Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

**Canadian Science Advisory Secretariat (CSAS)**

**Proceedings Series 2013/045**

**Pacific Region**

# Proceedings of the regional peer review of a synthesis of the outcomes from the Strait of Georgia Ecosystem Research Initiative, and their ecosystem-based management and policy implications

**September 11-13, 2012**

**Nanaimo, BC**

**Chairperson: Marilyn Hargreaves**

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Fisheries and Oceans Canada
3190 Hammond Bay Road
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November 2013

**Foreword**

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

**Published by:**

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

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csas-sccs@dfo-mpo.gc.ca


ISSN 1701-1280

**Correct citation for this publication:**

DFO. 2013. Proceedings of the Regional Peer Review of a synthesis of the outcomes from the Strait of Georgia Ecosystem Research Initiative, and their ecosystem-based management and policy implications; September 11-13, 2012. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2013 /045.

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## SUMMARY

Fisheries & Oceans Canada (DFO) has committed to a sustainable, precautionary and integrated ecosystem approach to oceans management. To support the development and implementation of such an approach, seven Ecosystem Research Initiatives (ERIs) were established by DFO Science to facilitate integrated research on a particular ecosystem with predefined geographical boundaries. The overall purpose of the ERIs was to serve as a pilot for DFO's ecosystem-based approach and enhancing the capacity to provide scientific advice in support of ecosystem approaches to management. Going forward, knowledge gained from these large scale ecosystem studies would allow the development and testing of tools required to manage human activities within broader aquatic ecosystems.

In Pacific Region, the Strait of Georgia was selected as the pilot study ecosystem. The Strait of Georgia Ecosystem Research Initiative began in January 2008, and concluded its directly-funded phase on 31 March 2012.

These Proceedings summarize the relevant discussions and key conclusions that resulted from a DFO Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of September 11-13, 2012 at the Pacific Biological Station in Nanaimo, B.C. A working paper, focusing on the synthesis of key results and recommendations arising from the Strait of Georgia ERI, was presented for peer review.

In-person and web-based participation included Fisheries and Oceans Canada (DFO) Science and Fisheries and Aquatic Management Sectors staff from regional and national offices, as well as staff from other federal government agencies, and external participants from academia and environmental non-governmental organizations.

The conclusions and advice resulting from this review will be summarized in a Science Advisory Report to provide fisheries scientists and managers with some preliminary findings to consider as they transition to an ecosystem approach to management. In addition, the products of this review will contribute to a national CSAS review of the lessons learned from the ERI processes conducted nationwide, scheduled to be held in November 2012.

The Science Advisory Report and supporting Research Document will be made publicly available on the CSAS Science Advisory Schedule.

**Compte rendu de la réunion d'examen régional par les pairs d'une synthèse des résultats de l'initiative de recherche écosystémique du détroit de Géorgie et leurs répercussions sur la gestion et les politiques en matière d'écosystèmes ; du 11-13 septembre 2012**

## SOMMAIRE

Pêches et Océans Canada (MPO) s'est engagé à adopter une approche écosystémique intégrée, durable et prudente en matière de gestion des océans. Afin d'appuyer l'élaboration et la mise en œuvre de cette approche, le Secteur des sciences du MPO a lancé sept initiatives de recherche écosystémique (IRE) pour faciliter la recherche intégrée sur un écosystème donné aux limites géographiques prédéfinies. Dans l'ensemble, les IRE ont pour but de servir de projets pilotes pour les besoins de l'approche écosystémique du MPO et d'améliorer la capacité d'offrir à la direction des conseils scientifiques à l'appui des approches écosystémiques. Pour la suite, les connaissances acquises dans le cadre d'études écosystémiques à grande échelle permettront d'élaborer et de mettre à l'essai des outils de gestion de l'activité humaine dans nos écosystèmes aquatiques plus vastes.

Dans la région du Pacifique, c'est le détroit de Georgia qui a été choisi comme écosystème pour le projet pilote. L'initiative de recherche écosystémique du détroit de Georgia a débuté en janvier 2008 et son étape financée directement s'est terminée le 31 mars 2012.

Le présent compte rendu résume l'essentiel des discussions et des conclusions de la réunion d'examen régional par des pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS) qui a eu lieu du 11 au 13 septembre 2012 à la station biologique du Pacifique de Nanaimo, en C.-B.  Un document de travail, portant essentiellement sur les principaux résultats et recommandations émanant de l'initiative de recherche écosystémique du détroit de Géorgie, a été présenté aux fins d'examen par des pairs.

Au nombre des participants à la réunion en personne ou par conférence Web, mentionnons des représentants des secteurs des Sciences et de la Gestion des pêches et de l'aquaculture de Pêches et Océans Canada (MPO) des bureaux régionaux et national, et des représentants d'autres organismes fédéraux et des participants externes représentant le milieu universitaire et les organisations non gouvernementales de l'environnement.

Un résumé des conclusions et des conseils découlant de cet examen sera présenté dans un avis scientifique pour mettre à la disposition des scientifiques et des gestionnaires des pêches certains résultats préliminaires aux fins d'examen pendant la transition, vers une approche de gestion écosystémique.  De plus, les résultats de cet examen contribueront à un examen du SCCS à l'échelle nationale des leçons tirées des processus d'IRE que l'on prévoit lancer à l'échelle du pays en novembre 2012.

L'avis scientifique et le document de recherche à l'appui seront rendus publics dans le calendrier des avis scientifiques du SCCS.

# INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on September 11-13, 2012 at the Pacific Biological Station in Nanaimo to review a synthesis of the results and recommendations arising from the Strait of Georgia Ecosystem Research Initiative (2008-2012).

The following working paper (WP) was prepared and made available to meeting participants prior to the meeting (a summary is provided in Appendix D):

*Perry, R.I. et al. A synthesis of the outcomes from the Strait of Georgia Ecosystem Research Initiative, and their ecosystem-based management and policy implications. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/P59. vi + xx p.*

The meeting Chair, Marilyn Joyce, opened the meeting by welcoming participants and reviewing general meeting logistics. Mary Theiss was introduced as the rapporteur for the meeting. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they could be heard by those online. A round of introductions followed. The Chair then reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The Chair discussed the role of participants, the purpose of the various regional peer review (RPR) publications (Science Advisory Reports, Proceedings and Research Documents), and the definition and process around achieving consensus decisions and advice. Everyone was invited to participate fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice, based on the best available current knowledge.

The Chair reviewed the Agenda (Appendix A) and the Terms of Reference for the meeting, highlighting the objectives and expected outcomes of this review. The Chair emphasized that the review was not intended to discuss the technical findings of individual projects within the Strait of Georgia ERI, since these are being published in detail elsewhere, but to provide an overall synthesis of the findings and to provide direction for future ecosystem-based research efforts. Additionally, the Chair noted the agenda was organized in discrete blocks, to reflect the working paper sections, and to guide discussions. In total, 44 people participated in the regional peer review (RPR).

Participants were informed that Dr. John Dower had been asked before the meeting to provide a detailed written review for the working paper to assist everyone attending the peer-review meeting. This review was distributed to participants in advance of the meeting. In addition, two Fisheries and Oceans Canada (DFO) managers (Aleria Ladwig (Fisheries Management) and Dr. Jon Chamberlain (Aquaculture Management) were asked to provide reviews of the working paper from a management perspective. These reviews were presented at the beginning of the second day of the meeting.

Ian Perry presented an overview of the working paper: *A synthesis of the outcomes from the Strait of Georgia Ecosystem Research Initiative, and their ecosystem-based management and policy implications, CSAP Working Paper 2012/P59, by R.I. Perry et al.,* on behalf of the co-authors. Points of clarification raised during the overview presentation are included in the appropriate discussion section below.

# EXTERNAL REVIEWS

## SCIENCE REVIEW: JOHN DOWER

Ian Perry presented the scientific review since Dr. Dower was unable to attend the meeting. The review was well-annotated and focused on the scientific aspects of the working paper, leaving the management perspective to other reviewers. Overall the review was favourable, with only a few clarifications required. The full review is included in Appendix E. Only elements of the review requiring clarification or further comment from the authors are addressed here.

2.1.4 (Page 5): Comment regarding shift in herring spawning activity since the 1990s.

- *The authors agree this has potential to be a future research project though they suspect the reasons for the shift are more likely environmental than human.*

2.1.5 (Page 6): Questions regarding the calculation of trophic efficiency for the Strait of Georgia

- *The specifics of the trophic efficiency calculation are outlined in Table 2. There is no known way to quantify loss of productivity for fish that rear in Strait and then are fished elsewhere (e.g., salmon); The authors will revise the statement to focus on the fact that the Strait of Georgia is productive, without getting caught up on the relative significance of the numbers. It was also identified that if a point estimate is given, then the authors also need to quantify uncertainty around that estimate and/or focus on relative values rather than absolute ones (i.e., build precautionary principles into estimates). The second sentence of Section 2.1.5 needs to differentiate between trophic dynamics and trophic efficiency.*

2.1.5 (Page 7): Comment regarding recent work investigating decreases in total larval fish abundance in the Strait of Georgia.

- *These findings (though not yet published) are interesting and not contradictory to those presented here.*

2.1.5.2 (Page 8): Herring recruitment versus spring bloom timing as a match-mismatch example.

- The authors agree—it could increase the probability of a timing mismatch and that is why it is considered an important indicator.

2.1.5.3 (Page 9): Possible link between reduced food quality encountered by juvenile herring and other fish species in the Strait of Georgia in recent years and poor survival.

- *The authors agree that this is possible, though it was not investigated by this initiative. It could be considered as a future project.*

2.2 (Page 9): Asks for a brief explanation about the statement that physical and chemical processes are the primary pathway for contaminants to be taken up by zooplankton rather than feeding.

- *The authors agree to get Ross et al. to add a clarification statement about this point.*

2.2 (Page 10): Question regarding Preikshot et al.'s estimated "primary production anomaly" time series obtained from their Ecopath model.

- The authors noted that an inverse approach is used and that primary productivity is not used to tune the Ecopath with Ecosim (EwE) model. They also noted that processes regulating primary productivity anomalies by wind require further research. They will include additional clarifications in the figure captions for figures from underlying publications that also appear in the research document to clear up these questions.

3.1 (Page 12): Problems with the flow of the paragraph on invasive species in the Drivers of Change section.

- *The authors will include additional text and consider moving most of section 3.1 to 2.2. It was noted that this was a limited example among many other potential vectors. It was agreed that this section needs additional information and references. There was some discussion about the varying degrees of detail that seemed to implicitly reflect importance. Given that this is not true (no judgment on the relative importance or priority rankings of factors was included in the ERI), more context will be provided at the beginning of the section to caution readers that no risk assessment has been done and more (as yet, unstudied) factors may exist. This could also include references to CSAS reports regarding SWISH, etc.*

3.2 (Page 14): Question regarding the lack of biological state variables in the study by Perry (In review).

- *The authors point out that biological state variables were considered responses to drivers and pressures in the model. In addition, the zooplankton data set was insufficient, and was subsequently dropped from analysis.*

3.3 (Page 15): Notes the lack of reference to the VENUS program in this section.

- *The authors agreed and will add a reference to the VENUS program.*

4.2 (Page 16): Suggests the need for the inclusion of a biological indicator in the regime shift indicator model (Perry, in review).

- *The authors point out that this is not the way the analysis was set up.*

4.3 (Page 17): Need more information about the sensitivities of probabilistic models investigated, and how (or whether) model sensitivity might be used to identify specific environmental variables on which new research should be targeted.

- The authors will provide additional details to clarify the sensitivity analyses conducted on these models.

4.4 (Page 18): Questions regarding the EwE simulation model and the data used to inform it.

- *The authors note that where data are insufficient to support individual variables, they were aggregated into broader categories. The figure in the working paper relating the EwE model did not reproduce well and may be contributing to some of the confusion. The authors will include a clearer version of the figure in their revisions.*

5.1 (Page 20): Comments about data and knowledge gaps. In particular, the reviewer highlights ongoing research and strongly supports the development of a multi-sectoral group concerned with marine ecosystems issues in the Pacific Region.

- The authors fully agree with this comment and note that recommendations on how specific logistics (e.g. field work) will be undertaken are “glaringly absent” by design.

Section 6 and 7 (Pages 24-25): Questions about a plan for implementing the recommendations for new research on ecosystem indicators in the Strait of Georgia.

- *Sections 6 and 7 were tabled for discussion later in the meeting.*

## MANAGER’S REVIEW: ALERIA LADWIG

This review was provided at the start of the second day. It was not circulated in written form to participants.

Ms. Ladwig clarified that she was not providing a scientific review, just commenting on how usable the information is from her perspective as an Ecosystems Approach Officer. She found that the working paper succeeded in achieving objectives 1, 3 and 5, but that objectives 2 and 4 required further discussion. Given that this synthesis was not based on a management request for science advice, she suggested that the objectives may need to be framed more in line with existing policy framework constraints to improve their relevance to managers.

From the 5-step process identified in section 2, Ms. Ladwig's two primary concerns were: the need for resource-intensive sampling required to monitor the ecosystem (e.g., the annual monitoring needed to identify match-mismatch events); and the need to identify what feature(s) or structure(s) contribute to make areas of concentration.

Within the section discussing drivers of change, Ms. Ladwig notes that harvest levels for a sustainable ecosystem do not exist (they are species-dependent).

Ms. Ladwig also acknowledged that elements that would be welcomed by managers include easy-to-use indicators and well-defined ecologically and biologically significant areas (EBSAs). She fully supports the development of a multi-sector working group (i.e., Table 8B in the working paper).

Within the section on modelling tools, Ms. Ladwig suggests that a layman's description would be helpful. She feels they are useful tools, but cannot comprehend them without additional information. She also suggests the need to expand on the role of sand lance in the Strait of Georgia ecosystem, and the need to set clearer goals for collecting missing information (i.e. in terms of what policies the data will be relevant to).

Ms. Ladwig felt the section on spatial management fits well with policies currently in place, but that more work on herring (such as critical habitat, primary predators, and the links between herring and commercially exploited species) should be expanded. She also suggested that it would be worthwhile to include assessments of economic benefits in decisions using an ecosystem approach.

Finally, with respect to reflections on the structure of the ERI, Ms. Ladwig questioned what other sectors were involved in identifying knowledge gaps, projects to be funded, etc.

The authors thanked Ms. Ladwig for her comments. They also responded by saying that a lack of management regulations, policies, or quotas should not be a limiting factor to science research. They also clarified that management used "instruments" (such as regulations, policies and quotas), whereas the ERI developed "tools" (such as the various models). The authors note that it is worthwhile to attempt to move ahead within the framework of existing policies, while also looking to develop new policies. The economic cost benefit analysis was recognized as a very good suggestion, and a recent 2012 CSAP research document was identified as having partially addressed this aspect (DFO 2012)). Finally, the authors clarified that sand lance were selected for study over herring because it has been studied less in the past.

## MANAGERS REVIEW: JON CHAMBERLAIN

This review was also provided at the start of the second day and was not circulated in written form to participants.

Dr. Chamberlain began by saying that the Strait of Georgia ERI set out to address three departmental priorities and in the end, did a reasonably good job of doing that. By way of example, he recognized the 19 or more primary publications generated from the ERI are a testament to the amount of work completed by the program. He noted that there was some degree of disconnect between various projects (but that the authors did a good job of weaving a narrative around connected issues and balancing of differences of opinions that arose).

That being said, Dr. Chamberlain then pointed out that the working paper needs to stress more strongly that it is providing *examples*, not exhaustive or prioritized lists of issues for the department.

Dr. Chamberlain also had reservations about the transferability of the ERI work to other areas, since the working paper did not include a balancing of the shortcomings of using the Strait of Georgia as a pilot project area, along with why it was chosen (this might then indicate how its applicability might be limited in other areas such as PNCIMA and LOMAs).

In agreement with Ms. Ladwig, Dr. Chamberlain identified that objectives 2 and 4 of the 5-step approach require additional work (Section 2). Dr. Chamberlain provided additional issues that should be considered (e.g., habitat, the influence of the 98% of the Strait of Georgia not connected to outside waters, cumulative effects of stressors, setting of thresholds for anthropogenic effects, etc.) Specific comments for Section 2 include the layout of Figure 2 in the working paper does not suggest “wasp-waistedness”; sand lance appear to be missing from the model; and the fact that the model appears to reflect the state of current knowledge (existing data), not necessarily what are considered relevant factors (with or without data).

Dr. Chamberlain suggested that engagement with client groups appeared to have been limited for the development of management considerations (Section 3). As such, the end products are of limited utility.

While all tools presented in the working paper appear interesting (Section 4), Dr. Chamberlain suggested that three core questions need to be answered in order to evaluate or compare the models presented: does the model adequately capture the processes that it attempts to represent, do the data available allow for the assumptions of the model to be met, and do the model and data combined make sense? He suggested adding a *brief* narrative in the working paper to cover this. He also noted that management is able to cope with grey areas as long as these are identified (using DEPOMOD as an example). The models outlined in the working paper need to have their assumptions described fully and clearly. The complexity of some of the models may prevent this from happening in this working paper. He suggested that some discussion around what the modelling exercises did not capture might be helpful.

Dr. Chamberlain identified some of the information in Section 6 as useful as long as it leads to recommendations (and further stressed the need to clearly state assumptions and data gaps). He also acknowledged that time would be needed to consider the recommendations provided in section 7, and later to adopt and transition to them.

The authors thanked Dr. Chamberlain for his comments and noted that they attempted to engage management and relevant policies at many points during the ERI process, but that the degree of disconnect between management and science was considerable. The authors also agreed with Dr. Chamberlain that science should not hesitate to make recommendations to management. With respect to Dr. Chamberlain’s concern about the recommendations to management included in the working paper, the authors clarified that they were provided as suggestions of *possible* issues and to prompt future requests for management advice, not as concrete (unsolicited) recommendations. The authors also agreed that it is important to understand the significance of the remaining 98% (nearshore) environment of the Strait of Georgia *not* connected to outside waters.

## GENERAL DISCUSSION

Once the reviews were completed, the Chair provided an opportunity for participants to discuss the various sections of the working paper. The discussions summarized below are provided in the order they were discussed.

# HOW THE STRAIT OF GEORGIA ECOSYSTEM WORKS

## General Features

Five processes were presented as the main features that affect the overall productivity of the Strait of Georgia: enrichment, initiation, retention, concentration and trophic dynamics. Participants were in agreement that these processes were generally well-organized and summarized.

During the overview presentation, a point of clarification was raised during the trophic dynamics sub-section (2.1.5) concerning the measures used in the calculation of "trophic efficiency" (Table 2). The authors clarified that they were replicating a previous analysis in order to make their results comparable, so were not at liberty to test or use other (possibly more appropriate) measures. A similar case was noted in the retention sub-section (2.1.3), and the authors' use of "connectivity" instead of "total volume exchanged".

Participants noted that a key component missing from this section was any process relating to the nearshore environment (physical habitat quality, transport mechanisms, population reproduction/gene flow mechanisms). They were left with the impression that this part of the Strait of Georgia was not considered important by the ERI. It was pointed out that the "benthic" node in the Bayesian network model (section 4) captures nearshore effects, but noted that it did not make enough specific linkages to other nodes (i.e. early marine survival of Chinook). The authors agreed to add a paragraph to the trophic dynamics sub-section to address this topic.

Participants also noted that the working paper did not specifically address the Fraser River estuary or any of the fjords leading into the Strait of Georgia. It was suggested that the paper include a better definition of the "Strait of Georgia" and what it includes (and excludes). It was also suggested that Table 1, column 2 take a broader focus, or add a qualifier to the caption specifying that the table contains examples, and is not meant to convey an exhaustive or prioritized list of issues.

## Drivers of Change

During the overview presentation of the drivers of change section (2.2), a point of clarification was raised as to whether landings could really be used to represent abundance (Figure 4). The authors felt that it could with the caveat that it was mediated by management actions. That is, if populations weren't decreasing, no management actions would be taken. It was noted that actions taken in response to decreases in fish population may not be changed to reflect later increases in population. Thus decreases in landings would likely be representative of decreases in abundance, but any increases in landings may not reflect the full extent of increases in population abundance (if it continued to be mediated by management actions). It was also recognized that using absolute numbers of fish rather landings (total weight) would remove the effects of changes in population size structure (e.g., the issue of discerning a larger population of smaller fish from a population of fewer, larger fish).

There was considerable discussion around changes needed to Table 4 in the working paper. Participants noted that they had trouble making linkages between the middle and right-hand columns as there was not a one-to-one link between them. They also noted that no cross-scale impacts were included in the table. The authors noted that the table was meant more as a readable summary linking to the text rather than an exhaustive list. The following suggestions resulted from the discussion:

- strengthen the links between columns because they are examples
- change the middle column heading to "Examples of drivers to change"

- provide a link to Figure 3 in the caption
- items that could be included in the "Large" spatial scale section: wind, freshwater discharge, climate variability (to differentiate from [anthropogenic] climate change)

There was some difficulty reading the Driver-Pressure-State-Impact (DPSI) assessment shown in Figure 3 because it did not reproduce well in the working paper (a better version will be provided in the research document). It was suggested that Figure 3 should include disease and/or parasites as a pressure. Additionally, there was some question regarding why management actions did not appear as a pressure. The authors clarified that management actions were considered to be a response in the DPSI assessment and that the response level was omitted intentionally from the figure.

Participants felt that overall, the language in this section should be standardized to align more closely with language used in ongoing projects (e.g., "stressors" vs. "threats" vs. "drivers" vs. "activities", DFO 2012/044.) It was recognized that there is a need to **quantify** the potential impacts of the various drivers at each of the three spatial scales and show how this could be used to inform decision making processes and risk assessments (i.e., management actions). There is also a need to identify, quantify and monitor cumulative effects of drivers (listed as a knowledge gap). The authors clarified that the relative importance of the examples given was not evaluated. The examples were chosen simply based on the availability of data and the interests of the researchers involved. It was also noted that, no matter how thoroughly studied, there will always be the possibility for unexpected events or unanticipated changes to the ecosystem going forward.

### Potential Future Conditions for the Strait of Georgia

Participants wondered if this section (2.3) should be changed to reflect how the drivers will change, rather than the Strait of Georgia itself. It was noted that predictions of future states are available for only some of the stressors.

Clarification was needed for the section on contaminants, particularly the statement about contaminants "persisting" followed by measures of their decline. The authors agree to check with the project contributor to clarify this language. It was felt that the statement referred to non-monitored and unregulated chemicals persisting while monitored and/or regulated ones declined. There was additional discussion about whether the contaminants issue was being overemphasized in the synthesis compared to other ERI projects. Although it was suggested that the working paper should try to capture general direction of trends in stressors, pressures, etc., the authors pointed out that they consciously tried to stay away from this type of reporting.

Additional editorial changes suggested for this section include:

- move the second paragraph in the section to precede the first;
- consider adding Merryfield et al. reference in paragraph regarding wind predictions and future wind conditions, to balance differing conclusions and capture the types of uncertainty that exist;
- add examples of potential changes to biotic factors, not just abiotic ones.

## TOOLS & MODELS

The authors again stressed that the tools and models presented in the synthesis were examples of the types of products that could be used to conduct future ecosystems research. They noted that each approach has advantages and limitations, and that there are likely other approaches not covered in this work that will also be appropriate (e.g. Mike Foreman's Discovery Islands simulation work should be referenced, even though it was conducted at a much higher resolution than the other simulation models).

Participants requested more general description and definition of terms used to assist readers with limited modelling experience, along with less detail about the model mechanics. Each subsection (4.1-4.5) will define what the tool/model does and what its limitations are. In addition, they suggested that the authors highlight the benefit of presenting two simulation models more in the text (agreement in their results increases confidence in the outcomes).

There was considerable discussion around reformatting of Table 7. In particular:

- In the first column, list specific models presented under the overall large classes of models to improve linkages between large classes and specifics (e.g., list “D-P-S-I” under “Ecosystem assessments”).
- Rename the third column to “Resource Needs” from “Data needs”
- Add a fifth column called “Applicability” which will provide examples of where the models can be used and what products they provide. This information could also be used to determine whether the models presented would be suitable for use in other regions.

### Ecosystems Assessments

Participants discussed the design of the ecosystems assessment model presented in Figure 2. In particular, they noted that the two size classes of hake are lumped together in the assessment, and that because population dynamics have changed in recent years, some of the linkages illustrated do not exist anymore (e.g., there are very few “large” hake in the Strait of Georgia anymore, so the “hake” category shouldn’t be shown to consume small pelagics; and although juvenile salmon are the second most dominant species in the Strait of Georgia from spring to fall, they are aggregated with “small pelagics”, but should qualify as their own group). Thus, participants felt that structural changes to the model are required and that the model needs to reflect the most up-to-date information currently available in all cases. The authors agreed to adjust the text to address these changes and acknowledged future versions of the model will require additional refinement.

### Statistical Analysis of Ecosystem Data

No specific revisions suggested.

### Probabilistic (Bayesian) Networks

No specific revisions suggested.

### Simulation Models

There was concern expressed over the results obtained from the EwE simulation model investigating the relationship between Chinook salmon, resident killer whales and pinnipeds. Participants were concerned that the model did not use the most current diet data available and as such, the results should not appear as if providing advice. Once again, it was stressed that the synthesis provides examples of the types of results that can be obtained. If a request for advice on this matter came from management, the model would need to be re-evaluated with the most current data available. It was also suggested that a reference be provided for the paragraph discussing the ROMS model.

### Habitat Models

Figure 14 is to be swapped with a higher resolution one from the peer-reviewed paper.

## CONSIDERATIONS FOR MANAGEMENT

This section was discussed following the managers' reviews on the second day of the meeting.

Specific suggestions arising from these discussions include:

- Section 3 Introduction, paragraph 2: remove the word "normal" from the second sentence. At present, there is no accepted definition of what "normal functioning" means with respect to the Strait of Georgia.
- This synthesis needs to consider what other processes are providing advice and defer to them, ensuring recommendations/advice given agree with those provided by the other processes or that only one set of recommendations/advice are provided.
- Use the term "learnings" rather than "recommendations" since no clear objectives have been set for the Strait of Georgia, and thus no prioritization of competing goals, which means recommendations cannot be made.

### Drivers of Change

Participants felt that this section needed more of an introduction to frame the following paragraphs as examples of the types of drivers that can exist (i.e., Aquatic Invasive Species (AIS) and fishing). This elaboration should include recognition that there are additional drivers that have not been considered yet (i.e., a future risk). Additional information from AIS project contributors relating to habitat and/or spatial contexts will be sent to the authors for inclusion in the research document. Participants wondered if the AIS piece should be moved to the Spatial Management sub-section. There was also extensive discussion around the herring example used in the fishing paragraphs of this section. There was no uncertainty provided around the critical threshold stated for herring fishing mortality rate, and participants thought it was misleading to state that current herring fishing levels are well below this critical threshold (suggesting that the Strait of Georgia ecosystem could bear fishing herring at a higher rate). The authors agreed to reword this part of the section to remove ambiguity.

### Indicators

Participants felt this section needed more preamble in order to provide more context for the examples that are included in this sub-section (regime shift indicators, zooplankton biomass indicators for coho early marine survival, etc.). A number of indicators have been identified as "useful" as a result of the Strait of Georgia ERI project findings. Although they can be used alone, they could also be considered as part of a suite for broader application. It was suggested that the authors add a table to the document outlining the various indicators, what they can be used for, and what their monitoring requirements and/or data needs are. The authors agreed and noted that this table will be reproduced from Perry *et al*. They also noted it was important to distinguish the difference between "drivers" (i.e., correlated, responsive factors with known operational mechanism) and "indicators" (i.e., correlated, responsive factors with an unknown underlying operational mechanism), as well as "state indicators" versus "management indicators". The current list of indicators is based on information that has already been collected. Future work should consider developing new indicators based on the information that <u>should</u> be collected to address stated objectives.

### Spatial Management

Participants emphasized that spatially localized species and/or habitats can still have considerable impact on an ecosystem. (e.g. sand lance and nearshore habitats). They felt that this issue was not addressed sufficiently in the working paper. Participants also suggested that work on rockfish conservation areas in the Strait of Georgia and the VENUS program should be mentioned in this section. Additionally, it was felt that the AIS information could be moved to this section. It was noted that even though the Strait of Georgia has low connectivity to outside waters, it is not isolated. In terms of spatial management, participants then questioned where the boundaries should be drawn to define this ecosystem? Participants also wondered if the results identifying suitable sand lance habitat should be placed in a bigger context, suggesting that there are likely other areas of the Strait of Georgia providing important habitat for other species.

When asked, the authors clarified that there were no aquaculture projects funded by the ERI because no proposals relating to aquaculture were received when the ERI was established. It was also noted that the work from Baynes Sound is not mentioned and should be considered for inclusion. Participants suggested that more cross-communication among projects while they were ongoing may have lead to more information sharing among overlapping project areas. Finally, participants cautioned the authors against using key DFO policy terminology (e.g., "critical habitat" or "precautionary approach"), unless it is being used in the appropriate context with respect to their respective policies.

## DATA AND KNOWLEDGE GAPS

Several data and knowledge gaps were identified from among those presented in the working paper. These included:

1. There is a need to consider cumulative, synergistic or roll-up effects among the individual factors identified in the working paper.
2. The importance of sand lance in the Strait of Georgia ecosystem needs to be investigated further based on the initial findings from the ERI. This includes life history and spawning habitat information.
3. There are data missing from the ERI research projects relating to diets and trophic levels. This information will be needed by the forage fish policy and laws pertaining to habitat. Could diets and changes to diets be used as an indicator of ecosystem change?
4. The EwE model is missing information (in particular, zooplankton life history and timing, and hake/Pollock population structures)
5. The current list of indicators in use is based on information we already have. Future work should focus on developing new indicators based on information we would like to have.
6. There is a need to include the potential for aquaculture interactions. (It was noted that this element was missed by the ERI research projects because it was not a priority issue when the ERI was established.)
7. Need to develop ecosystem approach to risk assessments, including a triage-type method for addressing identified stressors.
8. There should be reference to nearshore habitat work that has already been completed (by non-ERI projects) that provides a critical spatial management tool (for example, the *ad hoc* DFO working group on nearshore and benthic ecosystem processes)

It was stressed once again that the results from the Strait of Georgia ERI were provided as examples of data and knowledge gaps, not exhaustive or prioritized lists. The group discussed the ERI's ability to identify existing sources of information, recognizing that although it was fairly good, there were likely many untapped sources, particularly among departments not represented by ERI contributors. An open floor discussion then took place where participants could identify additional gaps. The following list developed (bearing in mind that this list is neither exhaustive or prioritized):

1. Should consider additional physical drivers of the Strait of Georgia ecosystem.
2. Need to confirm the suspected change in diet, abundance and/or distribution among mid-trophic forage species (e.g. Pollock, hake, dogfish).
3. Untapped data sources must be considered, as well as data management issues such as data consolidation, storage and archiving, particularly in light of pending changes to DFO library systems, retirements, changing technologies, etc. (Pacific Salmon Foundation data repository project could be important here).
4. Better monitoring of the inherent variability in the Strait of Georgia ecosystem is required, particularly given that the magnitude of variation in the ecosystem can and is changing. This will contribute to better understanding of tolerances among organisms using the Strait of Georgia ecosystem.
5. Improved understanding around the mechanisms regulating juvenile salmon survival, and the links to (or interactions with) young of the year herring during their very early marine period. This could then be expanded to include more resident stocks, such as invertebrates (e.g., geoduck recruitment is constant in some areas, sporadic in others).
6. Better definition and measurements to determine the timing of the spring phytoplankton bloom is needed. It was noted that ferry boxes (part of the VENUS project) will provide insight into southern Strait of Georgia bloom timing, but more northern data may also been needed (this program will also have two gliders available to survey other parts of the Strait of Georgia).
7. Mapping of important habitat for herring is needed (though some is already available).
8. Future work should consider incorporating socioeconomic analyses of ecosystem approach decisions. In addition, single species stock assessments should find a way to incorporate ERI-type analyses.
9. Need to identify and quantify sources of variability in the seasonal timing (phenology), species composition and life history of zooplankton, particularly as it pertains to zooplankton availability for predation (trophic dynamics issue).
10. An improved understanding of mechanisms connecting large scale oceanographic processes to local realizations is needed, keeping in mind that correlation does not equal causation. This includes the missing “nearshore dynamics” piece and how it leads to or links with larger scale processes. There is a significant lack of data for water depths less than 30m (called the “whitestrip”).
11. Need to investigate the physiological and biological differences of stocks or species utilizing the northern migration corridors out of the Strait of Georgia versus the southern migration route (i.e., for salmon, herring, eulachon, etc.)
12. Macrophytes listed are listed in Figure 2, but little is presently known about them. There is a need to measure abundance/population structure of this group.
13. There may be additional issues of “scale”, related to defining the ecosystem and how big or small researchers need to study in order to accurately capture the system in its entirety.
14. Shipping (as a form of acoustic pollution) was recognized as an emerging issue.

A DFO Habitat Manager provided additional comments on the potential utility of this ERI program and its outcomes to habitat issues:

- Changes to habitat programs, several years of uncertainty (new Fisheries Act)

- Key issues: quantification and thresholds; management decisions made on a different scale than science info is collected
- Links between habitat change and fisheries productivity must be established
- 2 other major challenges: scale & data; quantify impacts of habitat change in light of larger scale processes acting concurrently
- Recommends authors attend departmental mgmt process meetings (SEP, etc.)

## REFLECTIONS ON THE MANAGEMENT OF THE STRAIT OF GEORGIA ERI

A focused discussion on this topic was deferred in the interest of time. Several items relevant to this topic were identified at other points in the meeting and are subsequently included here.

Three over-arching issues that should be considered at the outset of future ecosystem research projects are:

1. Consistency: Ensure contributors have clear definitions of common terms and use these terms consistently throughout the work to enable clearer communication. Consider maintaining a glossary that can be expanded and refined over the course of the project. This will be critical in projects that span multiple fields, where a terms may be used differently by each functional specialist (e.g., differentiating an “indicator” from a “factor” in an ecosystem analysis).
2. Scale: Determining the scale of an ecosystem is vital for directing the work to be conducted by the project, and resolution of the data needed by the project (e.g. analysis of nearshore ecosystems could require higher resolution data compared to similar studies in the Strait of Georgia)
3. Balance: The ability to incorporate a level of uncertainty attributable to unknown or unmeasured (data deficient) factors or influences among elements that are well-known and/or data-rich in an ecosystem is vital. For example, very little is known about sand lance in the Strait of Georgia, but they potentially play a key role in the ecosystem.

It was identified that if desired products, outcomes or needs are known in advance, it becomes easier to involve partners (e.g., community groups, other departments, academia) to achieve them. It was also felt that strengthening these partnerships with other sectors and programs should be a key consideration. Questions about logistics surrounding these partnerships—such as data quality assurance—will need to be addressed. This topic was tabled for future work. Participants suggested that the “Considerations” section from the 2011 Strait of Georgia ERI CSAP research document could be re-iterated here.

## NEED FOR A PROCESS TO DELIVER SCIENCE ADVICE FOR AN ECOSYSTEM APPROACH TO MANAGEMENT IN PACIFIC REGION

The discussion surrounding this topic opened with a short presentation by a national headquarters representative on the Strategic Program for Ecosystem Research and Advice (SPERA), which has evolved from the ERI work completed to date. This program will have a much more top-down structure focused on answering specific management needs or questions. It will likely have a five year funding horizon. An ecosystem approach working group has been formed under SPERA by the policy group at national headquarters. Management representatives from national headquarters programs (Oceans, Species at Risk, Fisheries Management, Habitat Management) will coordinate with regional managers to identify priority ecosystem management science needs. The next step for the SPERA program is a scoping exercise to set objectives and to determine how future work will fit with current, ongoing programs, as well as how to transition to a new approach. The next round of funding decisions is imminent (call for proposals slated for January 2013), so Pacific region will need to get organized in order to be prepared to submit requests to this project.

There was some discussion about the need to better utilize the State of the Pacific Ocean report as a means of communicating ecosystem issues and results. The November 1, 2012 release date for the Cohen Commission report was also identified as an external pressure that may impact funding and priorities. Participants identified the need to get other sectors, agencies and external groups involved (e.g., universities, NGOs, etc.) in order to have the resources necessary to tackle these large projects. (Particularly since it was also pointed out government funding for basic data collection has and continues to decline.)

## CONCLUSIONS

The working paper was accepted with revisions that have been summarized throughout these proceedings.

The draft Science Advisory Report was distributed at the beginning of the meeting's last day and the remaining half day was used to refine the draft. Revisions were primarily comprised of editorial changes to wording and content to best reflect the scope and results of the Strait of Georgia ERI projects and the synthesis generated from them. It was agreed that a final version would be circulated to all participants for validation with agreed upon edits.

## RECOMMENDATIONS

The following recommendations were agreed upon by meeting participants at the close of the meeting. While not an exhaustive list, key recommendations from the review of the Synthesis of the Strait of Georgia Ecosystem Research Initiative include:

1. To implement EAM, a process for the collaboration and coordination among Sectors is necessary. A cross-sector working group is recommended. This working group could also serve to interface with other Regions and other external initiatives.
2. For the Strait of Georgia and other areas, identify and prioritize potential indicators, including their data requirements, to meet EAM objectives.
3. Consideration of productivity regimes and food web dynamics (predation and prey requirements) should be integrated into stock assessments, and inform other Departmental planning processes.
4. The nearshore zone in the Strait of Georgia, and elsewhere in the Pacific Region, is poorly described and its role in ecosystem processes is not well understood. To provide science advice with respect to the value of this zone to ecosystem dynamics, including fish productivity, further study is necessary.
5. Ecosystem data are dispersed in a variety of formats making their collection and synthesis difficult; common platforms for data collection and storage are needed.
6. Recognizing that tools developed through this process have broader applicability than just the Strait of Georgia and should be considered for other areas and regions.

## ACKNOWLEDGEMENTS

The Chair and working paper authors are grateful to Mary Thiess (DFO Science) for her skill as rapporteur for the meeting and editor of these proceedings in capturing the relevant discussion, agreements and recommendations. The Chair thanks the working paper authors Drs. Ian Perry, Diane Masson, Dave Preikshot, and Mr. Andres Araujo for a well written paper and spirited participation in responding to all questions and comments. The chair and authors thank Dr. John Dower (University of Victoria) for his detailed and constructive review of the working paper that stimulated highly constructive discussion and recommendations. She also expresses her appreciation to Dr. Jon Chamberlain and Ms. Aleria Ladwig, both managers with DFO for their thoughtful consideration of the management implications of this work and constructive comments on future science directions for ecosystem approaches to management. Meeting participants are commended for engaging in a highly collaborative dialogue with the authors and Chair that improved all of the products resulting from this meeting.

## REFERENCE

DFO. 2012. Risk-based Assessment Framework to Identify Priorities for Ecosystem-based Oceans Management in the Pacific Region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/044.

# APPENDIX A: AGENDA

**Canadian Science Advisory Secretariat**
**Regional Peer Review**

**A synthesis of the outcomes from the Strait of Georgia (SOG) Ecosystem Research Initiative (ERI), and their ecosystem-based management and policy implications**

**AGENDA**

September 11 - 13, 2012

Pacific Biological Station
Nanaimo, British Columbia
Chairperson: Marilyn Joyce

**Day 1 – Tuesday, September 11th**

| | | |
|---|---|---|
| 10:00 | Introductions & Agenda Review | Marilyn Joyce |
| 10:10 | CSAS Overview & Meeting Procedures | Marilyn Joyce |
| 10:20 | Review of Terms of Reference | Marilyn Joyce |
| 10:30 | Overview Presentation of Working Paper | Ian Perry |
| 11:30 | External Review | John Dower *(presented by Ian Perry)* |

**12:00 Lunch Break**

1:00 Discussion: How the Strait of Georgia Ecosystem Works (Section 2 of working paper): — RPR Participants

- General Features
- Drivers of Change
- Potential Future Conditions for SOG

**2:30 Break**

2:45 Discussion: Tools & Models (Section 4): — RPR Participants

- Ecosystem Assessments
- Statistical Analysis of Ecosystem Data
- Probabilistic (Bayesian) Networks
- Simulation Models
- Habitat Models

**4:30 Adjournment**

**Day 2 – Wednesday, September 12th**

| | | |
|---|---|---|
| 9:00 | Introductions & Housekeeping | Marilyn Joyce |
| 9:10 | Review Day One Progress & Agenda for the day | Marilyn Joyce |
| 9:30 | Manager's Review | Jon Chamberlain/ Aleria Ladwig |
| 10:00 | Discussion: Considerations for Management (Section 3): | RPR Participants |

- Drivers of change
- Indicators
- Spatial management

**10:30 Break**

10:50 Discussion continued: Considerations for Management RPR Participants

**12:00 Lunch Break**

1:00 Discussion: Data and Knowledge Gaps (Section 5) RPR Participants

**2:30 Break**

2:50 Discussion: Reflections the management of the SOG RPR Participants

ERI and future directions complex ecosystem science programs. (Section 5)

**4:00 Adjournment**

**Day 3 – Thursday, September 13th**

9:00 Introductions & Housekeeping Marilyn Joyce

9:10 Review Day Two Progress & Agenda for the day Marilyn Joyce

9:30 Outstanding Items for Discussion form Day 1 & 2 RPR Participants

**10:30 Break**

10:50 Discussion: Conclusions & Recommendations RPR Participants

(Review Author's material and new material from meeting)

**12:00 Lunch Break**

*(afternoon break scheduled as convenient)*

1:00 Developing the Science Advisory Report (SAR) RPR Participants

Finalize the Conclusions & Recommendations

- Sources of Uncertainty
- Summary
- General content

**4:00 Adjournment**

# APPENDIX B: ATTENDEES

## Centre for Science Advice Pacific
## Regional Peer Review – Strait of Georgia ERI Sept. 11 -13, 2012

| Last Name | First Name | Affiliation | Attend Sep 11 | Attend Sep 12 | Attend Sep 13 |
|---|---|---|---|---|---|
| **DFO Participation - ERI Project Participants** | | | | | |
| Brown | Robin | DFO | A | A | A |
| Fu | Caihong | Science | A | A | A |
| Holt | Carrie | Science | A | X | X |
| Irvine | Jim | Science | A | A | X |
| Mackas | Dave | Science | X | A | X |
| Masson | Diane | Science | X | A | A |
| Neville | Chrys | Science | A | A | A |
| Nichol | Linda | Science | A | A | X |
| Olesiuk | Peter | Science | A | A | A |
| Perry | Ian | Science | A | A | A |
| Schweigert | Jake | Science | A | A | A |
| Sutherland | Terri | Science | A | A | A |
| Sweeting | Ruston | Science | A | X | X |
| Therriault | Tom | Science | A | A | A |
| **Additional DFO Participation** | | | | | |
| Araujo | Andres | DFO | A | A | A |
| Boldt | Jeniffer | Science MEAD | A | X | X |
| Boutillier | Jim | Science MEAD | A | A | A |
| Bradford | Mike | Science, SAFE | X | X | X |
| Brown | Laura | Science MEAD | A | X | X |
| Chamberlain | Jon | FM Aquaculture Management | A | A | A |
| Francis | Kelly | DFO, SARA | X | A | A |
| Galbraith | Ryan | OHEB SEP | A | A | X |
| Gillespie | Graham | DFO Science | A | X | X |
| Johnson | Stewart | DFO Science | A | A | A |
| Joyce | Marilyn | Science, CSAS | A | A | A |
| Ladwig | Aleria | FM Ecosystem Officer | A | **A** | A |
| Ludke | Wilf | South Coast Science SA | A | X | X |
| Nishimura | Derek | OHEB Habitat | A | X | ? |
| O | Miriam | Science | A | A | A |
| Rasmussen | Glen | | A | A | A |
| Salomi | Corino | Fraser River, Oceans, Habitat, Enhancement | A | A | A |
| Saunders | Mark | Science SAFE | A | A | A |
| Silverstein | Adam | South Coast, Oceans, Habitat | A | X | X |
| Thar | Jonathan | DFO, SARA | A | X | A |
| Thiess | Mary | | A | A | A |
| White | Andrea | Ocean and Science - NHQ | A | A | A |
| **External Participation** | | | | | |
| Akenhead | Scott | Ladysmith Institute | A | A | A |
| Allen | Susan | UBC | A | A | X |
| Pearsall | Isobel | Pacific Salmon Foundation | A | A | X |
| Robinson | Cliff | Parks Canada | A | A | X |
| Tunnicliffe | Verena | University of Victoria | A | A | X |
| Wong | Cecelia | Environment Canada, Vancouver | A | A | ? |

## APPENDIX C: TERMS OF REFERENCE

### A synthesis of the outcomes from the Strait of Georgia Ecosystem Research Initiative, and their ecosystem-based management and policy implications

### Regional Peer Review - Pacific Region

11-13 September 2012
Nanaimo, B.C.
Chairperson: Marilyn Joyce

### Context

Fisheries & Oceans Canada (DFO) has committed to a sustainable, precautionary and integrated ecosystem approach to oceans management. To support the development and implementation of such an approach, seven Ecosystem Research Initiatives (ERIs) were established by DFO Science to facilitate integrated research on a particular ecosystem with predefined geographical boundaries. The overall purpose of the ERIs was to serve as a pilot for DFO's ecosystem-based approach and enhancing the capacity to provide scientific advice in support of ecosystem approaches to management.

Going forward, knowledge gained from these large scale ecosystem studies would allow the development and testing of tools required to manage human activities within broader aquatic ecosystems.

In Pacific Region, the Strait of Georgia was selected as the pilot study ecosystem. The Strait of Georgia Ecosystem Research Initiative began in January 2008, and concluded its directly-funded phase on 31 March 2012.

The main objectives of the Initiative were to 1) improve understanding of how the ecosystem system works (e.g. what controls the productivity?); 2) examine the impact of the drivers of change on the ecosystem and consider how these drivers might change in the future (what controls the resilience?); and 3) develop ecosystem-related science-based management and decision-making tools to support healthy and sustainable marine resources.

Key results from this Initiative pertaining to these objectives will be presented and their implications for an ecosystem approach to managing human interactions with the Strait of Georgia ecosystem will be examined in this peer review process. In addition to the advice pertaining to ecosystem based management in Pacific Region, the results of this process will provide important contributions to a national DFO CSAS process on lessons learned from the ERI programs in each region, which is scheduled for November 2012.

### Objectives

1. Provide a synthesis (based largely on the Strait of Georgia Ecosystem Research Initiative) of how the Strait of Georgia ecosystem works (what controls the productivity), what drivers of change are acting on the Strait, and how these drivers might change in the future;
2. Identify potential issues and specific recommendations for management attention within an ecosystem approach to management that result from (1), including examples of specific applications of existing DFO ecosystem-related policies (e.g. forage fish policy);
3. Provide guidance on tools developed and used during the Strait of Georgia Ecosystem Research Initiative for generating science advice within an ecosystem context;
4. Identify critical knowledge gaps and future research needs to advance the development of integrated ecosystem assessments and management approaches in Pacific Region;
5. Provide lessons learned and recommendations on how to deliver Science advice for an ecosystem approach to management in Pacific Region.

Discussions and advice will be based on the following working paper:

Perry, R.I. et al. The Strait of Georgia in an ecosystem context: a synthesis of key findings and management implications from the DFO Pacific Ecosystem Research Initiative. CSAP Working Paper 2012/P59.

**Expected publications**

- CSAS Science Advisory Report (1)
- CSAS Research Document (1)
- CSAS Proceedings

**Participation**

- DFO Science Branch
- DFO Fisheries and Aquatic Management Branch
- DFO Oceans, Habitat and Enhancement Branch
- Parks Canada
- Province of BC
- Commercial and recreational fishing interests
- First Nations organizations
- Non-government organizations
- Academia

**References**

Research objectives, plans, and annual reports from the Strait of Georgia Ecosystem Research Initiative projects

DFO. 2012. Developing a framework for science support of an ecosystem approach to managing the Strait of Georgia, British Columbia. DFO. Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/075.

DFO. 2012. Proceedings of the Centre for Science Advice, Pacific Region Review of A framework for an ecosystem based approach to managing the Strait of Georgia, British Columbia; February 16-17, 2011. DFO. Can. Sci. Advis. Sec. Proceed. Ser. 2011/069.

# APPENDIX D: SUMMARY OF THE WORKING PAPER

A synthesis of the findings available to date regarding understanding of how the Strait of

Georgia marine ecosystem 'works', the drivers of change acting on the Strait, and how some of these may influence the Strait in the mid-future (next few decades) are presented. They are based on but not exclusively from the DFO Strait of Georgia Ecosystem Research Initiative (ERI), a program consisting of several projects that ran from 2008 to 2012. The report also provides guidance to some of the ecosystem-related science-based tools that were developed and expanded during the program in order to assist with management decision making in an ecosystem context. The report addresses three of the steps in DFO's implementation of an ecosystem approach to managing human interactions with the Strait of Georgia, specifically characterizing and assessing the state of this ecosystem; identifying indicators and thresholds for assessment and management, and aspects of monitoring, evaluating and reporting on changes in this system. It also provides detail to several of the key science elements of an ecosystem approach to the Strait of Georgia, specifically the identification of anthropogenic stressors, indicators, thresholds, spatial management, and modeling.

Five key processes were identified which govern how the Strait of Georgia marine ecosystem 'works', and what controls its productivity. These are enrichment, initiation (of plankton blooms), retention, concentration, and trophic (food web) dynamics. These key processes provide a framework to evaluate the potential impacts of any stressor, natural or anthropogenic, on this system. Stressors which interfere with or interrupt any of these five key processes can be expected to have consequences for the productivity of the Strait of Georgia ecosystem. The report also discusses several specific considerations for management attention within an ecosystem context, grouped under three topics: drivers of change, including non-native species introductions and fishing; indicators, both ecosystem-wide and specifically for coho and herring early marine survivals; and spatial management, relating to the Roberts Bank area and important habitat for sand lance in the Strait of Georgia.

Reflections are provided on how the Strait of Georgia ERI was managed, for the consideration of future large collaborative programs. The report concludes with suggestions for how DFO in Pacific Region might develop a regular process for the discussion and evaluation of ecosystem issues.

# APPENDIX E: WRITTEN REVIEWS

Centre for Science Advice Pacific
Regional Advisory Process

Month 09, 2012

Written Review

Date: September 4th, 2012

Reviewer: **Dr. John Dower**, Department of Biology and School of Earth & Ocean Sciences, University of Victoria

Working Paper: **Perry RI, Masson D, Preikshot D, and Araujo, HA (2012)** A synthesis of the outcomes from the Strait of Georgia Ecosystem Research Initiative, and their ecosystem-based management and policy implications**. CSAP Working Paper** 2012/P59.

**Summary:** Within the context of the Terms of Reference for the Strait of Georgia ERI, this working paper set out to address five objectives:

1. Provide a synthesis of how the Strait of Georgia ecosystem works, what drivers of change are acting on the Strait, and how these drivers might change in the future;
2. Identify potential issues and specific recommendations for management attention within an ecosystem approach to management that result from (1), including examples of specific applications of existing DFO ecosystem-related policies;
3. Provide guidance on tools developed and used during the Strait of Georgia Ecosystem Research Initiative for generating science advice within an ecosystem context;
4. Identify critical knowledge gaps and future research needs to advance the development of integrated ecosystem assessments and management approaches in Pacific Region;
5. Provide lessons learned and recommendations on how to deliver Science advice for an ecosystem approach to management in Pacific Region.

In summary, I think that the working paper succeeds in achieving these goals. Having conducted research in the Strait of Georgia (SoG) for the past 12 years, I found that the document did a very thorough job of synthesizing how much we know about the Strait (which is considerable), while simultaneously highlighting how much we still don't know (which is considerable). Having been informed that two DFO managers have been asked to review the paper from the perspective of manager usability, I will focus my comments primarily on the scientific merit and theoretical aspects of the working paper.

Specific comments (numbers refer to section headings in the working paper):

2.1.3 (Page 4): Although I've always considered the SoG to be a relatively isolated ecosystem, it was both interesting and somewhat surprising to see this quantified. At the very least, from an ecosystem management perspective, this helps justify treating the SoG as a discrete unit (links to the WCVI and regional climate forcing notwithstanding).

2.1.4 (Page 5): Since the 1990s, herring spawning in the SoG has apparently become progressively concentrated along the NW shores of the SoG. This is quite intriguing, but I found it odd that no hypotheses were advanced to account for this seemingly dramatic shift. Given that one of the main stressors on the SoG is purported to be the growing human population, one can't help but wonder whether this shift in spawning activity reflects the fact that the NW part of the SoG is one of the least "human-impacted" regions left.

2.1.5 (Page 6): "*The Strait of Georgia has a trophic efficiency of 6.18…*" How exactly was this number arrived at? I ask because, given the uncertainties involved with estimating trophic efficiencies, coupled with the datapoor situation for many key biological variables in the SoG, it seems like a very accurate value. The fact that this value is also strongly dependent on "*the import of primary production from the WCVI (sic) in particular by herring…*" makes the value even more suspect. Leaving aside the question of how adult herring import primary production from the WCVI, when the WCVI influence is removed, the trophic efficiency of the SoG appears to be only 4.82%. I point this out primarily because almost every paper about the SoG (my own included) usually starts with a motherhood statement about the SoG being one of the most productive ecosystems within Canadian waters. Have we all been getting it wrong, or does a trophic efficiency of 4.82% still count as "productive"?

2.1.5 (Page 6): I must admit to never having considered the SoG to be a "wasp-waisted" ecosystem, a designation generally reserved for permanent coastal upwelling ecosystems. However, given the biomass dominance of herring and sand lance, and their pivotal role in SoG trophic linkages, this assertion seems plausible. Certainly, the modeling results presented elsewhere in the synthesis point to the key role played by these two species in the SoG food web. It is worth pointing out that while wasp-waisted ecosystems are generally highly productive, they are also prone to higher decadal-scale variability in productivity than are many other coastal ecosystems. So, if the SoG is indeed wasp-waisted, this could have important implications from an ecosystem management perspective.

2.1.5 (Page 7): Regarding the decadal-scale trends in fish biomass in the SoG, I just wanted to add that recent work by one of my PhD students (Lu Guan), in collaboration with Skip McKinnell, suggests that there have also been significant changes in the abundance and relative composition of the ichthyoplankton community in the SoG since the 1980s. Comparing John Mason's ichthyoplankton data from around 1980 with data that we collected over the past five years, we see a significant decrease in total larval fish abundance (by about a factor of four), including considerable declines in the abundance of larval Pacific hake, walleye pollock, and Northern smoothtongue. These data are currently being prepared for publication.

2.1.5.2 (Page 8): I found the link between herring recruitment and the spring bloom in the match-mismatch section to be quite interesting. The authors found that September abundance of YOY herring was highest in years when the spawning commenced three weeks prior to the start of the spring bloom. Conventional wisdom holds that a "match" for larval fish occurs in years when the abundance of their prey (primarily copepod nauplii) is high. However, convincing examples of this from field studies remain surprisingly few. In this case, given that herring eggs take 2-3 weeks to hatch, followed by a week-long yolk-sac phase, it suggests that peak recruitment occurs in years when exogenous feeding of herring larvae begins about a week after the spring bloom begins….just about when one might first expect an increase in naupliar production in response to the bloom. While being a particularly good example of the match-mismatch hypothesis in action, this also raises the question of whether the increasing variability in spring bloom timing in the SoG may make such "match" conditions (and thus the production of strong year-classes of herring) less frequent in the future.

2.1.5.3 (Page 9): Regarding the link between YOY herring weight and the total amount of zooplankton after the end of the spring bloom, there might also be a role here for the composition of the zooplankton. In particular, and in terms of food quality, the reduction in the abundance/dominance of large lipid-rich copepods such as *Neocalanus plumchrus*, may have reduced the quality of the food encountered by juvenile herring and other fish species in the SoG in recent years.

2.2 (Page 9): This section contain a statement (based on an in review paper by Frouin et al.) that "Physical and chemical processes, rather than feeding, have been found to be the primary pathway by which these contaminants are taken into the lipids of the zooplankton in the Strait of

Georgia." I would have liked to hear a brief explanation of how this works, as it seemed counter-intuitive to me.

2.2 (Page 10): It was not clear to me how Preikshot et al. were able to derive a "primary production anomaly" time series from their Ecopath model. My understanding is that primary production is one of the factors used to tune Ecopath models in the first place. Primary production certainly isn't measured with any regularity in the SoG. I presume they must have used some sort of inverse approach to back out how much primary production would have been required to support the production observed at higher trophic levels? In any case, a little more explanation here would have helped. I was also a bit confused by the conclusion that declining trends in mean annual and winter wind speeds may have led to an overall reduction in production in the SoG in the late 2000s. What mechanism is being implied here? One the one hand, I could see how weaker winter winds might reduce the supply of nutrients to the surface layer. However, as pointed out elsewhere in the document, nutrients levels in the SoG are relatively high to begin with due to estuarine circulation and direct inputs from the Fraser River. On the other hand, weaker winds (particularly in winter) could allow the surface layer to stratify earlier (and more strongly) in the spring. Assuming enough nutrients are available, this could promote earlier spring blooms and increased primary production, as phytoplankton would be concentrated closer to the surface. Either way, this section could use a little more by way of explanation.

3.1 (Page 12): The paragraph on invasive species in the Drivers of Change section seems to come out of nowhere. While I agree that invasive species pose a potential threat to native biodiversity in the SoG, this part seemed like something of an orphan that should be further developed here and elsewhere in the document.

The following paragraphs contain a lot of information on the EwE model of Preikshot et al. The conclusion that reducing fishing on Chinook is unlikely to have a positive effect on killer whale numbers (because there are alternate predators on Chinook) is a noteworthy example of how an ecosystem approach to management can inform policy decisions. My one concern is the extent to which the model is parameterized using real SoG data (i.e. as opposed to literature-derived estimate or from EwE models form other regions). Elsewhere in the document it is stated that this is often the case with this particular modeling approach. I have no problem with the approach *per se*, as it has proven a very useful management tool in many other contexts. However, I would like to know how many of the "boxes" in the model are based on actual data from the SoG, if for no other reason than to get a sense of how representative the model might be. Presumably, sensitivity analysis forms part of the process - if so, it would have been informative to hear the results. Specifically, are the model outputs particularly sensitive to any components for which we do not have any data from the SoG? If so, identifying such components might be useful in terms of identifying potential "ecosystem indicators" that should be monitored in the future.

3.2 (Page 14): The study by Perry (In review) comes up with a list of six variables that could contribute to a regime shift index. I was a bit surprised to see that the list did not include any biological state variables, per se. I have no problem accepting that things such as SST, wind speed, and NPGO may be indicative of the potential for a regime shift. However, since the shifts in question (at least for the SoG) are argued to be mainly bottom-up, might it not also make sense to track some biological state variables that could give an "early" warning that these climate-related factors are actually having measurable biological effects? An obvious one (to me at least) would be the anomaly of zooplankton biomass, as it integrates effects on nutrient supply and primary production, while also indicating the potential for knock-on effects at higher trophic levels. Certainly, the next section regarding SoG coho by Araujo et al. (in review) points to this.

3.3 (Page 15): The section on spatial management focuses on the importance of the Fraser River estuary, Boundary Bay and Roberts Bank. However, there was no mention of the VENUS infrastructure in the SoG, as their instruments are located not too far away from these sites (especially their Delta Dynamics Laboratory). While the existing instruments may not be ideal for the purposes described in the synthesis document, there could be an opportunity for future collaboration and ecosystem monitoring as additional instruments are added to VENUS. The same could be said for the new “ferry boxes” that VENUS is installing on the BC ferries that traverse these regions that are of interest to DFO activities.

4.2 (Page 16): I was pleased to see the application of a statistical forecasting approach to provide early warnings of regime shifts in the SoG (Perry, in review). My only comment here again would be that it might be useful to include some sort of biological indicator in addition to the physical and climatic indices mentioned in Section 3.2. For example, supposing that an early warning of a regime shift is indicated, one way to confirm whether things are actually changing might be to track some biological response that might be expected to change fairly quickly in response to a regime shift. As mentioned elsewhere in the synthesis document, and also in my review, the zooplankton anomaly time series could be one such candidate.

4.3 (Page 17): The diversity of modeling approaches undertaken as part of the ERI is quite remarkable. The section on Bayesian networks offers an interesting alternative in situations where “regular” data are lacking, but other sources of information (e.g. expert opinion, etc.) are available. The main attraction would seem to be the ease with which, once constructed, such models can be used to play “what if games” for different management scenarios or future climate scenarios. As mentioned regarding the EwE model in Section 3.1, it would have been informative to hear more about how the sensitivities of such models are investigated, and how (or whether) model sensitivity might point the way to specific environmental variables on which new research should be targeted.

4.4 (Page 18): As stated previously, it would be informative to know how many of the “boxes” in the upper trophic level ExE models are based on real data from the SoG, and to which ones the model output is most sensitive. Throughout the synthesis document the timing and magnitude of the spring bloom and the biomass and composition of the zooplankton community are linked to interannual variability in the survival of herring, coho, and other species in the SoG. Thus, I cannot help but be somewhat wary of predictions from an upper trophic level model that aggregates these key groups into just a couple of size classes. I understand that logistical constraints make this a necessity, but given the growing awareness that (for example) food quality may be as important as food quantity under certain circumstances, I can’t help but wonder what we miss with this approach.

5.1 (Page 20): I strongly support the identification of a core set of ecosystem indicators for the SoG, particularly those which represent strait-wide and local process and that would complement the large-scale climatic factors/drivers identified by the Perry paper. Likewise, the development of spatially-explicit coupled biophysical models is a critical step in developing the ability to explore options for the placement of MPAs, the location of hot-spots, etc. I would note that some progress is currently being made on this front through the NSERC funded Canadian Healthy Oceans Network (CHONe), in which researchers from UVic (my lab) and UBC (Susan Allen’s lab) are collaborating with DFO researchers to map the distribution of ichthyoplankton in the SoG to identify larval “hotspots” and using DFO’s ROMS model (with Diane Masson) to forecast/hindcast larval drift trajectories.

The other issues for which the need for further research is identified (shift in the abundance of lipid-rich copepods, links to variability in bloom timing, declines/increases in hake/pollock, the diets of seals and sea lions) are all scientifically justifiable. In fact, my guess is that further research on these topics will have the knock-on effect of better informing the various ecosystem modeling approaches outlined elsewhere in the synthesis document. Glaringly absent, however, were any specific recommendations for how such field research should be undertaken, what resources would be required, and what specific questions should be investigated. The link to the emerging risks of acidification and hypoxia are also scientifically justified. Here again, there are potential linkages to be made to both the VENUS and NEPTUNE Canada cabled observatories, both of which are conducting research related to these questions.

As the remainder of Section 5 focuses on issues that are primarily related to internal DFO management policy and practice, I will not comment further, other than to state that I fully support the creation of a multi-sectoral group concerned with marine ecosystems issues in the Pacific Region, along the lines of the former PSARC-FOWG committee.

Section 6 and 7 (Pages 24-25): As these sections mainly reiterate points raised elsewhere in the synthesis (and which I have commented on elsewhere in my review), I don’t have much to add here. I do wonder whether there is a plan in the works for implementing the recommendations for new research on ecosystem indicators in the SoG? The synthesis document makes a clear case that further research on certain state variable in the SoG is warranted. However no mention is made regarding the resources that would be necessary to undertake such research. It will clearly not be cheap, but it will need to be done. Exploring partnerships with other marine research agencies (e.g. universities, VENUS/NEPTUNE) might be one option with considering. Certainly, the federal government has pumped millions into university-based ocean observing infrastructure.

My final point is that there should be an explicit link made between Recommendations 2 and 4. In terms of developing science advice, the utility of advice generated using the hierarchical approach proposed in Recommendation 4 will rely strongly on the ecosystem indicators identified in Recommendation 2, further justification for implementing Recommendation 2.