussing Pacific Fisheries Management Council attention on ecosystem-based management issues, serves to emphasize this point (i.e. that all of the physical oceanographic work on this issue was done outside of NWFSC).

Considerations to address these issues:

- Continue the focus on ecosystem-based fisheries management from the Headquarters levels, in particular in the context of the 'roadmap' (which clients referred to as being helpful), but include more recognition of the importance of non-fisheries related issues and pressures.
- Continue to support and enhance 'human dimensions' work, for example by providing more consistent support for social scientists and their work as embedded within natural science divisions (funding support for salary and research). Care needs to be taken that social scientists feel they have the latitude and support to conduct social science research, i.e. ensuring there is an effective minimum 'critical mass' of social scientists.
- This period of transition in ecosystem science leadership within the NWFSC needs to be actively managed. For example, a written and clear document needs to be developed which lays out the Center's current ecosystem science activities and goals, and presents

the needed near-future activities and goals (i.e. where are we now and where are we going). This should be done by the current Center science leadership and not left to their replacements. It will be an important legacy.

- Raise the profile of marine spatial planning among the tools for ecosystem science and management of human interactions with ecosystems. Include benthic invertebrates as integral parts of marine ecosystems and incorporate their interactions with vertebrate species (if not already done). Consider needs for, and prioritisation of, physical oceanographic studies and information.

Theme 2 – Ecosystem data

- There is an apparent distinction between "core" ecosystem science activities (e.g. as related to direct stock assessment and endangered and threatened species requirements such as fishery-independent surveys) versus 'peripheral' or 'ancillary' studies which inform about broader ecosystem conditions but for which, at least at present, impacts to assessments and endangered and threatened species are indirect. The latter include, for example, plankton studies, small pelagic surveys, and harmful algal blooms. Information on these issues is crucial for detecting changes in marine ecosystems due to natural processes, but their direct input into assessments may be more 'contextual". Research teams on these issues are small, and research funding appears to be largely reimbursable via outside proposals, or by collaborations with outside groups (e.g. reliance on community observers for HAB events and sample collections). This places these programs at significant funding risk and collapse, in particular if key researchers leave. I note that the plankton observations focus on one transect off Oregon. This is excellent high temporal data (every two weeks), but it is unclear whether plankton observations are being taken at other locations along Oregon and Washington coasts.
- Food web models require observations of who is eating whom, and how these vary over time and space. There is a need for lots of gut contents analyses, and/or chemical/genomic techniques to define food web structure and variability. This issue was also highlighted as a direct management (Council) need. At present, food web studies appear to be program-specific, done by some programs, e.g. marine mammals, small pelagic fishes, some groundfish surveys, but not other programs.

Considerations to address these issues:

- ‘Peripheral’ studies and programs should be incorporated more fully into assessment and endangered and threatened species programs so they become essential information
- A Center-wide examination of how information on feeding relationships (gut contents, etc.) are obtained would be helpful to obtain better use of these data. This examination would benefit from analyses of the number of samples needed to show differences and trends, considering the often huge time and space variability of predator-prey relationships.

Theme 3 – Ecosystem modelling and analysis

- The ecosystem statistical and modelling activities of the Center are world-leading, and very impressive.
- Length (number of years) and breadth (variables observed) of time series are very impressive, for example plankton, small pelagic fishes, fishery-independent bottom trawl surveys. Surveys of non-trawlable grounds is a gap, but one which is recognised and in the process of being addressed by alternative methods. However, the small size of these teams (e.g. plankton, which currently seems to be one FTE surveying one line off Oregon) and the ephemeral nature of funding for these activities (i.e. via outside grants and proposals) is a concern. It is unclear how critical these programs and their data are to the Center’s ecosystem science activities, and to the data integrating studies, e.g. models, in particular. Similar comments and concerns apply to the Harmful Algal Bloom studies.

Considerations to address these issues:

- Ecosystem science programs at the Center would benefit from analyses to determine the weight and importance of these time series to the various integrating/model studies. For example, how reliant/vulnerable are the ecosystem models to loss of any of these time series (in particular consideration the ephemeral nature of their funding)? Analyses to answer this question could be done within a management strategy evaluation framework of data needs for these models.
- Similarly, collection of these time series would benefit from structured analyses of optimal sampling strategies. This should be facilitated by the long length of many of these series and the variety of oceanographic and environmental conditions which they span.

Theme 4 – Incorporation into management

- Overall, the incorporation of ecosystem science into marine management advice is a 'work-in-progress'. The Integrated Ecosystem Assessment (IEA) framework and the California Current IEA are clear and significant advances on this problem; they need to be fully supported. However, application of the IEA is at a disadvantage with lack of clear objectives on the part of management 'clients' for how to incorporate ecosystem science into management advice. A clear management concern is advance warning of significant changes of state, and their potential impacts (cf. tipping points), or at least rapid identification post-event that significant changes have occurred (which is different from variability). Impacts of ecosystem changes to human communities which are dependent on marine systems are also clear management concerns.
- Lack of ecosystem science in statutes, other than NEPA, is also a disadvantage
- To date, major accomplishments have been to provide important contextual/background information on ocean and ecosystem conditions. The importance of this is hard to demonstrate quantitatively, but it appears to have significant qualitative impact. Illustrating the importance of ocean and ecosystem conditions to the business of the Pacific Fisheries Management Council has been enhanced by the very unusual conditions in 2015 (warm "blob"), of which the ecosystem science programs of the Center have taken advantage.
- Need to work with assessment scientists to find ways to incorporate ecosystem indicators and advice into 'regular' stock assessments. Progress is being made with sablefish assessments. There is huge international effort regarding incorporating ecosystem indicators into stock assessments; the extent to which the Center is involved in these activities is unclear.
- Harmful Algal Bloom issues have clear management implications and a process for inclusion into management advice (including both fisheries and human health issues).
- Important ecosystem science is being conducted by the NWFSC in Puget Sound, in collaboration with other agencies and organisations. These are very important for learning and demonstrating how to move towards ecosystem-based management, as a laboratory for building an ecosystem approach to management, and as a case study for comparisons with the California Current System. Thought should be given as to the spatial scale for ecosystem-based management (scale of the California Current System, scale of Puget Sound).

Considerations to address these issues:

- The lack of clear ecosystem objectives on the part of the Pacific Fisheries Management Council, and potentially other management clients, provides an opportunity for the CC IEA team (and other ecosystem scientists) to shape these ecosystem objectives (already partly on-going, although perhaps via ad-hoc approaches rather than specific and directed efforts).
- Take advantage of strong unusual ecosystem conditions and events in the environment to underline their importance and potential impacts to the Council's mandates. Last year it was the warm anomaly, a decade ago it might have been the low oxygen event off Oregon, etc.
- Can practical lessons be learned from the Harmful Algal Bloom experiences in regards to providing ecosystem science advice to management?

Theme 5 – Communication and peer review

- The publication record of the ecosystem science activities of the NWFSC is outstanding. There are no concerns regarding peer review or the scientific credibility of the materials produced.
- Not much information was provided on how to condense and present complex ecosystem information into succinct and informative formats for decision-makers or the public. Very nice graphics and 'cartoons' were presented, which are very important. But considerable thought needs to be given on how to present and summarise the ecosystem science information and model outputs, especially for a lay audience. These will help with communicating complicated results to managers and decision-makers, and thereby also with communicating the importance of ecosystem science to their decisions.

Northwest Fisheries Science Center Review – Ecosystem Science
Final 17 July 2016

General Comments:

1. The quality of the presentations and the demonstrated commitment of the staff to the importance of ecosystem science to the NMFS mission was overwhelming. The statements of support from the Council, the Region, local NGOs and industry were equally impressive. And, the numerous references to the support of NWFSC leadership in the pursuit of ecosystem science are indicative of a well run program.
2. The last two presentations by NWFSC leadership were nothing less than inspirational. In contrast, while the ecosystem science overview provided in the Center's Strategic Plan is comprehensive, it is not motivational. Some effort to codify the underlying principles and strategy that should guide ecosystem science at the NWFSC would be beneficial to the Center's ecosystem science research program, especially given the anticipated turn-over in Center leadership over the next 6 months. This should be in the form of a stand alone document.
3. Given the fluidity and uncertainty associated with the NMFS fiscal environment, the Center research mission would benefit from a budget planning process that was more transparent and explicit. It was noted that most of the elements to implement such a system are in place (i.e., Strategic Science Plan, Annual Guidance Memo, project descriptions, online project database, ranking criteria); however, not all elements are in place at this time.
4. While difficult to ascertain, it may be that the current breadth of proposals written in response to funding opportunities is diluting what otherwise might be a more focused effort to achieve Agency priorities with base support. Center leadership should review it's current practice and existing policies regarding reimbursable funding.

Specific Comments:

Theme 1. Management Context and Strategic Planning

1. *(i)Do the Centers/ST have clear goals and objectives for an ecosystem-related science program? (i i) Is ecosystem-related science integrated with the other science activities across Divisions within the Center/ST? (i i i) Are the Center's/ST's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?*

(i)While both the Center's Strategic Plan and Annual Guidance Memo address ecosystem-related science, it is hard to clearly describe the underlying goals and objectives of the program. The ecosystem-related science program (ERSP) at the Center is very broad, including research to address 1) impacts of climate change on Living Marine Resources (LMR), 2) impacts of climate change on local communities, 3) impacts of commercial fishing on the California Current Large Marine Ecosystem (CC LME), 4) Harmful Algal blooms, 5) ecosystem function within the CC LME and Puget Sound marine ecosystem, 6) incorporating environmental and ecological information in traditional stock assessment, and 7) the development of various indices and metrics to assess and monitor the status of the CC LME and Puget Sound marine ecosystem. The number of key stakeholders informed by the Center's ERSP is very large; the interests of these stakeholders divergent. The Center would benefit if the primary stakeholders for the CC LME and Puget Sound would separately develop metrics to describe acceptable ecosystem states, strategies to manage LMRs when

they are part of a healthy marine ecosystem state, management strategies to recover depleted stocks to a healthy state or degraded habitats to a healthy state, and metrics to track progress or efficacy of management efforts.
(ii)Within the Center, there is a phenomenal degree of integration across divisions. Center leadership should be commended for developing novel incentives to promote such integration and for rewarding staff initiatives related to interdisciplinary collaboration at the Center.
(iii) The protocol for prioritizing base-funded research activities appears to be subjective. To a large extent, Center base funds are dedicated to covering fixed costs. Operational funds to a large extent are limited by Congressional directives. In addition, Center leadership has done an outstanding job in controlling fixed costs by forcing a net loss in FTE in the labor force over the last 5 years. Absent this effort, base funding would be insufficient to cover fixed costs, and the Center would have become a "job shop" for temporary funding from NMFS HQ or Agencies that provide reimbursable funding. This result would have been detrimental to the stewardship activities of the West Coast Region, the Pacific Fishery Management Council, and the Puget Sound Partnership. Nonetheless, the Center would benefit from the development of an objective protocol for ranking research activities and then allocating funding to only those research activities that scored above a given threshold, where ranking criteria were developed such that they reflected priorities of the Center, West Coast Region and Agency. Criteria for ranking research activities should be developed jointly by the Center and West Coast Region leadership.

2. *Do the Center's/ST's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem- related information to achieve their mission?*

The Center's ERSP received high praise from Regional staff and Council staff at the review. Center leadership works closely with Regional staff and Council staff in all phases of its ERSP, included research design, execution, and communication. Further, it was clear from both presentations made to the panel and comments from the public that Center staff are highly integrated into the production of key management related documents, such as Fishery Management Plans and Fishery Ecosystem Plans. In addition, presentations regarding the Puget Sound Partnership reflected a similar effort to incorporate the priorities of the Puget Sound Partnership in allocated limited fiscal resources, as well as staff time, to research activities contributing to ecosystem science and successful resource management.

3. *Has the Center/ST appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy[1]?*

Yes. The two west coast Science Centers (NFWFS/SWFSC) have produced a draft Regional Action Plan for the West Coast Region (i.e., California Current LME). (see - Northwest and Southwest Fisheries Science Centers http://www.nwfsc.noaa.gov/ and https://swfsc.noaa.gov/).

[1] http://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/documents/NCSS_Final.pdf

4. *What is the status of oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs? Has the Center developed strategies to obtain and manage such data?*

The Center follows NOAA policy regarding the availability of digital information. The Center uses InPort, which is the centralized repository of documentation for NMFS data, as well as providing tools for accessing these data. In addition, the Center has developed protocols for access to and management of ecosystem-related information, and is working with the SWC in the use of ERDDAP software, for the purpose of data access and plotting routines to provide for quick views of data. The degree to which all of the ERSP data is accessible via ERDDAP or some other software protocol at the Center was not specified during the review. Based on the presentations to the Review Panel, the Center analysis of and access to ecosystem-related information might benefit from a review as to whether or not closely related databases should be combined into a single database. Some stove-piping of data within a Division was discussed, but the extent to which this is a problem at the Center was not made clear to the Panel. However, it was noted that Center efforts have been successful in creating bioinformatics clusters, where internal and external scientists have access to comprehensive data sets at a single data portal (e.g., FRAM database). These efforts should clearly be expanded, as funding and staff time allows.

Theme 3 – Ecosystem modeling and analysis

5. *Is the Center appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?*

The Center is fortunate to have access to a number of significant data sets related to ecosystem-level processes (e.g., Newport Line, CalCOFI time series). In addition, the Center is very fortunate to have considerable expertise in ecosystem modeling, including spatial modeling, time series analysis, ecosystem modeling (e.g., intermediate complexity), food habits modeling, identification of ecological tipping points, and modeling of HAB events. The series of talks on these topics were especially impressive, and indicate a center of excellence level of quality.

Theme 4 – Incorporation in Management

6. *Is the Center's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?*

Based on the comments from the WCR, Council, and other stakeholders, the Center is doing an excellent job providing ecological advice to resource managers. A number of examples were provided during the presentations, including forecasting HAB events, near term ocean conditions, short term forecasts of recruitment strength of sablefish, some salmon stocks, and some rockfish stocks, as well as forecasts related to socio-economic impacts to coastal communities of climate change. The CC IEA protocol appears to be an excellent vehicle for providing ecosystem advice to managers regarding management of the California Current. Similarly, participation by Center

staff in the Puget Sound Partnership provides a suitable vehicle for informing managers regarding a host of environmental concerns. Finally, Center staff involvement in the Council's CC Fishery Ecosystem Plan indicates a successful partnership between managers and ecosystem-related scientific practitioners.

Theme 5- Communication and Peer Review

7. *Are the Centers'/ST's ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the Center/ST developed a strategy for peer-review?*

The Center has a number of peer-review protocols that provide for a comprehensive review of all technical documents, including protocols for review of 1) in-house papers, 2) stock assessments, 3) annual CC IEA report, 4) FEP, 5) WRAP, etc. The production of peer-review publications by Center staff working on ERSP is worthy of special notice. Per FTE, the publication of first authored or co-authored papers is on the order of 3 papers per year. Seven publications since 2010 were published in either Science, Nature, or PNAS. This output would be considered outstanding in this line of research at any academic institution. The Center's IEA report received considerable accolades from the the WCR, Council, and other constituents. It was very clear during the course of this review that ecosystem-related scientific information for the CC LME characterized and presented in the annual IEA report is thoroughly reviewed by experts in a diverse set of fields. Center staff should be commended for the quality of this annual report.

8. *Does the Center/ST appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?*

The Center, as noted above, has an outstanding publication record in the field of ecosystem-related science. In addition, based on comments from the West Coast Region and PFMC, the annual production of the CC Integrated Ecosystem Assessment (IEA) serves as an outstanding vehicle for updating management and stakeholders regarding the status of the California Current, current catch levels, economic and social indicators of coastal community welfare, and on-going research.

Theme 6 – Other Comments

1. The research collaboration between the Center and the Southwest Fisheries Science Center was abundantly evident through the presentations by Center, Region and Council staff, as well as through associated background material. This is commendable and no doubt contributes to the overall success of the science mission at both Centers. In addition, several references indicated on-going collaboration between staff at the Center and the Alaska Fisheries Science Center (AFSC). Nonetheless, it appears that greater collaboration between the Center and the AFSC would strengthen the ERSP at both Centers. For example, the nature and magnitude of the degree to which the CC LME and Gulf of Alaska

LME interconnect should be more thoroughly investigated, especially given the recent oceanographic feature referred to as the "warm blob". Another example is the on-going efforts of the two Center staffs to work collaboratively on sablefish stock assessment. It is recommended that leadership from the Center and the AFSC schedule a one-day workshop or some other venue for the purpose of identifying best practices at each Center and ways in which scientific partnerships and collaborations could be enhanced.

2. Funding to support a comprehensive IEA approach for the CC is inadequate. Given the fiscal environment in the US, additional funding in the near future is unlikely. Current funding provides for reasonable coverage of the lower trophic level, and parts of the upper trophic level of the CC (e.g., commercially important fish species). However, the middle trophic level and certain marine mammal (e.g., harbor seals) and seabird elements of the upper trophic level have had relatively little support in the past and currently. Some effort to evaluate the merits of reprogramming funding, as current appropriate rules allow, to better support these underfunded elements of the ecosystem is recommended. Without better information on these species, the reliability of the ecosystem model output is open to some question.
3. Increased efforts to determine optimal sample sizes for certain elements of on-going ecosystem research programs is needed. For example, it was not clear from the presentations if the current protocol for collecting fish stomach samples from research vessel surveys and at sea observers is supported by a proper experimental design (i.e., where pre-specified targets for statistical power or precision are included in the experimental design). That is, at present it is not possible to determine if the current sampling regime results in a sample size that is appropriate, over-sampled, or under-sampled. A similar argument can be made regarding harbor seal scat samples. In addition, the Center's ERSP would benefit from an MSE to elucidate the susceptibility of existing time series to breaks in data collection, associated with loss of funding or logistical problems. With such an analysis in hand, the modeling efforts most likely to fail in meeting management needs because of a break in time series data could be identified and protected, as possible.

Northwest Fisheries Science Center Review – Ecosystem Science

Preamble

The three days of review have been extremely stimulating. My exposure to the full sweep of NWFSC Ecosystem Science reveals to me a robust, cutting edge and very impressive sweep of scientific engagement by an enthusiastic cadre of researchers in a supportive institutional environment extending downwards from the Center leadership and upwards from the newest member of the team. The range of collaborations across Center programs is remarkable as is the engagement with tribal, state, private sector and NGO participants. The effective leveraging of federal funding to obtain funding and other support from research partners has produced significant benefits and helped to achieve a more coherent and comprehensive body of research than otherwise possible.

The publication of research results has earned NWFSC a reputation as a leader in the international peer review community. However, equally or more importantly, the NWFSC has made significant efforts to communicate the ecosystem sciences to multiple audiences concerned with the geographies of the California Coastal Current and Puget Sound/Salish Sea.

Everything we heard in presentations or read in reports and other materials spoke directly to the NWFSC commitment to NOAA Missions – from basic marine monitoring to fisheries management, to National Marine Sanctuary stewardship, to prevention and recovery under the Endangered Species Act, to developing integrated ecosystem assessments in Puget Sound and the California Current.

From top of the Center to the bottom there is a commitment and genuine enthusiasm for the scientific research being performed and a sense of mission to develop and communicate top quality scientific understanding for myriad ocean activities and functions.

Kudos to all.

Review

I am organizing my review to start at the very highest conceptual level and then working my way back to basic and more detailed comments. Because my background is in the science policy of marine resource management I find I have more to offer in terms of the former than the latter area. In any case these comments are forwarded not as criticisms but as fodder for discussions and planning that I expect will flow from these recommendations at NWFSC.

The Great Debate. The Center science is aware of and engaged with the on-going debates about how to think about management of marine ecosystems that can be most easily characterized as E.O.Wilson et al. v. P. Karieva et al. The outline of the debate is over protecting what remains of pristine ecosystem vs. accepting functioning but vastly altered ecosystems. The Center is being asked to inform this debate because of the competing objectives, management policies and diverging human values that drive the discourse around ocean management. Thus, I think it useful to frame the role of the Center's ecosystem science in this contentious arena by making it clear that there are trade-offs among the differing approaches to management with social, economic and

ecosystem determinants of outcomes ultimately to be decided in public policies. While the Wilson/Karieva debate is primarily with respect to management/protection of biodiversity I believe the role of the Center to be a more broadly defined in terms of a linked social-natural system. Still, ecosystem sciences [social and natural] will be called upon to clarify options and to provide advice. Therefore, I encourage the Center and its scientists to fully recognize their role as a scientific moderator and interpreter.

Healthy Ecosystems /Resilient Ecosystems. In that context, NOAA and the fishery science centers are still searching for appropriate ways to understand management goals and objectives. Center scientists seem to use the terms healthy/resilient ecosystems interchangeably but there is sufficient understanding to know that they may not be exactly the same thing. In lieu of having a societally determined goal these terms are reasonable surrogates to use. In terms of management, goals tend to be set by legislation and are often competing. Where the goals have to be set by negotiation, e.g., in a planning process, this tends to be a tortuous process and one determined by the exigencies of the process and moment. Thus, I recommend that the Center personnel remain cognizant of the potential for confusion in user communities over the use of terms when they are used interchangeably / or in ways not fully defined.

US EBFM Policy and Roadmap: Reflecting on the efforts to develop a policy statement and a roadmap for implementation for EBFM, it seems to be a useful way to assist Fisheries Management Councils to think in ecosystem terms about management. As several of the speakers stated, there is some feeling that the policy and roadmap largely mirrors the PFMC and CC management efforts – especially under the Magnuson Stevens Act [MSA] with the Fisheries Ecosystem Plan. The Policy and Roadmap do raise the bar with respect to risk assessment, management strategy evaluation, cumulative effects analysis [NEPA] and other matters. It seems that Center science is headed in these directions and can only accelerate progress.

These two documents are not as helpful for the direction of NMFS's EBFM in the context of management of Endangered Species Act, Marine Mammal Protection Act, FORAM Act, etc. The unique nature of the CC system especially its Tribal Treaty responsibilities, recovery actions, setting of optimum yields and broader ecosystem issues need to be recognized. Similarly, the extensive and way breaking work on CC and PS IEAs [and Atlantis Modeling] contributes to achievement of the MSA EBFM policy and roadmap but it is also intended to serve other marine management purposes that underpin EBM approaches by coastal managers, restoration programs, climate change adaptation planning, etc. as well as serving the work of the Regional Planning Body.

IEAs: The role of the NWFSC in providing the ecosystem science for IEAs is exemplary. The path to putting that information to use through the Council for the CC and the Puget Sound Partnership is proving to be very successful. The question is how to get other potential users and beneficiaries to pay attention to the availability of the IEA for their own purposes. There seems to be an unfortunate disconnect where a tool developed by NOAA as a fishery science center is perceived as narrowly focused [despite being developed with many partners] instead of as a valuable tool for all to use. Continued efforts to communicate the value of IEA to multiple users are necessary.

Transition in Leadership at NWFSC: The leadership for the ecosystem science program at the Center is in transition. Leadership form the NMFS Chief Scientist, Center Director and Program Director has been invaluable in the development of a strong ecosystem science program. It is

extremely important that the strength of the NWFSC ecosystem science program be maintained and given new vigor through a thoughtful planning process for the transition. Given the interdisciplinary nature of the ecosystem science and the cross program collaborative approach so far developed some form of transition planning that incorporates the outcomes of this Review, the internal evaluations and participation of the scientists, advice from user and advocacy groups in a "visioning" process would be invaluable. More than appointments of individuals to leadership positions and definition of individual responsibilities, having a united view of the way forward for ecosystem science at NWFSC would be the goal.

Social Science as Integral: I understand that the social science program review will take place next year. Still, I have been impressed at the efforts to integrate social sciences into ecosystem science considerations. Despite these efforts and the consistent inclusive discourse heard throughout the review presentation, there remains a mismatch between the recognized need to include human dimensions and the requisite data to address those needs. This can be seen especially in the need to broaden the range of constituents served by ecosystem sciences. This is most acutely seen in the context of IEA development and modeling where logical users of the ecosystem science, e.g., PFMC is important, but there are others: states, Tribes, sanctuaries, coastal zone managers, disaster planners, the public, other sectors, etc. Each of these users and NOAA's line offices has guidance from additional bodies of law besides MSA. This is particularly true for how the human dimensions and habitat elements of EBM are conceptualized. Thus, the Center is to be applauded for strongly supporting the development of social sciences and should continue to do so to help social sciences earn their way into models and information for decision processes.

Funding. Yes, there is always a need for more funding. The Center's budget is a very interesting mix of dedicated / obligated funds by mission, funding associated with initiative of the Center and individual researchers and other mostly short term competitive grants. In addition, partnering with joint and other funding takes place with foundations and industry [lesser extent]? I heard that there are difficulties in dealing with projects with short term funding when it takes half the year to obtain the funds for agreed projects and leaves only six months to perform the work. Perhaps, annual cycles for these competitive funds within the agency may not be the best approach.

Retrospective/ vs. Prospective – Forecasts: There is tremendous retrospective work being done and prospective work being done. We all want to understand why Puget Sound fisheries are not improving, etc. Similarly, we all are concerned about how to manage under climate change, etc. I suspect that given tight funding and the need for prioritization the balance of research is going to continue to shift toward forecasts – and retrospective analysis about past change will become less relevant.

Now I shift to short responses to the questions posed to reviewers.

1. Do the Centers/ST have clear goals and objectives for an ecosystem-related science program? Is ecosystem-related science integrated with the other science activities across Divisions within the Center/ST? Are the Center's/ST's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?

Research seems to be driven by multiple goals and objectives. Many of them are

complex, diverse and overlapping. Thus, the Center emphasis on integration and on incorporating social and natural sciences is appropriate. I did not get a very good sense of how strategic prioritization takes place. I was impressed by a common understanding of what was being done and why among researchers. I did not detect any strong division among different participants in the sense of direction or purpose of work.

2. Do the Center's/ST's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?

The short answer is that, yes, the priority needs are appropriately incorporated in the research agenda of the Center. As a note: there were a number of questions posed the first day of the review relative to diet and foodweb data/ the use of eDNA and other techniques to obtain foodweb data. The final day, the FEP lead for the CC region indicated that more diet analysis and an updated foodweb would be a valuable input into fishery management assessments and plans to revisit the FEP.

3. Has the Center/ST appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy[1]?

It appears that some planning that incorporates ecosystem science has been done but mostly in pursuit of other sub objectives. An overarching plan could bring more coherence to the existing efforts in this regard and identify gaps.

4. What is the status of oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs? Has the Center developed strategies to obtain and manage such data?

There was some discussion about the lack of presentation re: oceanographic data in the review but it is clear that the Center seems to have an adequate system in place to deal with current data [maybe a couple of data sets that might be combined] but plans are in progress to improve on the system in light of hardware and software advances. Concerns were expressed all around about data security and the present impediments in place to restrict access. This too was a hurdle the Center is working to overcome.

5. Is the Center appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?

This is not an area where I feel competent to evaluate the adequacy of analyses being

conducted. I was and remain under the impression that the Center is in the forefront of modeling, e.g., Atlantis model of the California Current and the development of IEAs.

6. Is the Center's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?

I believe the answer to this question is unequivocally yes. Two way communication seems very common and straightforward. Even the discourses around uncertainty and risk are respectful and represent a scientific sophistication that promotes critical but positive exchange.

---

[1] http://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/documents/NCSS_Final.pdf

7. Are the Centers'/ST's ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the Center/ST developed a strategy for peer-review?

I tend to think of peer review in very practical ways.

A. For agency internal consistency and quality

B. For peer review in the form of published papers

C. When there is a concern raised about the quality of the science and external review is valuable to ensure highest quality methods, data and analysis are used and the conclusions are reasonable from that work, e.g., C.I.E. review.

D. In the Council process the SSC is expected to ensure that Best Available Science and Information are used in Council decision making.

E. Review to obtain additional insights or perspectives on how to approach research on a particularly vexing or unfamiliar problem.

As best I can tell, NWFSC uses all of these effectively. There was some discussion about use of peer review type E for more programmatic review to assist in internal planning and research design. I would support this addition as a best practice but do not think that it is necessary in each program/ research design.

8. Does the Center/ST appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?

The Center seems to be developing excellent communication with its primary constituents in the fishery management community and in the PSP. Some concerns were expressed about the need for capacity building internally and with

external partners to be able to effectively use products of more sophisticated scientific assessments and models [e.g., risk assessments, and trade-off analysis]. One area where perhaps more planning might be devoted would be in the use of models to present alternative scenarios related to Management Strategy Evaluation and for management/ decision-making under uncertain conditions associated with climate change.