Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2016/016

Pacific and Maritimes Region

Proceedings of the zonal peer review on the Evaluation of Hierarchical Marine Ecological Classification Systems for Pacific and Maritimes Regions

September 29 – October 2, 2015
Nanaimo, British Columbia

Chairpersons: John Holmes and Nadja Steiner
Editor: Lesley MacDougall

Fisheries and Oceans Canada
Science Branch
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

May 2016

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

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1701-1280

Correct citation for this publication:

DFO. 2016. Proceedings of the zonal peer review on the Evaluation of Hierarchical Marine Ecological Classification Systems for Pacific and Maritimes Regions; September 29 – October 2, 2015. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2016/016.

TABLE OF CONTENTS

SUMMARY v
SOMMAIRE vi
INTRODUCTION 1
REVIEW OF PACIFIC WORKING PAPER 2
PRESENTATION OF THE WORKING PAPER 2
WRITTEN REVIEWS 3
Overall Review of both Working Papers: Dr. John Roff 3
Pacific Working Paper Review: Cliff Robinson 4
DISCUSSION OF PACIFIC WORKING PAPER 4
Objective 1: Data/Methods 4
Appropriateness / adequacy of data used 4
Different types of taxa combined (e.g. fish and invertebrate taxa) 5
Inclusion of abundance, biomass, or species richness data 5
Methods used 5
MPA NETWORK IDENTIFICATION PROCESS IN CANADA 5
REVIEW OF THE MARITIMES WORKING PAPER 6
PRESENTATION OF THE WORKING PAPER 6
WRITTEN REVIEWS 6
Maritimes Working Paper Review: John Harper 6
DISCUSSION OF MARITIMES WORKING PAPER 6
DISCUSSION OF BOTH WORKING PAPERS 7
Terminology 7
Hierarchical Consistency 7
CONCLUSIONS 7
RECOMMENDATIONS/ADVICE 8
Hierarchical Consistency and Fidelity 8
Populating Finer Scale Units 8
Data Bias, Gaps, and Potential for Future Improvements 9
REFERENCES CITED 9
APPENDIX A: TERMS OF REFERENCE 10
APPENDIX B: PARTICIPANTS 13
APPENDIX C: AGENDA 14
APPENDIX D: WORKING PAPER ABSTRACT 18
APPENDIX E: WRITTEN REVIEWS 19

Technical Reviews of Maritimes Working paper 19
Technical Reviews of Pacific Working Paper..23
Maritimes Working Paper Review 35
Pacific Working Paper Review 37
High Level Review 44
APPENDIX F: CROSSWALK OF MECS IN MARITIMES AND PACIFIC WORKING PAPERS .58
APPENDIX G: SUGGESTED DATA SCALES FOR DFO DECISION-MAKING.........................62
APPENDIX H: WORKING PAPER REVISIONS...63

SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Zonal Peer Review meeting of September 29 – October 2, 2015, at the Pacific Biological Station in Nanaimo, B.C. Two working papers focusing on the hierarchical classification of marine benthic ecosystems in the Northern and Southern Shelf Bioregions (Pacific) and the Scotian Shelf Bioregion (Maritimes) were presented for peer review.

In-person and web-based participation included Fisheries and Oceans Canada (DFO) Science Oceans, and Fisheries Protection Program staff; and external participants from First Nations organizations, environmental non-governmental organizations, and academia.

The conclusions and advice resulting from this review will be provided in the form of one Science Advisory Report providing advice to Oceans Sector to inform marine protected area network design in Maritimes and Pacific Regions and other DFO marine spatial planning initiatives.

The Science Advisory Report and the two supporting Research Documents will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

Compte rendu de l'examen zonal par les pairs sur l'évaluation des systèmes de classification hiérarchique de l'écologie marine pour les régions du Pacifique et des Maritimes

SOMMAIRE

Le présent compte rendu résume les discussions et les principales conclusions de la réunion d'examen zonal par les pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS) qui a eu lieu du 29 septembre au 2 octobre 2015 à la Station biologique du Pacifique de Nanaimo, en Colombie-Britannique. Deux documents de travail portant sur la classification hiérarchique des écosystèmes benthiques marins dans les biorégions des plateaux du nord et du sud (région du Pacifique) et dans la biorégion du plateau néo-écossais (région des Maritimes) ont été présentés aux fins d'examen par les pairs.

Au nombre des participants en personne ou par conférence Web, il y avait des employés du secteur des Sciences et du Programme de protection des pêches de Pêches et Océans Canada (MPO), des participants externes d'organisations des Premières nations, d'organisations non gouvernementales de l'environnement et des universités.

Les conclusions et avis découlant de cet examen seront présentés sous la forme d'un Avis scientifique fournissant des conseils au Secteur des océans pour éclairer la conception d'un réseau d'aires marines protégées dans les régions des Maritimes et du Pacifique et d'autres initiatives de planification spatiale marine.

L'avis scientifique et les deux documents de recherche à l'appui seront rendus publics sur le site Web du Secrétariat canadien de consultation scientifique (SCCS).

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Zonal Peer Review (ZPR) meeting was held on September 29-October 2, 2015, at the Pacific Biological Station in Nanaimo, British Columbia, to review two working papers that developed and applied methods for hierarchically classifying marine benthic ecosystems in the Northern and Southern Shelf Bioregions (Pacific) and the Scotian Shelf Bioregion (Maritimes). John Holmes and Nadja Steiner co-chaired the meeting.

These proceedings report on the main points developed during the presentations, reviews and discussions as part of the evaluation of the hierarchical marine ecological classification systems identified during this peer review. The zonal peer review is a process open to all participants who have appropriate technical expertise, experience and interest in the topic to participate in a robust peer review of the data, methods and application of the hierarchical frameworks. In this regard, participants from inside and outside DFO were invited to take part in the activities within the defined Terms of Reference (TOR) for this peer review (Appendix A). The TOR for the science review were developed in response to a request for science advice from DFO Ecosystems and Fisheries Management, Oceans Program. Notification of the science review and conditions for participation were sent to representatives with relevant expertise within DFO Maritimes and Pacific Regions, First Nations, the Government of British Columbia, the Government of Nova Scotia, non-governmental organizations, and academia (Appendix B).

John Holmes welcomed participants and invited them to introduce themselves and give their affiliation. Lesley MacDougall was identified as the Rapporteur for the proceedings of the meeting. The Chair reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. He also discussed the role of the participants, the purpose of the various CSAS publications (Science Advisory Report (SAR), Proceedings, and Research Documents (ResDoc)), and the definition and process around achieving consensus decisions and advice, noting that the meeting was a science review and not a consultation. The Chair reviewed the Terms of Reference for the meeting and the Agenda (Appendix C). He noted that he would lead the meeting for the first 1.5 days, that his Co-Chair Nadja Steiner would take over for the next 1.5 days and that both would lead the discussion on developing the Science Advisory Report. It was confirmed that copies of the Terms of Reference, working papers, and a meeting agenda had been distributed to participants prior to the meeting.

The following working papers (WP) were prepared and made available to meeting participants prior to the meeting (see Appendix D for summaries of each WP):

1. *Methodology of the Pacific Marine Ecological Classification System and its Application to the Northern and Southern Shelf Bioregions by Emily Rubidge, Katie Gale, Janelle Curtis, Erin McClelland, Laura Feyrer, Karin Bodtker, and Carrie Robb. CSAP Working Paper 2014OCN02.*

2. *A subtidal ecological classification system to represent species diversity and distribution patterns in the Maritimes Region by Michelle Greenlaw, Kayla Smith, Emily Rubidge and Ryan Martin. CSAP Working Paper 2014OCN02.*

All participants were invited to join fully in the discussion and to contribute their knowledge to the process, including the development of the SAR, with the goal of delivering scientifically defensible conclusions and advice. Participants were reminded that everyone at the meeting had equal standing and that they were expected to contribute to the review process, if they had information or questions relevant to the paper being discussed.

A hierarchical review process was implemented to ensure that the best available data were used in each Region and that the results, conclusions and advice represent the state-of-the-art for marine spatial planning and conservation. First, technical experts from each Region reviewed the Regional paper to ensure that the appropriate datasets were used and to assess the results for consistency with expected outcomes given their experience and expertise, i.e., address Objective 1 in the TOR. Second, each working paper was reviewed by an expert in marine ecological classification (Cliff Robinson, Pacific paper; John Harper, Maritimes paper) addressing:

1. the uncertainties and consequences associated with data availability and classification decisions in the application of the conceptual framework,
2. guidance for classifying areas at spatial scales not completed in these applications, and
3. guidance for future applications of the hierarchical marine ecological classification system (Objectives 2 and 3 in the TOR).

Finally, since the working papers represent two implementations of the same conceptual classification system, driven by data availability and other decisions, a high level review of the strengths and weaknesses of the marine ecological classification system tool that was developed and guidance for marine spatial planning going forward was solicited (John Roff). All written reviews are included in Appendix E. The goal of soliciting these reviews was to inform, but not limit, discussion by participants attending the meeting. The data reviews by technical experts were not formally discussed during the meeting, but were distributed to participants who were encouraged to identify potential oversights. The other reviews (Harper, Robinson, and Roff) formed the basis for discussion documented in these Proceedings. Copies of all reviews were circulated to participants prior to the meeting.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report and used to achieve the representativity criterion in the design of marine protected area (MPA) networks in both DFO Regions. The SAR and the supporting Research Documents will be made publicly available on the CSAS Science Advisory website.

REVIEW OF PACIFIC WORKING PAPER

PRESENTATION OF THE WORKING PAPER

The Pacific Marine Ecological Classification Systems (PMECS) Working Paper (WP) was presented by the lead author, Emily Rubidge. She noted that a hierarchical marine ecological classification system (HMECS) underpins marine spatial planning in DFO, and the initial focus is on MPA network design, but the data and HMECS will be used to address other objectives.

Ms. Rubidge noted that the PMECS WP was designed to achieve the following goals:

1. Develop a central geospatial database; this database collates over 600 biotic and abiotic data layers;
2. Develop methods to classify benthic areas at scales finer than the current bioregional level of classification; these methods include the use of a dissimilarity index and a Random Forest Analysis to determine clusters of similarity without pre-defining grid cell occupation based on prior knowledge of the areas. Clusters were delineated based on which environmental variables were the best drivers; maximizing inclusion while minimizing bias and errors associated with using data from multiple sources;

3. Develop repeatable methods, using the Benthic Terrain Modeler (BTM), to identify known seascape features at the scale of Geozones for the Northern Shelf. The BTM tool uses a bathymetric position index, and a set of scripts in GIS on a raster layer to look for specific bathymetric features, and categorize and define them; and
4. Recommend methods that could be used for the finer scale categories, such as primary and secondary biotope levels. These recommendations are based on a review of current work that could eventually be included in PMECS to provide classification at those scales.

The authors concluded that a broad range of sources of biological and environmental data can be successfully incorporated into the central database, and be used with the identified methods to populate finer scale levels for ecological classification. The authors identified some key limitations with the current work, including the decision to leave out coastal data and pelagic species, as each will require analysis at different scales and potentially adjustments to the classification hierarchy. The authors also noted that biological validation of the geospatial data would be necessary at a later date, and the potential effects of climate change with respect to the classification layers may require exploration.

WRITTEN REVIEWS

Overall Review of both Working Papers: Dr. John Roff

This section provides an overview of the written review provided by John Roff (Appendix E), his presentation at the meeting, and the decisions/agreements on revisions to the working papers based on this discussion.

Dr. Roff noted the challenges associated with using a ‘hybrid’ classification system of geospatial/physical/biological data, in that there are multiple ways to define the classification and develop layers. For example, both working papers arrive at classification levels that are labelled differently but quite likely are categorizing at the same spatial scale. He suggested that a comparison of the two classification hierarchies be made with the intent of developing a harmonized hierarchy that is consistent for both papers.

Dr. Roff suggested that the overall context and purpose should be emphasized more clearly, in particular with respect to the concept of representativity, and if there is a recommendation regarding at what level should MPA planning occur. These working papers identify representation almost exclusively at the community/habitat level – it is unclear if the authors are recommending level 4 is the appropriate level of specificity to ensure representation in an MPA network or if this is just an example.

Geomorphic features were interesting but it was unclear how they would be used. Dr. Roff noted that habitat heterogeneity and rugosity could also be used, and suggested that interannual variability and seasonal variability also needed to be explored. In particular, the question of whether the data time series straddles a significant climate shift should be evaluated. Further discussion on this topic confirmed that the time period covered was within one climate regime, and did not include a period of climatic shift and thus could be considered a reasonable representation of data for that regime.

Dr. Roff also noted that it would be useful to analyse the relationships between water masses and fish populations (or variability in water masses and their relationship with variability in fish distribution, guild dominance, or abundance) to identify potential important features. This suggestion was revisited several times and it was determined that the analyses of water masses would be a useful future recommendation, and in particular may have utility for the pelagic classification still to come.

The potential for data aliasing was acknowledged and discussed. Data aliasing occurs when the spatial and/or temporal scales of sampling are not commensurate with the variability in the data, which affects the ability to detect meaningful associations between variables and ultimately the location of boundaries between spatial units in HMECS. For example, relationships between abiotic and biotic variables should be developed using data sampled at appropriate scales and resolutions, otherwise the resulting trends may obscure the detection of meaningful associations.

Pacific Working Paper Review: Cliff Robinson

Mr. Robinson noted that he was unclear what levels of PMECS would be used for MPA network planning, and suggested this could be clarified in the working paper, along with the earlier suggestion of further context regarding how this work fits in to the larger goal of MPA network planning as well as other ecosystem based management.

The slope and shelf analysis as presented did not indicate a North-South difference in benthic species assemblages for the shelf or slope bioregions (i.e., supporting the identification of both the Northern Shelf and Southern Shelf Bioregions). Further discussion on this issue highlighted that the North-South difference may be more apparent at a finer scale of evaluation, or may be a product of the type of data included (e.g., primarily benthic). The expected North-South differences may also be more prominent for pelagic systems and should be revisited in further analyses. The analysis conducted for this work indicated that slope species were much more similar to each other, regardless of where on the slope they were located, than they were to other communities e.g. shelf, etc. It was suggested that the same analysis could be performed for each bioregion separately, so that inter-bioregion differences may not be eclipsed by larger intra-bioregion differences. Discussion regarding the original impetus for identifying a North and South shelf and slope region concluded that a range of biological and management considerations may have been incorporated into that decision.

The requirement to address inshore classification was raised, and it was noted that this topic, along with the requirement to address pelagic classification, would be discussed more broadly for both working papers.

DISCUSSION OF PACIFIC WORKING PAPER

Objective 1: Data/Methods

Appropriateness / adequacy of data used

The authors compiled approximately 600 spatial layers in a geospatial database, with clear criteria applied to determine which data sets should be used in the classification layers of PMECS. There was discussion regarding samples or species data that were not used and were called “rare” in the working paper: it was determined that “under represented” or “under sampled” would be a more accurate definition, as these were not rare species, but species that were not being targeted by the sampling methods, gear or areas used and therefore would not be considered part of a representative sample. The discussion regarding the inclusion of rare species (species that are infrequently encountered, but would be sampled by the gear used if available to it) into a MPA network design was out of scope for this paper, although it was acknowledged that rare species protection is one MPA network objective and therefore will be addressed through other processes. Through this discussion it was determined that the way the datasets were used was appropriate for this exercise, and adequate data were used.

Different types of taxa combined (e.g. fish and invertebrate taxa)

The Gradient Forest Analysis model used for the PMECS working paper combines different types of taxa for ecosystem analyses, with other studies/literature demonstrating that this method has been used effectively elsewhere. Additionally, the authors noted that they had run sensitivity analyses to confirm that combining fish and invertebrate taxa did not bias the results from the Gradient Forest Analysis. It was recommended that the authors include the results of the sensitivity analyses as an appendix in the WP and add an explanation of these results.

Inclusion of abundance, biomass, or species richness data

This discussion outlined the importance of clearly explaining the purpose of the current work. As this work is a community and habitat analysis where similarity/dissimilarity and representation are key, it was less valuable to determine dominance through biomass, or to identify species richness or distribution of rare species. For future MPA planning processes, centroid analysis could be sensitive to the centre of abundance, which may be useful, and species richness and rare species distribution may need to be explored. For this WP, it is important to ensure that the definitions used for these terms are accurate and appropriate for what is actually being categorized (e.g., communities). It was determined that, considering this is a habitat/community exercise, it would be useful to note that other data exist, but will be used for indicating rare species or species abundance in other exercises later.

Methods used

Several topics were discussed relating to the methods used. There was agreement that the methodology used to populate layer 4 and 5 as described in PMECS was acceptable. It was noted that the coastal/nearshore areas had not been classified yet. The proposed methodology for classification of finer scale layers, a form of bottom type modelling, warrants further investigation. It was recognized that bottom type modelling performance in deeper areas has not been assessed; and scale issues would need to be addressed prior to its application.

There was a recommendation that future classification applications should incorporate the ability to explore development of fine scale layers from an ecological process perspective, to ensure the identification of ecologically meaningful groups at small scales.

There was discussion on transition zones identified by the random forest model. These areas had less support from the data and often occurred along the edges of the biomes. It was pointed out that this may not be an indicator that there was less certainty in the data, rather it may point to the fact that these areas represent environmental gradients between Biophysical units rather than absolute distinctions between habitats/communities, and may be an important Biophysical unit on their own.. It was suggested that an investigation into using least mappable units to identify transitional zones for PMECS be carried out in the future.

MPA NETWORK IDENTIFICATION PROCESS IN CANADA

Marty King provided a brief overview of the MPA network identification process in general. Currently, MPA network design is in the data and information gathering phase. During this phase, a habitat classification system will be used to develop one of several ecological layers incorporated into the overall MPA network design. The MPA network design will be the next phase, which includes setting conservation objectives, proposing MPA network configurations, consulting on the proposed configurations, and then revising to finalize an MPA network design. The design is expected to incorporate various considerations including, among others, representativity, size, spacing, connectivity, and socio-economic considerations. Therefore the marine ecological classification system is not expected to be able to account for all required considerations, but it should be sufficient for coarse-level accounting for habitat representation at a bioregion level.

REVIEW OF THE MARITIMES WORKING PAPER

PRESENTATION OF THE WORKING PAPER

The Maritimes marine ecological classification system (MMECS) WP was presented by the lead author, Michelle Greenlaw. She highlighted the fact that, unlike PMECS, biological surrogates were used in lieu of biological data to create the classification layers, following a habitat template model approach. A Gradient Forest Analysis was employed to develop a ranking to identify the most influential variables for the ecological correlations.

Ms. Greenlaw described her approach as a ‘top down’ physical approach to abiotic ecosystem classification, and provided an explanation of each of the layers. Two primary scales of data were used: Physiographic units (Mesoscale) and habitat (macroscale). Mesoscale units are analogous to biomes in PMECS, but developed using physical data. Finer scale habitat units in the 10s of metres were validated in the offshore region only, to show that the method could be validated.

A method for Biotope classification based on substrate characteristics was presented for the coastal Biophysical unit (nearshore waters < 50 m deep) in MMECS. The method has not been evaluated, due to insufficient peer review at the time, but It is recommended that such substrate models be applied for classifying Biotope units when biological data are not available and that its application in deeper waters be investigated.

WRITTEN REVIEWS

Maritimes Working Paper Review: John Harper

John Harper provided background and context for the development of Canada’s marine regions (Appendix F). At the time, benthic and pelagic zones were not explicitly identified and addressed, which remains a problem today. Mr. Harper recognized that ecoregion is an important conceptual tool, differentiation of why one area is different from another.

DISCUSSION OF MARITIMES WORKING PAPER

There was some discussion regarding inductive (based on environmental data) and deductive (based on biological data) development of layers. It was agreed that the deductive method is preferred, but the inductive method is also valid and appropriate if biological data are not available.

Substrate layers at the primary Biotope level are useful for defining spatial units at that level. However, substrate data are less useful for delineating finer spatial units. There is no 1:1 correspondence between one and the other. It was recommended that the coarser substrate layer be used for this report, and identification of a finer substrate layer is being developed in other work, that could be explored for its applicability to finer classification layers in the future.

It was noted that the hierarchy can be disaggregated and re-aggregated for various uses, if there is a desire to use the classification to identify elements other than representativity. If there are distinct assemblages the classification should be able to identify them, but it was noted that there is a risk regarding what level of detail is used to determine appropriate areas.

It was noted that the oceanographic variables were weighted based on data that covered 2/3 of the areal extent of the Scotian shelf domain – this needs to be explicit in the WP.

The removal of SST in the gradient forest analysis for the benthic MMECS was discussed. It was recommended that a correlation-sensitivity test be performed to evaluate the influence of removing/including SST on the results (oceanographic domains). It was further recommended to add text in the revised WP to explain why SST is not a good choice for benthic classification.

DISCUSSION OF BOTH WORKING PAPERS

Terminology

Discussion focused on the need to standardize terminology across both WP's where possible. Additionally, appropriate geological terms for Geozone units were provided as examples for incorporation into the geomorphology sections of the WPs.

Hierarchical Consistency

One of the first points raised during the discussion was the need to develop a standardized ecological classification (i.e., terms for major units, spatial scales and resolution) from the operational classifications proposed in PMECS and MMECS. Meeting participants developed a crosswalk table (Appendix F) between the PMECS and MMECS classifications and the conceptual classification (DFO 2013). The resulting harmonized marine ecological classification system (HMECS; DFO 2016) was developed through review of the classification layers of both WPs and agreement during the peer review meeting.

Further discussion regarding the classification hierarchy identified a data gap with respect to the PMECS classification. A coastal unit in the Biophysical domain was not identified in PMECS because of insufficient data at the appropriate scale. Delineation of this unit may influence the boundaries of adjacent Biophysical units. Further guidance regarding coastal classification is provided in the “Data bias, gaps, and potential for future improvements” section below.

There was discussion on the levels of the HMECS that would inform MPA network planning as well as supporting other ecosystem based management initiatives. Participants developed a consensus table during the meeting that captures a first approximation of the spatial levels used to support decision-making within the present DFO context (Appendix G). It was noted that spatial data may be used in multiple decision-making processes and that multiple spatial scales may be used in these decisions. The spatial level used to support decision-making will depend on the specific objectives to be achieved.

CONCLUSIONS

Both WPs were accepted. The Marine Ecological Classification Systems presented in both the Pacific and Maritimes examples provide a structured approach to ensure that all types of benthic habitat, community and ecosystem are effectively represented in marine spatial planning according to their attributes. A list of recommended revisions for each WP was developed (Appendix H) and provided to the authors. It was noted that the HMECS applies specifically to benthic systems and it is recommended that the HMECS be used as a template for the development of a marine ecological classification for pelagic systems in the future.

RECOMMENDATIONS/ADVICE

Hierarchical Consistency and Fidelity

The hierarchical classification is recognized to have built in redundancies, and in some cases overlaps – the 'nesting' is not perfect at each layer; for example, there is likely overlap between Biological Facies and Biotope levels. The classification is hierarchical, not the data analysis as that would amplify potential data errors or bias. The hierarchy should have similarity in concepts and intent even for different areas with different data. The hierarchy should be robust and inclusive. The harmonized marine ecological classification system (HMECS) developed during the meeting (Appendix F) is recommended for future benthic classification applications.

Populating Finer Scale Units

A best practices recommendation is that *in situ* data will be required to populate and validate at finer scales (e.g., Biotope level). The following provides guidance regarding the required outputs and potential sources of data for the population of finer scale units.

- E.g., Biological Facies: Outputs needed:
  - Range of probable areas for Facies – distributional range, distributional pattern within the range
    - Models are good, as long as there are data from which to develop predictions, in that they will help to identify areas where you may want to start looking (narrow the focus), species distribution models – which will likely be identifying Biotope units. Local knowledge would also help to narrow down the areas.
      - Resolution of the environmental variable model will dictate the spatial resolution of predictions: model confidence will vary in determining potential range for predicting areas where Facies may occur.
    - And mapping is needed to delineate the range, along with survey data collection
  - Confidence/uncertainty metric
    - The metric used may change over time
    - A temporal element may also affect the level of confidence
    - Also need to consider the level of confidence associated with the survey used to collect the data upon which model outputs are based
  - Data compilation and visualization methods – with multiple types and scales of data
    - Standards should be applied to data collection
    - A protocol should be developed to govern procedures when standards have not been applied to data collection
    - Patchy or continuous? E.g., shoreline dataset
- E.g. Biotope: Outputs needed:
  - Distributional range, pattern and area
    - Volume, biomass
    - Bottom patch model is proposed by PMECS authors – helps develop a substrate layer, substrate analysis; Kostleylev's statistical analysis of Biotopes (Browns bank) from multi-beam acoustic data proposed by MMECS authors, Craig Brown's species distribution statistical analysis combined with multi-beam acoustic data, e.g., upper

level geomorphology, or suites of variables like SST, ecosystem modelling (oceanographic model with biogenic component) or biogeochemical modelling, water masses as a predictor of the variability for benthic systems and potentially strong predictor for pelagic systems. Habitat suitability indices, and species distribution models, community distribution modelling (e.g., gradient forest analysis, random forest analysis)

- Individual Based Modeling was proposed, and after discussion it was determined that it would be less useful at this level. Perhaps at population level.
- Local / FN knowledge

o Confidence/uncertainty

- Model confidence/uncertainty

Data Bias, Gaps, and Potential for Future Improvements

Combining data from many sources (trap, trawl) should be recognized and described, e.g., there is no trawling in rocky areas or deeper zones. It is recommended that guidance be provided for the assembly of the datasets to minimize sampling bias, as well as appropriate statistical analyses dependent on the kinds of data that were used.

No obvious bias was identified in either WP, but it is known that there are certain missing areas (e.g., coastal areas in the Pacific) which are also a source of uncertainty. Other sources of data, potentially usable for finer layers were identified, and a general recommendation was made to identify other potential datasets (e.g., from museums, habitat assessments, aquaculture siting proposals, 3rd party data collection) and coordinate within DFO to standardize data collection requests. Delineation of this unit is recommended since it may influence the boundaries of the adjacent Biophysical units.

As noted earlier, coastal classification was noted as important gap that will require further (and explicit) investigation. The scale of analysis for a coastal classification may differ from that used for the offshore classification.

Similarly, a pelagic classification will require assessment of available data to determine an appropriate scale of analysis.

Data often represent snapshot in time, and the related uncertainty affects outputs of the random forest analysis. This information can be informative (e.g., identifying transition zones) or not.

REFERENCES CITED

DFO. 2016. Evaluation of Hierarchical Marine Ecological Classification Systems for Pacific and Maritimes Regions. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/003.

DFO. 2013. Key elements in the development of a hierarchical marine ecological classification system to support ecosystem approaches to management in Pacific Canada DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/065.

APPENDIX A: TERMS OF REFERENCE

Evaluation of Hierarchical Marine Ecological Classification Systems for Pacific and Maritimes Regions

Zonal Peer Review Process – Pacific & Maritimes Regions

September 29 – October 2, 2015
Nanaimo, BC

Chairpersons: John Holmes and Nadja Steiner

Context

The need to develop a hierarchical marine ecological classification system for classifying the structure and distribution of Canada's marine biota and habitats at multiple spatial scales has been recognized regionally, nationally and internationally for a variety of reasons, including:

- to ensure that all types of habitat, communities and ecosystems are effectively represented in marine spatial planning according to their ecological attributes; and
- to ensure that a structured approach is used to consider biodiversity at local, regional and basin - wide scales.

A Fisheries and Oceans Canada (DFO) National Canadian Science Advice Secretariat (CSAS) peer review process identified 12 major biogeographic units (bioregions) for Canada's three oceans (DFO 2009). This process advised that each of the major biogeographic units represent a "maximum scale" that can be disaggregated/subdivided further into smaller units that are ecologically meaningful, as well as that there is no single prescription for determining the level of disaggregation for finer scale units. A DFO Pacific Region CSAS peer review process identified a conceptual framework (Pacific Marine Ecological Classification System [PMECS]) for development of a regional hierarchical ecological classification system (DFO 2013).

Application of the conceptual framework could provide three main outputs for use in ocean resource management and conservation in the DFO Pacific Region:

- a systematic spatially-explicit classification of ecosystems at multiple scales within the study area, which can be used to ensure representation and replication of different habitat, communities and ecosystems in Marine Protected Area (MPA) network design;
- a database of spatially-referenced information for identifying and locating key ecological properties in support of MPA network design; and
- a set of spatially-referenced information that could be integrated in the future with other data layers (e.g. social, economic) to inform integrated management planning related to sustainable siting and assessment and monitoring of human activities in the marine environment. This would also help reduce uncertainty around management decisions across sectors.

The conceptual framework has been applied independently to classify areas according to their ecological attributes at multiple spatial scales in the DFO Pacific Region Northern Shelf Bioregion and the DFO Maritimes Region Scotian Shelf Bioregion. The application of the conceptual framework differs based on the available data in each Region and some Region specific variations in number, type and boundaries of the areas being classified.

DFO Oceans in both the Pacific and Maritimes Regions have requested that DFO Science provide classifications of the Northern Shelf and Scotian Shelf Bioregions in support of marine spatial planning initiatives. This work has been completed for a subset of spatial scales in both the DFO Pacific and DFO Maritimes bioregions. Since these serve as first applications of the conceptual framework, it is the intent of this Zonal Peer Review (ZPR) process to assess the approaches taken for each application, as well as the resulting classifications.

The assessment and advice arising from this CSAS ZPR, and subsequent application of the framework, will be used to inform management decisions, such as the identification of candidate areas for MPAs and the design of MPA networks, but could also inform other DFO ecosystem-based management decisions.

Objectives

The following working papers will be reviewed and provide the basis for discussion and advice on the specific objectives outlined below.

> *Rubidge, E M.., K. Gale, J.M.R. Curtis, E. McClelland, L. Feyrer, Karin Bodtker, Carrie Robb. 2015. Methods for applying the Pacific Marine Ecological Classification System (PMECS) to Northern Shelf Bioregion. CSAP Working Paper 2014OCN02a*
>
> *Greenlaw, M.E., Smith, K., Martin, R. 2015. A subtidal ecological classification system to represent species diversity and distribution patterns in the Maritimes Region. CSAP Working Paper 2014OCN02b*

The specific objectives of this review are to:

1. Review the methods and results of the application of the conceptual classification framework in each Region given data availability and their intended purposes;
2. Discuss uncertainties and consequences associated with data availability and classification decisions (e.g., number, boundary, type, etc.) made in the DFO Pacific and DFO Maritimes application of the conceptual framework, and provide guidance for future application; and,
3. Provide guidance on appropriate types of analyses to classify areas at spatial scales not completed as part of these applications.

Participants are asked to review DFO (2013) and Robinson et al. (2015) in preparation for this ZPR. These two documents provide the necessary background to participate in this peer review.

Technical written reviews of the data and results (Objective 1) by species and habitat experts from each Region will be conducted in advance of the ZPR meeting to ensure that appropriate regional datasets were used and that resulting classifications are consistent with expert knowledge of each Region. This is not intended to limit the contribution of participants with specific expert knowledge of species or habitats in either Region, but add to the overall peer review process.

Guidance provided in Objectives 2 and 3 will be developed by meeting participants based on the review of material provided to meet Objective 1, input on each working paper and through discussions based on the expertise of participants. Objectives 2 and 3 are intended to synthesize lessons learned from both the DFO Pacific and DFO Maritimes experiences with applying the conceptual framework.

Expected Publications

- Science Advisory Report (1)
- Proceedings (1)
- Research Documents (2)

Expected Participation

- Fisheries and Oceans Canada (DFO) (Science Branch, Aquaculture, Fisheries, Oceans, Species at Risk and Fisheries Protection Programs)
- British Columbia Provincial Government
- Other federal departments (Environment Canada, Parks Canada Natural Resources Canada, and Transport Canada)
- Academia
- First Nations
- Environmental Non-governmental Organizations

References

DFO. 2009. Development of a Framework and Principles for the Biogeographic Classification of Canadian Marine Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/056.

DFO. 2013. Key elements in the development of a hierarchical marine ecological classification system to support ecosystem approaches to management in Pacific Canada. DFO Can. Sci. Advice. Sec. Sci. Advis. Rep. 2013/065.

Greenlaw, M.E., Gromack, A.G., Basquill, S., MacKinnon, D., Lynds, A., Taylor, B., Utting, D., Hackett, J., Grant, J., Forbes, D., Savoie, F., Bérubé, D., Connor, K.J., Johnson, S.C., Coombs, K.A., and Henry, R. 2013. A physiographic coastline classification of the Scotian Shelf Bioregion and Environs: The Nova Scotia coastline and the New Brunswick Fundy shore. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/051. iv + 39 p.

Robinson, C., Boutillier, J., Biffard, D., Gregr, E.J., Finney, J., Therriault, T., Greenlaw, M., Barrie, V., Foreman, M., Pena, A., Masson, D., Bodker, K., Head, K., Spencer, J., Bernhardt, J., Smith, J., and Short, C. 2015. Key elements in the development of a hierarchical marine ecological classification system to support ecosystem approaches to management in Pacific Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/028. viii + 58p.

APPENDIX B: PARTICIPANTS

Last Name	First Name	Affiliation
Bigg	Michelle	DFO Fisheries Protection Program
Bodtker	Karin	Environmental Consultant
Boutillier	Jim	DFO Science Emeritus
Bundy	Alida	DFO Science
Chiasson	Mireille	DFO Oceans Management Section
Clark	Don	DFO Science
Curtis	Janelle	DFO Science - Conservation Biology
Gale	Katie	DFO Science
Giles	Amber	Maliseet Nation Conservation Council (MNCC)
Greene	Gary	Emeritus, Moss Landing Marine Labs
Greenlaw	Michelle	DFO Science
Gregr	Ed	UBC--Scitechconsulting
Grinnell	Matt	DFO Science
Hannah	Charles	DFO Ocean Sciences Division
Hargreaves	Marilyn	DFO Science CSAP
Harper	John	Moran Coastal and Oceans
Hillier	Joy	DFO Science, Oceans Program
Holmes	John	DFO Science
Ibey	Hilary	DFO Science
Jayawardan	Aruna	Maliseet Nation Conservation Council (MNCC)
King	Marty	DFO Science
Lee	Lynn	Fisheries Mgmt Gwaii Haanas
Lemieux	Jeffrey	DFO Science
Lessard	Joanne	DFO Science
MacDougall	Lesley	DFO Science, CSAP
Mar	Amy	DFO Science
McDougall	Chris	Haida Nation
McNeely	Joshua	Maritimes Aboriginal Peoples Council (MAPC)
Metaxas	Anna	Dalhousie
Nutton	Byron	DFO Fisheries Protection Program
O	Miriam	DFO Ocean Sciences Division
Oldford	Greig	DFO Science
Robb	Carrie	Living Oceans Society
Robinson	Cliff	Oceanus Ecological
Roff	John	Acadia university
Ross	Tetjana	DFO Science
Rubidge	Emily	DFO Ocean Sciences Division
Rutherford	Kate	DFO Science
Steiner	Nadja	DFO Science
Stevenson	Kira	BC Ministry of Environment

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Zonal Peer Review Meeting

Evaluation of Hierarchical Marine Ecological Classification Systems for Pacific and Maritimes Regions

September 29 – October 2, 2015

Pacific Biological Station
Nanaimo, BC

Co-Chairs: John Holmes & Nadja Steiner

DAY 1 – Tuesday, September 29, 2015

Time	Subject	Presenter
0900	Introductions Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference & Meeting Structure/Agenda	Chair
0945	Presentation of Pacific Marine Ecological Classification System (PMECS) Working Paper	Authors
1030	***Break***	
1045	Roff and Robinson Written Reviews	Reviewer & Authors
12:00	***Lunch Break***	
1300	Identification of Key Issues for Group Discussion	RPR Participants
1330	Discussion of the PMECS Working Paper	RPR Participants
1445	***Break***	
1500	Discussion of the PMECS Working Paper	RPR Participants
1700	**Adjourn for the Day**	

DAY 2 - Wednesday, September 30, 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1	Chair
0930	Discussion & Resolution of PMECS Results & Conclusions	RPR Participants
1030	***Break***	
1045	Discussion & Resolution of PMECS Results & Conclusions	RPR Participants
1200	***Lunch Break***	
1300	Presentation of Maritimes Marine Ecological Classification System (MMECS) Working Paper	Authors
1330	Harper Written Review	Reviewer & Authors
1415	Identification of Key Issues for Group Discussion	RPR Participants
1430	***Break***	
1445	Discussion & Resolution of Technical Issues	RPR Participants
1700	***Adjourn for Day***	

DAY 3 - Thursday, October 1, 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1 & 2	Chair
0930	Discussion & Resolution of MMECS Results & Conclusions	RPR Participants
1030	***Break***	
1045	Identification of Overarching MECS Guidance Themes for Group Discussion including but not limited to (from TOR): • Data availability • Classification decisions • Uncertainties	RPR Participants
1200	***Lunch Break***	
1300	MECS Guidance – Group Discussion by Theme	RPR Participants
1430	***Break***	
1445	MECS Guidance – Group Discussion by Theme	RPR Participants
1600	***Adjourn for Day***	

DAY 4 - Friday, October 2, 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping	Chair
0915	Review Status of Day 1-3 Dealing with Outstanding issues from Days 1-3	
1015	Introduction to Day 4 Focus - TOR Objective 3 Classifying areas at other spatial scales	Chair
1030	***Break***	
1045	Discussion Overarching guidance for classifying areas at other spatial scales	RPR Participants
1200	***Lunch Break***	
1300	Develop Consensus: • Working Paper Acceptability & Agreed-upon Revisions • Key conclusions, Uncertainties & Advice for SAR	RPR Participants
1400	*Science Advisory Report (SAR)* Develop consensus on guidance bullets - Overarching guidance for classifying areas at other spatial scales	RPR Participants
1430	***Break***	
1445	*Science Advisory Report (SAR) – Review and finalize all summary bullets, guidance and advice for all objectives*	RPR Participants
1600	***Adjourn Meeting***	

APPENDIX D: WORKING PAPER ABSTRACT

Methodology of the Pacific Marine Ecological Classification System and its Application to the Northern and Southern Shelf Bioregions

Marine ecological classification systems are needed to place species, habitats and ecosystems at varying spatial scales into ecological and management contexts. In Canada, the need to develop a hierarchical ecological classification system has been recognized at national and regional scales. The Pacific Marine Ecological Classification System (PMECS) conceptual framework to disaggregate the four major bioregions in Canada’s Pacific Region into smaller spatial units has been developed over the past several years (2009–2013). In this paper, we advance PMECS towards implementation by developing analytical methods, and integrating classifications that are currently being developed in the region, to populate the hierarchical layers of the conceptual PMECS framework proposed by Robinson et al. (2015). Six specific objectives were met in this working paper to move PMECS from a conceptual framework to implementation. First, we compiled existing spatially referenced biotic and abiotic data for used in marine spatial planning in Canada’s Pacific Region into a central geodatabase. Second, we selected appropriate datasets from the geodatabase and developed a biologically driven community approach using both abiotic and biotic data to generate a broad-scale classification for the Northern Shelf and Southern Shelf Bioregions (NSB, SSB). Third, we applied the community model to the entire NSB and SSB to populate Level 4a & b of PMECS framework (Super-biomes and Biomes). Fourth, we used an indicator species analysis to identify species that were most commonly associated with each super-biome and biome. Fifth, we developed and applied classification methods to NSB/SSB to delineate a geomorphological layer (Level 5) called “Geozones” using a 75 m bathymetry raster and the benthic positioning index (BPI) in the Benthic Terrain Modeller toolbox. Sixth, we proposed quantitative methods suitable for classifying areas at finer scales (lower levels) of PMECS. We recommended that ongoing efforts to classify and map substrate types using the bottom patch model (Gregr et al 2013) can be modified and applied to populate Levels 6 & 7 of PMECS (Primary and Secondary Biotopes) as more data become available. Known distributions of sponge reefs, kelp forests, and other Biological Facies (Level 8) can be incorporated into PMECS with the understanding that these units may be incompletely mapped in Pacific Region. Classification results at Levels 4 and 5 are recommended for use in MPA network design, and classifications at Levels 6-8 are proposed for integration into MPA network design as these analyses are completed within bioregions.

APPENDIX E: WRITTEN REVIEWS

TECHNICAL REVIEWS OF MARITIMES WORKING PAPER

David Brickman - Comments on the oceanography layers described in:

Greenlaw, M., K. Smith, E. Rubidge, R. Martin. 2015. A subtidal ecological classification system to represent species diversity and distribution patterns in the Maritimes region. 2014OCN02b

I have read the sections that I was directed to read, and other parts as well in order to get a sense of the overall document.

In general: The document text needs a lot of work. There are numerous grammatical/typographical errors, missing references, problems with acronyms (e.g., SHDD, see P.2 onward) and sentences that are hard to follow due to errors or excessive jargon. The introduction should be improved so that the authors don't lose readers at the start.

A note to CSAS: There should be better vetting of documents before you solicit scientists to spend time reviewing them.

The Oceanographic Units section (P.9-10):

General comment:

The section needs re-writing for clarity and to fill in details. I am tasked with commenting on the appropriateness of the data sources, but frankly I could not really figure out what sources were used. It seems as if Chl-a was used, but no source was given. This may be contained in the Pitcher or Smith references, but that is not good enough in this context. The authors seem to describe the sources for the TS data but not the Chl-a data. The data used and the sources should be clearly noted and background provided.

Other comments:

- The first paragraph (P9) is OK but could use some references. For example: P9: "During late winter and spring, the Nova Scotia Current supplies the shelf with most *Calanus* species, which originate from the Gulf of St. Lawrence to the north" o This statement requires a reference.
- The second paragraph on P9 is confusing: The authors talk about Pitcher's analysis for the western Scotian shelf, then seem to apply his technique to the entire Scotian Shelf (if I have understood correctly) : "These variables were weighted based on their "importance" (a metric output from the gradient forest analysis) for structuring biodiversity composition; benthic temperature 40%, chlorophyll a 35%, salinity 15%, benthic current stress 15% (Figure 5), **based on the results of Pitcher et al. 2012**". This is likely OK, but should be discussed in the text.
- As noted in the text, the TS sources end in the early 1990s so are a bit old. However, I do not think that this should be a problem.
- Fig 5: I think this is the result of: *"importance" (a metric output from the gradient forest analysis) for structuring biodiversity composition; benthic temperature 40%, chlorophyll a 35%, salinity 15%, benthic current stress 15% (Figure 5), based on the results of Pitcher et al. 2012.*
    - Should put more details in the caption to make it easier for readers to follow
    - The plot should have a scale to explain the colours: what is blue compared to red?

- In general, more details in all figure captions would be useful.
- P10. What is the box with header “Oceanographic Domains include (Figure 4):” referring to? Certainly not the figure 4 in the document P42.

Comments on Greenlaw et al.

Comments from Tetjana Ross

I have many editorial comments to make on the paper, but have been asked to comment specifically on the oceanographic data used to create the layers. However, I will mention that the paper needs to be edited more carefully. There were many typos and places where the language was either redundant or unclear. Also, the structure of the document was odd. Section C seemed to be a large introduction to different methods – some of which were presumably used in Section A, so it would make more sense to this reader if they came first.

The questions I was asked to address:

1. ***Have the appropriate regional datasets been included? Are there other datasets that should be considered?***

It was quite hard to figure out what oceanographic data were included and excluded. Many of the references did not cover the entire region (e.g. Pitcher et al, 2012). There is only a title given for the Smith (2005) reference and I could not find it based on title alone, is it published?

The only figure associated with the oceanographic data is Figure 5, which is not well explained. You need to give detail on how Figure 5 was constructed and used. How does it relate to the text describing oceanographic data on pages 9 and 10?

Although it is hard to tell for sure, it may be that based on the Pitcher et al (2012) study, only sea surface temperature, benthic temperature, surface chlorophyll, benthic salinity and benthic current stress were included in any out-going oceanographic layer. If this is true, there is certainly the chance that important oceanographic data – that are available as can be seen in either Pitcher et al (2012) or Greenlaw et al (2010) – may be left out. The Pitcher et al (2012) analysis found that the ranking of oceanographic variables was different for different regions, so their Gulf of Maine results may not apply over the entire Scotian Shelf region. Pitcher et al (2012) also found a different ranking of oceanographic variables for bottom grab vs trawl data and had included depth as a variable. These lead me to question whether the Pitcher et al (2012) ranking/weights are the most appropriate.

2. ***Do the results seem consistent with expected outcomes, given your experience and expertise?***

This is even harder to evaluate. The only results I can see relevant to oceanographic data are Figures 5 and 7b and both are very difficult to interpret. As mentioned above, what is plotted in Figure 5 needs to be fully described. Figure 7b is very hard to read. The contour lines are faint and unlabelled. However, I would strongly urge the authors to quantitatively compare the two results because I don’t think it’s possible to construct a legible figure that allows the reader to compare the 2 method by-eye.

Comments from Charles Hannah

The paper does not provide a clear description of where the oceanographic data fields came from. Here I try to provide some guidance.

The fields used to generate Fig. 5 do not come from Pitcher (2012). The ones in Pitcher et al. (2012) are based on Smith (2005) and Naimie et al. (1994). But the area covered in those fields ends at Halifax.

The area covered in Figure 5 looks like the region discussed in Kostylev and Hannah (2007; not referenced in the working paper) which are also the subject of Kostylev and Hannah (2004) and Kostylev (2005).

On page 10 of the report the authors express uncertainty on how the temperature variability layers were calculated. I assume they are talking about the layer in the Kostylev and Hannah work. They were not calculated by Hannah et al. (2001). Kostylev and Hannah (2007) provide a reasonably clear description of how it was calculated. There were 2 separate estimates of the temperature variability:

1. amplitude of the seasonal cycle computed from the seasonal mean fields of Hannah et al. (2001) and Han et al. (1999) both based on Loder et al. (1997);
2. a measure of the interannual variability whose calculation is described in Kostylev and Hannah (2007).

DFO CSAS Science Advice Reports generally do not have named authors – they are a group effort. According to the pdf on the CSAS website the proper author of Kostylev (2005) is DFO.

Kostylev, V.E., and Hannah, C.G. 2007. Process-driven characterization and mapping of seabed habitats. In: Todd, B.J., and Greene, H.G., eds., Mapping the Seafloor for Habitat Characterization: Geological Association of Canada, Special Paper 47, p. 171-184.

I assume Smith (2005) is

Smith, K.W. 2005. A benthic habitat model for the Gulf of Maine . Numerical Methods Laboratory Report NML-05-1, unpublished manuscript with 21 pages. Dartmouth College, Hanover NH.

Naimie, C. E., J. W. Loder, and D. R. Lynch. 1994. Seasonal-variation of the 3-dimensional residual circulation on Georges Bank. J. Geophys. Res.-Oceans. 99: 15967-15989.

Pitcher, R., P. Lawton, N. Ellis, S. J. Smith, L. S. Incze, C.-L. Wei, M. E. Greenlaw, N. H. Wolff, J. A. Sameoto, and P. V. R. Snelgrove. 2012. Exploring the role of environmental variables in shaping patterns of seabed biodiversity composition in regional-scale ecosystems. J. Appl. Ecol. 49: 670-679.

Reviewer: Marty King

Bedford Institute of Oceanography
Oceans and Coastal Management Division
Oceans Biologist

Working Paper: Greenlaw, M., K. Smith, E. Rubidge, R. Martin. 2015. A subtidal ecological classification system to represent species diversity and distribution patterns in the Maritimes region. 2014OCN02b

TERMS

- Page 1. Macro-habitat. 10s of metres to 100s of kilometers seems like a very wide range.

INTRODUCTION

- Page 2. General suggestion regarding EAM. DFO Maritimes has clearly defined how EAM will be operationalized so I suggest you only refer to EAM in general terms and put more emphasis on specific examples of how DFO is applying EAM in the region (e.g., EBSAs, SBA Policy and MPA network development).

- 1st paragraph. Reference to EAM is clear and high-level… so do not change this sentence.
- 2nd paragraph. I suggest you remove the portion of the last sentence that mentions EAM.
- 3rd paragraph.
  - 1st sentence. Suggest you replace “processes striving to incorporate EAM, and assists” with “coastal and oceans management and planning”.
  - Last sentence. Suggest you add “marine protected area (MPA) network development” following “… (EBSAs).”

SECTION A:

- Page 4. 3rd paragraph. What is meant by a “risk–averse approach to the classification process.”?
- Page 4. 2nd last paragraph. Suggest you provide a short summary of the Kostylev classification because: (a) I thought it was the subject of a second benthic habitat classification Regional Science Review meeting around 2007 (if so, this RAP should also be referenced); and (b) it is the classification that your classification will replace in certain applications (e.g., MPA network development).

DISCUSSION

MPA Network Planning sub-section

- Page 24. Suggest you start this section with a few sentences that state:
  - The HMECS proposed in this paper can be used in different stages of MPA network planning and implementation
  - For instance, at the planning stage, it can be used as a basis for achieving coarse-scale habitat representation while during implementation, finer-scale levels of the classification can be used to help design individual MPAs (e.g., by ensuring MPA boundaries follow ecological boundaries to the extent that is possible)
- Page 24. First sentence. Suggest you clarify what you mean by an “an appropriate starting point for preliminary MPA network planning”. I assume you mean the physiographic units would be an appropriate layer to use as a basis for habitat representation within the context of network planning.

Example MPA Network Objectives sub-section

- General suggestion: Page 25. Should structure the example objectives in a way that is consistent with the most recent guidance from NHQ on how to structure objectives. NHQ guidance recommends the following objectives hierarchy (this guidance is not formally published anywhere):
- **National Goals** (as stated in the National Framework)
  - **Strategic Objectives** (more specific but still high-level bioregional-level statements about what the network will aim to achieve)
    - **Conservation Priorities** (specific species, habitats or other ecological features the network will aim to protect)
      - **Operational Objectives** [more measurable and specify the desired state (e.g., healthy, intact) for each conservation priority]

- **Design Strategies** (specify how much or how many of each conservation priority the network should capture)

The current Strategic Objectives for the Scotian Shelf Bioregion are:

- Protect unique, rare, or sensitive ecological features in the bioregion
- **Protect representative examples of identified ecosystem and habitat types in the bioregion**
- Help maintain ecosystem structure, functioning and resilience within the bioregion
- Contribute to the recovery and conservation of depleted species
- Help maintain healthy populations of species of commercial, recreational and/or Aboriginal importance

Strategic Objective 2 is directly related to the current Science Advisory Process.

- The HMECS and data layers that make up the classification will be used as a basis for capturing representative examples of all ecosystem and habitat types in the Scotian Shelf Bioregion. Each Oceanographic Domain and Physiographic Unit type will be considered individual Conservation Priorities under the hierarchy presented above. Thus, a Design Strategy will be developed that specifies how much of each domain or unit should be included within the MPA network to be ensure the broader Strategic Objective is achieved.
- Under the hierarchy suggested by NHQ, the example objectives presented on Page 25 would actually be considered Design Strategies. Other than this terminology change, these examples are very appropriate.

Other comments:

- Page 25. The bioregion is officially called the "Scotian Shelf Bioregion" (but it does technically include the Bay of Fundy, and part of Georges Bank and the Gulf of Maine)…
- Page 25. Example objective 1. The oceanographic domains will certainly nest within the bioregions but will not nest within the "planning units", which were based more on pragmatic considerations. So, I suggest removing the term "planning units" from this example.

TECHNICAL REVIEWS OF PACIFIC WORKING PAPER

Reviewer: Kate Rutherford

Pacific Biological Station
Science Branch
Groundfish

Date: September 15, 2015

Working Paper: Rubidge, E M.., K. Gale, J.M.R. Curtis, E. McClelland, L. Feyrer, Karin Bodtker, Carrie Robb. 2015. Methodology of the Pacific Marine Ecological Classification System and its Application to the Northern and Southern Shelf Bioregions CSAP Working Paper 2014OCN02a

The comments below are in response for a request to provide a technical review of the groundfish data sources, the Biome section, and Appendix G of the above working paper.

The following questions were asked:

- Have the appropriate regional datasets been included? Are there other datasets that should be considered?
- Do the results seem consistent with expected outcomes, given your experience and expertise?

My comments below focus on the datasets and their inclusion (or not). However, it was not possible in the time I had available to totally recreate the data extractions conducted for this analysis. For this reason, the inclusion or exclusion of a species from the analyses based on number of occurrences is difficult to comment on. I also had some confusion about whether the authors queried the groundfish databases directly themselves or where supplied with the data to put into the geodatabase (see comment re: Appendix H below).

In answer to question 1, I believe that the selection of the included groundfish research surveys was reasonable. As noted below I question why groundfish commercial fishery data was not discussed. I might also note that I am surprised that the Shellfish section Shrimp research surveys on the west coast of Vancouver Island and in Queen Charlotte Sound were not included.

In answer to question 2, I don't feel that I have the expertise to comment on the expected outcomes beyond the fact that the indicator species for the various biomes seem reasonable based on my basic knowledge of fish distributions, particularly in terms of depth ranges.

Detailed notes:

Section 2 – review descriptions of datasets

2.1.2.1 OBIS – should be noted that some of the DFO records housed in OBIS are a duplication of what exists in GFBio

2.1.2.4 Groundfish Biological Survey Database (GFBio) – unclear whether catch records without a weight or piece count recorded were included, i.e., trace amounts.

Question why groundfish commercial fishery information was not examined – this is a rich source of information with a large geographic extent. I note that there are commercial groundfish layers listed in Appendix H but no mention as to why they were not considered in this analysis.

2.1.2.5 Name resolution – would be of interest to know which records were excluded from Groundfish datasets. The "Species" tables in our databases are populated from a regionally maintained species table.

Assignment to habitat – is there a listing of where species were assigned?

Section 3 – choice of datasets for inclusion

Choice to only include species-level information seems reasonable for delineation of the Biomes. For groundfish research surveys, in the years covered by this analysis, it has been the protocol to identify to the lowest taxonomic level possible and if you aren't confident you record at a higher level, e.g., record to Genus instead of Species. However, it would be prudent to point out that not every individual has the same skill for identification and while they may be confident in their results, they may still be incorrect. It isn't possible to guess at the magnitude of this possible problem but hopefully it is not a frequent occurrence.

Rationale to exclude species reported at less than 1% of sites or where only one species was recorded seemed reasonable.

3.1.2.1 Choice of species assigned to benthic, demersal, benthopelagic, and reef-associated (assignment mentioned in 2.1.2.5) – again, any listing of which species were assigned to which habitat? Table B3 notes that the cluster analysis was limited to just benthic and demersal species.

Appendix B

p. 17 Unable to duplicate numbers – in some cases can get close. Some species excluded due to wrong habitat? For example, Pacific hake (*Merluccius productus*) and Widow Rockfish (*Sebastes entomelas*) don't show up as included or removed.

Descriptions of general survey design – there is inconsistency in format between the groundfish and shellfish sections.

p. 18 Hake stock delineation. Should Be Midwater trawl

p. 22 Pacific Halibut Management Association – additional description necessary. e.g., This survey alternates annually between northern and southern areas of coastal BC. There is a target of 200 fishing sets selected in each year and three commercial vessels are chartered to fish in one of three areas within the northern or southern portion each year.

p. 22 Sablefish Research and Assessment Survey. Changes have occurred in what is done on this survey.

Excerpt from 2015 survey briefing document:

The 2015 sablefish research and assessment survey is comprised of two main components:

1. A Randomized Tagging Program that releases tagged sablefish and also produces a time series of catch rate data that can be used for assessing changes in stock abundance. There will be 91 Randomized Tagging Program sets in 2015.
2. An Inlets Program that includes standardized sets at four mainland inlet localities. Sablefish are tagged and released from inlet sets and also sampled for biological data. There will be 20 Inlets Program sets in 2015.

The Traditional Tagging Program that captured sablefish for tagging and release at historical tagging localities has not been conducted since 2007. The Traditional Standardized Program that captured fish in nine offshore indexing localities has not been conducted since 2010.

p. 23 Strait of Georgia Synoptic Survey

4th line – should be Pacific groundfish synoptic surveys

p. 24 Synoptic surveys

Paragraph 2, line 6 – tow bottom times for deepest west coast Haida Gwaii stratum were 40 minutes until 2008 but starting in 2010 the target time was changed to 20 minutes like the other strata.

Appendix H

Listing of PMECS biotic data holdings. Question about the source descriptions, e.g., DFO (Oceans) and DFO (ACCASP). Does this mean these groups extracted the data? But the actual source information was from the GFBio database or commercial fishery databases?

Reviewer: Jason Dunham

Technical review of PMECS (Pacific) paper

Working Paper: Rubidge, E M.., K. Gale, J.M.R. Curtis, E. McClelland, L. Feyrer, Karin Bodtker, Carrie Robb. 2015. Methodology of the Pacific Marine Ecological Classification System and its Application to the Northern and Southern Shelf Bioregions CSAP Working Paper 2014OCN02a

Main document

pp. 14 Shellfish databases

Note that in crab logbooks commercial fishers report only legal size male Dungeness crabs (their daily landings, the target of the fishery) and not small (sublegal) males or females. The point here is only small portions of crab populations are likely reported through commercial logbooks.

Are non-target species reported in commercial crab logbooks? I don't think so.

The research biology database does not only contain standardized research surveys undertaken by DFO biologists (mainly at the Fraser River delta and Tofino (RL in Access)). It also has locations where:

1. service providers sampled their own standardized traps (fishery independent; IL in Access)
2. service providers sampled commercial vessels (fishery dependent; CL in Access),
3. Area A charter vessels sampled reference sites for soft shell crabs (SS in Access).

The "usability" code (assigned by DFO to indicate good-quality records). For crab data, a usability code = 0 means a trap functioned perfectly, i.e., there were no problems with how the trap functioned that may have influenced its fishing capability. During data analyses such as calculating CPUE estimates, one might consider ignoring traps with usability codes >0 to ensure the standardized trap assumption holds true. However, if one is considering strictly presence/absence, I do not think one necessarily has to exclude those traps that had usability codes other than zero. For example, usability code = 12 signifies starfish in a trap meaning the starfish likely engulfed the bait jar and impacted the bait's ability to disperse, decreasing the catch of crabs. Nevertheless, this trap may have still caught a few crabs (and starfish), data which might be useful in your model.

Appendices

pp. 11. Table B1. It is unclear to me why no commercial crab logbook data (or really any commercial logbook data) were used in the working paper (cluster) analysis? (I'm sure it's in there somewhere).

pp. 13. Commercial crab by trap. "Traps must have escape rings to reduce bycatch and undersized catch." I would tweak this sentence to read, "Traps must have escape rings to reduce catches of undersized males and females." (Escape rings were not implemented for bycatch).

pp. 13. Research. What is written here implies only DFO conducts research. Please see comments above about the other kinds of research sampling that occurs.

pp. 13. Data Locations: It appears most research data came from Area A (Dogfish and Goose Banks). This probably reflects the Area A softshell sampling program and some recent service provider sampling. (Just a comment).

Please give me a call if you have any questions.

Reveiwer: Jim Boutillier

Review of the data used – PMECS (Pacific) paper

Good job bringing all that data together. I actually have only a very few comments on the invertebrate data. In general most but not all of the invertebrate data sets have been mentioned. For the type of analyses presented few were actually used because the surveys are restricted to known biotopes.

1. Have the appropriate regional datasets been included? Are there other datasets that should be considered?

Not all the DFO data sets have been mentioned as there were years of the Abalone surveys and some of the ROV surveys have been analyzed in select areas (albeit it is still a work in progress). These again may not be useful at developing the Level 4 classification (unless you lump all the various data sets together) but should be useful at the biotope and facies levels.

There is even more data from the private sector that is provided to aquaculture and FPP managers that is collected as part of the authorization for allowable harm to habitat but this data is not stored and accessible within the Department as it has not been made a priority to archive and retain.

2. Do the results seem consistent with expected outcomes, given your experience and expertise?

The level 4 discussion is not surprising but I think there will be further discussion on the known geographical ranges of the species chosen and how that might actually bias the results. We will leave that for discussion at the meeting.

One general comment in section 2.1.2.3. The statement that a “zero value generally indicates a given species was not present, but in some cases it indicated that a weight or count was not taken for that species although it was present.” If the species is noted in the catch record for a unit effort, i.e., trawl tow, trap catch etc. then it was present it is not always possible to get a small weight on a ship the standard practice is that when a trace amount of a species is caught then the species is coded and the data base should include a weight of 0.01 (which may show up in a query as zero).

Reviewer: Leslie Barton

Pacific Biological Station
Science Branch
Shellfish

Date: September 15, 2015

Working Paper: Rubidge, E M.., K. Gale, J.M.R. Curtis, E. McClelland, L. Feyrer, Karin Bodtker, Carrie Robb. 2015. Methodology of the Pacific Marine Ecological Classification System and its Application to the Northern and Southern Shelf Bioregions CSAP Working Paper 2014OCN02a

Thank you for the opportunity to review the biotic datasets used in the development of the PMECS. My review is focused on the datasets that are managed by the Shellfish Data Unit of the Marine Ecosystem and Aquaculture Division of DFO and the use of those datasets to inform the PMECS. The authors have assembled an extensive catalogue of datasets that have the potential to support marine ecological classification efforts. I commend them on the considerable effort that went into identifying and collating the many datasets.

My review is restricted to Sections 2 and 3 of the working paper, Appendix B and Appendix H. I will present my comments and questions, identified by section.

Section 2.1.1 Development of the PMECS geospatial database

The authors have gone to considerable effort to compile data layers within the PMECS geodatabase. In some cases the layers or data files represent the same underlying data, presented in a slightly different way (for instance commercial catch data presented as both grids [raster] and tabular [point] data). In another example, the DFO multi-species small mesh trawl (aka Shrimp Biological research) data served as the input data used to produce the Pacific Multispecies Small Mesh Trawl Survey (OBIS Canada). These two examples represent 4 discrete entries in the Biotic appendix H. Although in this case datasets representing the same underlying data were not included in the model I would question what effect this would have should duplicates be utilized as inputs. If is it undesirable to introduce duplicate data to the model, are the geodatabase entries well enough described to avoid this?

Section 2.1.2.3 Shellfish Databases: SF Log and SF Bio

The description of who was involved in the collection of the research data that are housed in SF Bio needs to be expanded. In addition to the biological research data collected by DFO staff in support of DFO program research, the database also houses data collected through collaborative efforts with FN, industry and academia. In some cases DFO's only role is to serve as an archive for the data that was collected by external parties but deemed to be of interest to the DFO Program.

It is not clear what the authors intended when they made mention of 'sub-databases'. This reviewer's interpretation of the term 'sub-database' is the existence of a database housed within another database; this is not the structure of the Shellfish data holdings (collectively SF Log and SF Bio). Shellfish data are housed in 1 of 6 primary MS SQL Server database files. Clients of the data, including the DFO authors of this paper, do not have direct access to the primary MS SQL Server files. MS Access has been adopted as the means by which clients may query the data holdings. User friendly MS Access front ends (data structures containing links to views of the primary data) are provided for clients to easily query the data. These front ends and the views of the data that they provide generally reflect Shellfish program organization. For instance Crab-related data arising from 7 separate types of investigations are made available within the Crab biological MS Access front end.

Confusion regarding the application of Shellfish usability codes is reflected in the authors' statement "…a positive "usability" code. Shellfish usability codes are intended to identify when there is a concern with the data record and to categorize the nature of the concern. The default value is zero (indicates no concerns). Values 1 through 16 identify a concern of some nature that, depending on the analysis, may render that record inappropriate to the analysis. For instance a record with code 2 "Mechanical or other problems affecting the catch" should not be used in a CPUE analysis.

It is not clear what is meant by "Zero values generally indicated a given species was not present…". This statement does not reflect the structure of the Shellfish data holdings. A record is included in Shellfish data holdings to reflect an observation; records are not included to reflect the absence of an observation. It is important to capture those instances where sampling effort has occurred but nothing was caught/observed. Within SF Bio, by convention, when gear is deployed and yields zero catch, a species code '848' is assigned (848 is defined as No Fish In Sample in the Regional Species Code table).

The authors have indicated that an average of available latitude and longitudes was calculated in those instances where start and stop locations were recorded. Caution should be exercised in the assumption of a straight line from start to finish. It is common for fishing effort (a trawl event or deployment of trap gear on a groundline) to follow a bathymetric contour such that the assumption of a straight line path from start to finish is not valid.

Section 2.1.2.5 Biotic data preparation

Did the authors make use of the DFO Regional species code tables when reviewing the taxonomic names in the data arising from DFO sources? When DFO regional taxonomic names differ from other sources such as WoRMS and ITIS, these differences are often supported with explanatory comments within the Regional species code table.

Section 3.1.2.1 Selection of Data

The authors identified two criteria by which data from the PMECS geospatial dataset were selected to be included in the analysis: multispecies surveys with no limit on number of species recorded and North-South spatial coverage across the study area. Two SF_Bio datasets were identified as meeting these criteria, Tanner Crab surveys and Crab Trap surveys. The authors identified that there could be exceptions to the criteria that would allow inclusion of records (the datasets covered sites that would otherwise not be represented). It is understood that Crab Trap surveys were included under this exception (per Appendix B, pg.13). It would provide clarity if the inclusion of the Crab Trap surveys dataset were identified as an exception within the body of the main paper.

Section 3.1.2.3 Indicator Species Analysis

The concerns expressed under section 2.1.1 of this review apply here as, based on my understanding of the analysis, there may be a potential for species prevalence to be artificially inflated when the same underlying data have been used to develop multiple input layers or files.

Section 3.1.2.4 Environmental drivers of biological clusters

In the final paragraph the definition of the term survey should be expanded to include individual traps as it is suspected that the Crab Trap survey data were presented as results from individual traps.

Appendix B Details on primary data collection and preparation

Table B 1. It would be helpful to define the term ‘survey’ as used in the column headers, as this word is being used in a somewhat non-traditional manner. I question the omission of the Scallop Dive Commercial database from inclusion in the PMECS geodatabase.

Table B 2. Same comment as for Table B 1. regarding the definition of the term ‘survey’. I have reservations with the treatment of the datasets represented in this table. I will present general comments followed by specific comments for each dataset.

The first general comment pertains to the citations that have been provided to describe the datasets. For example, Crab by Trap data holdings are a composite of 7 distinct types of crab-related investigations, each with distinct survey design. These 7 types are differentiated through the use of a database field type ‘Source’. The authors have provided a citation to describe the crab research data holdings that is appropriate to 3 of the 7 ‘Sources’ only. The list of citations should be expanded to reflect all the Sources of the data that the authors have included in the PMECS geodatabase. This comment is applicable to all the SF_Bio research data present in the PMECS geodatabase where multiple Sources are found (true for each of the entries in this table).

A second general comment is with regard to species names. It is cumbersome to include both current and past species names in the text. If the authors feel strongly that it is important to include both names it may be desirable to include a single table with past and present names, making for a cleaner presentation of the information. Regarding common names, in keeping with DFO having adopted the American Fisheries Society practice of capitalizing common names e.g. Dungeness Crab or Green Sea Urchin, the authors are encouraged to apply this style note to the working paper.

Crab by Trap p.13

Through the description of the Data locations it is inferred that the authors utilized crab softshell monitoring data to inform the cluster analysis. These data do not meet the 2 criteria set out for inclusion in the working paper analysis – the softshell data do not reflect a multi-species survey for the years 2000 through 2012; the data do not represent re-evaluate inclusion of the softshell data or at minimum restrict the data to the year 2013 as this is the only year for which species other than target Dungeness Crab were recorded.

Tanner Crab p.13

Research data exists for the period 1999 through 2006. The focus of the research shifted in 2005 to a broader, exploratory nature as industry interest in pursuing a commercial fishery waned. The authors are encouraged to contact Ken Fong (DFO) should they wish to the potential of this dataset further.

Geoduck and Horse Clam p.13

Commercial harvest occurs from geoduck beds, not quota blocks; quota blocks support allocation. Geoduck beds fall within Geoduck Management Areas, as opposed to sub-areas (a term more often associated with Pacific Fishery Management sub-areas).

Octopus by Dive p.14

There has been no directed research in support of Octopus assessment. Some biological data are reported by harvesters and is stored within the commercial harvest database.

Shrimp by Trawl p. 15

The DFO regional species code table has adopted *Doryteuthis opalescens* in place of *Loligo opalescens*. A more appropriate citation for the research data (known as the Multispecies Small Mesh Trawl survey data) would be Boutillier, J.A., Bond, J.A. and Nguyen, H. 1999. Evaluation of a new assessment and management framework for shrimp stocks in British Columbia. Can. Sci. Advis. Sec. Res. Doc. 1999/24.

I question why the authors chose not to include data from the Multispecies Small Mesh Trawl survey series in the working paper analysis. Granted this survey could be considered spatially limited, however other datasets have been included with even greater spatial restrictions. It is also noted that some groundfish trawl surveys provide coincident spatial coverage however there are differences in gear types that potentially could yield different species for the same area. I would be curious to know if this aspect was reviewed prior to excluding the data from the working paper analysis. A more fulsome discussion on the decision to not use these data would be welcome.

Appendix H: Biotic Data Holdings

It would be helpful to define the term ‘Source’ as used in the column name for the Biotic Data Holdings table. It seems that the entries under Source have not been applied in a consistent manner, making it difficult to understand where data have originated versus who provided the data to the PMECS. If the intention of this table is to catalogue what datasets may be available to modelling and planning exercises, clarity around source of original data is required. If this information is available in metadata associated with the files, presentation of this information in the appendix is desirable.

Considering first the commercial invertebrate data entries, many of the entries are identified as Source = DFO (Oceans) yet these layers were originally developed by the Shellfish Data Unit. For clarity it may be desirable to identify the distributer (which would be DFO (Oceans)) and the developer (which would be DFO (Shellfish)). It is unknown if DFO (Oceans) has post-processed the layers subsequent to having received them from the Shellfish Data Unit. If this was the case then it would be appropriate to list DFO(Oceans) as source. There are items (Layer Name starts with JIRA624) identified as source DFO(Shellfish); these were developed by the Fisheries Management Fisheries Data Service (formerly known as Regional Catch Statistics) and draw from the Fish Slips data holdings and should be identified as such. The data layers attributed to DFO (ACCASP) as source originated with the Shellfish Data Unit. The layers identified as source DFO(Shellfish) are layers developed by the authors themselves through self-serve access to the Shellfish data holdings. As such it seems inconsistent to identify these as DFO (Shellfish) For commercial invertebrate datasets many of those listed are developed from the same underlying data holdings, the potential implications of which are discussed under Section 2.1.1 of this review.

Considering next the research invertebrate data entries, the Pacific Multispecies Small Mesh trawl Survey (OBIS Canada) is derived from the Shellfish Data Unit Shrimp trawl research data and raises again the issue of duplication of data. On pg. 32 Multiple species, Shrimp trawl research point records the layer name references scallop trawl. Under Scallop there seems to be a missing layer type for Scallop dive research point records (see pg. 33). I would question the source of Aquatic invasive species point records for INVERTEBRATES. In all cases where source is DFO (Shellfish) these are layers that were developed by the authors themselves through self-serve access to Shellfish data holdings.

In closing, I was excited to see the level of effort that went toward the assembly of the datasets necessary to inform the PMECS analysis presented in this working paper. I hope that the authors will find value in the opinions I have expressed and will consider the suggestions put forward in this review.

Comments on Rubidge et al.

Charles Hannah and Tetjana Ross

There are no obvious oceanographic data types missing. (I find it difficult to refer to Chl-a as abiotic). However, some of the oceanographic data sources are not well explained and – most importantly – there is almost no information given on how the initial 59 oceanographic variables were reduced to 14.

The commentary below seeks some clarity on the details of some of the oceanographic data used. It also wanders into the application of the data and the proposed application of the classification scheme to climate change assessment.

Page numbering is erratic so we use section numbers.

Section 1.4 PMECS development

Table 3. Item 10. You don't actually make use of climate change projections – you assert that it can be done. I argue later that the naive application of the current framework can NOT yield useful results.

I don't understand the bold numbering that appears to cut across sub-sections, also the page breaks after each mention of Table 4 is disorienting. Can this be fixed?

Section 1.6 Approach

Table 4: Making Geozones the next level of categorization makes sense for benthic ecosystems, but little sense for pelagic. Can this be made more general, or will a completely different system need to be developed for pelagic ecosystems?

Section 2.1.2.5 Biotic data preparation

Why are diatoms excluded?

Section 2.1.3 Abiotic Data

Chl A: Does it make sense to bin sea surface chl-a data into 3 month seasons? Do these seasons make sense in BC?

Salinity, temperature, currents:

In order to understand whether you are using good quality S, T, u data, you need to better explain what they are. What is the relationship between the model and real observations? How is the model driven by observations and which ones? How good is the model at reproducing observations? Are you really using model output for T and S or simply the climatologies used to drive the model? The citation does little more to answer these questions than the text here – is there a better one?

Mean currents: Did you use the N-S and E-W currents separately or did you combine them into speed? The text does not say. I hope you computed speed.

Tidal currents: Do you mean tidal speed (rather than velocity, which should combine both speed and direction)? What is meant by tidal current direction? Is it the direction of the major axis for a particular component? Is it defined relative to compass direction?

It is hard to imagine how tidal current direction, defined relative to compass direction, has any relevance at shelf scales. It might make sense if defined relative to local bathymetric gradient directions.

I think you have introduced a truly random variable and it should be used to define the noise level in your later analysis (e.g. Figures 11, 15). For each biome, all variables with importance less than or equal to tidal direction should be eliminated from the predictive model.

Habitat template model

Kostylev et al 2005 is the wrong reference. They did nothing for the Pacific continental shelf.

The field for Adversity (scope for growth) may come from Kostylev et al (2015). That needs to be confirmed.

I don't know that there is a reference for the disturbance field – perhaps Kostylev (pers. comm. 201x, following procedure in Kostylev and Hannah 2007 using constant grain size). This also needs to be confirmed.

Kostylev, V., C. Hannah, V. Soukhovtsev, C. Dickson. 2015. Canada wide benthic scope for growth: Preliminary classification. Can. Tech. Rep. Hydrogr. Ocean Sci. 305: vi + 24 p.

If the adversity and disturbance fields were not taken from Kostylev et al (2015), then more information must be given on what choices were made (mainly the ranges of the parameters used, as this effectively adjusts the weights on different environmental factors) in the implementation of this model.

Discussion of errors or uncertainties associated with the adversity and disturbance fields is missing.

2.1.3.6 Grain size model.

Needs a reference.

Ed has a draft DFO technical report that can be cited. It should be included in the material for the meeting.

Discussion of errors or uncertainties associated with the grain size model is missing.

3.1.1 Approach

"… to incorporate whole assemblages…": This statement is confusing because random forest was already being applied to the cluster identified assemblages. Expand for clarity?

Last paragraph: Why hypothesize that biological assemblages are only driven by depth? Would substrate type be more meaningful?

3.1.2.1 Selection of Data

11. How did you judge whether the species had the correct habitat? Could doing this kind of pre-analysis bias your results?

3.1.2.2 Cluster Analysis Methodology

Wouldn't β_{dissim} make more sense, since it increases with dissimilarity? Perhaps βsim is the convention (and perhaps is even named after Simpson), but I found it confusing.

Figure 4: Would be easier to read if expressed as % or fraction of all sites rather than the number of sites in each cluster. This figure is repeated three times.

3.1.2.4 Environmental Drivers

2nd paragraph: Your preliminary analysis that reduced 59 variables to 14 should be discussed here. THIS IS IMPORTANT and should not be glossed over. It's hard to evaluate whether important variables were neglected because no process/rationale is given for the reduction aside from correlation. Correlation isn't enough, the reader needs to be convinced that you've eliminated only unnecessary variables. See comments in the appendix for some suggestions.

The remaining variables need to be explained.

What does sea surface temperature (overall) mean? Is it the average over the 10 years of data?

What does flow (summer and winter) mean? Is it surface, middle, bottom? Is it the speed for one of the horizontal components? Are these the seasonal mean flows from the model?

What is tidal velocity? Is it the rms speed over 29 days? Is it the amplitude of the M2 component? Is it the surface value, bottom value or the vertical average?

Nitrate, oxygen etc. – are these near bottom values? Mid depth values? Something else?

Model parameters and performance metrics: What are the default settings for the random Forest package? Can you explain what "10-fold cross validation repeated 10 times" means (in layman's terms)?

Figure 8 is repeated three times.

3.2.2.1 Level 4a

Fig 11: As stated before, I think tidal dir defines the noise floor. All variables less than or equal should be removed from the analysis. This applies to Fig 15 as well.

The fact that the Random Forest Model is uncertain in the transition zones is NOT a weakness in the model. It is the model trying to tell you that you are in a transition zone. It is a strength of the model. It is INFORMATION. The text in Section 3.3.1 makes more sense.

Figure 17 and 18: Why 2 figures? What information is in Fig. 17 that is not in Fig 18? Perhaps Fig 18 could be enlarged to full page-width, so that it's easier to see the colour inside the black boxes and then there'd be no need for Fig 17.

Section 3.3 Discussion

Dogfish bank: I think you will find that dogfish bank is highly mobile. It is sandy, shallow and subject to strong currents and waves (see the Kostylev et al disturbance plot). This sounds like ideal habitat for flat fish.

The weakness of your primary variable approach is that you cannot talk about the processes that structure the ecosystem.

3.3.2 Limitations

Last paragraph on climate change.

Consider Figures 14 and 18.

How can climate change affect these super-biomes and biomes? They are largely structured by depth – you cannot turn a trough into a shelf or a bank. Imagine you introduce new bottom temperature and bottom oxygen fields into the predictive model. How can the biomes change? Your classification areas do not change from one to the other smoothly in the parameter phase space. For example, there are no north-south gradients in the shelf biome. You put the southern Vancouver Island shelf in the same zone as northern Hecate Strait.

One impact that is thought to be happening now is that reduced oxygen levels are being seen higher in the water column and this is reducing the viable habitat space for ground fish along the shelf edge. I don't see how inserting reduced oxygen levels into your framework will show this affect.

I think by using depth as a variable you have eliminated the opportunity to allow for changes in variables that are strongly correlated with depth (salinity and oxygen).

Section 4 Level 5 geozones

Very interesting and Fig 22 is a beautiful figure.

What evidence is there that the classification has any relevance to the distribution of species or species groups? What features of the biological data are captured?

Fig 22 seems to be in the document twice.

Section 6: Level 8

I think I would have put tidal energy into level 4 or 5. Tidal mixing and tidal mixing fronts are known to be an important feature for structuring ecosystems and bank scales.

Section 7: General Discussion

First paragraph: You need to admit that you have NOT shown the BPI has skill in defining distributions of species for functional groups.

7.1.1

See early comment on climate change.

I think that either your model is insensitive to climate change or climate change will move the parameters outside the range of your statistical model. You may need to extend your analysis further south.

Sources

Is Foreman et al 2008 the best reference? It is a short note on dynamic topography.

Appendix C

You should list all the variables so that one can make sense of the correlation figure. You should this in the form of a table that lists each oceanographic variable, gives it's shorthand name for the correlation figure(s) and gives details on how it was calculated (e.g. average over X years and Y depth range).

Additionally, the correlation plot (Fig C1) is VERY hard to read with the lettering overlapping considerably. This could be fixed by staggering the labels and drawing lines to connect the distant labels to the correct row/column.

THE CORRELATION ANALYSIS IS NOT WELL EXPLAINED. Why were 14 oceanographic/environmental variables retained and not more or less? What rationale was applied to choosing 14?

Each of the 14 variables remaining must represent other correlated variables – which eliminated variable correlate strongly with which remaining variables? And, of the correlated sets, how did you choose which variable to retain?

How does ecological relevance play in? And, what was the evidence/rationale employed in applying ecological relevance to the decision making process?

Can you make a tree of correlation for these oceanographic variables and make a cut at some level and show how each entry in Fig C2 represents one family of correlated oceanographic variables?

Appendix D

Table D2: You mention the threshold for inclusion was species found in less than 1% sites. What is the rationale for the choice? Does this limit the possible biome size? Or is it well smaller than what could affect biome size? (Also shouldn't you be saying that less than 1% is the threshold for exclusion, not inclusion?)

MARITIMES WORKING PAPER REVIEW

Reviewer: John R. Harper

22 September 2015

A Review of "A subtidal ecological classification system to represent species diversity and distribution patterns in the Maritimes Region" by Greenlaw, Smith, Rubidge and Martin

General

Not sure what the terms of reference for this report might have been but having it sub-divided into three separate sections contributes to some organizational problems and "ranginess". And is "Subtidal" the right word for the title or should it be "Marine Ecological . . . "

I approached the topic from the stand-point of a "practitioner" who is assessing the methodologies and conclusions in terms of how they would be applied to another region (e.g., Gulf of St. Lawrence). That is, what procedures could be applied and what datasets are available to delineate ecoregions and validate those regions.

1. **Organization** – the three sections –
    i. HMECS,
    ii. MPA frameworks and

iii. Classification Methodologies

contribute to organizational challenges. There is considerable repetition of concepts. There is a loss of “messaging” as a result of the organization.

2. The distinct new contribution is the presentation of the 44 *Physiographic Units* (Fig. 3), although this may have been previously presented in Greenlaw et al 2014. Most of the remainder of the report is discussion about methodologies.
3. Benthic vs Pelagic – a common problem with marine ecosystem mapping is the distinction between pelagic and benthic components. Classification systems are often benthic-biased as substrate and morphology datasets are generally available and associated communities less transient and better documented. There is virtually no mention of the pelagic vs benthic issue (2 sentences), especially as the classification is pushed down. If one of the important applications is to Ecosystem Approach to Management for fisheries management, it is very important to provide insight to the issue.
4. Practitioner’s Perspective – I approached the paper from a practitioner’s view – what did I learn and how can that be applied to another region (e.g., southern Gulf of St. Lawrence)? The paper outlines a useful methodology with the HMECS classification scheme (combinations of Oceanographic Domains, Bathomes and Geomorphic Units) to the Meso Habitat level (Fig. 3). The pelagic vs benthic issue would still have to be addressed but this is a substantial subdivision and useful for all kinds of planning initiatives.
5. It would be helpful if the paper recommended a specific set of steps for more detailed classification – a detailed substrate map (Fig. 7) with hundreds of distinct units was presented but the methodology used to produce it is not included in the report. Also the GFA approach of Pitcher et al (2010) was suggested many times but not included as a specific recommendation for classification refinement. As a practitioner, I would also like to know, what will be the most helpful data to implement the GFA approach?

The additional of 44 Physiographic Units following a well-defined methodology is an important advance. The delineation of Oceanographic Domains and Physiographic Units provides good rational for addressing the pelagic vs benthic issue. I have made a suggested re-organization below that will help focus on the key message (HMECS for application to resource management) and that includes “steps for practitioners” and “what’s next.”

Suggestions

Reorganize - Use the HMECS Classification as Organizational Structure
- Intro should state goal and overall objectives of paper
- Intro should address *pelagic vs benthic* issue
- Work down through the classification levels as Section Headings
  - Review methodology appropriate to classification level including data requirements
  - Where methodology is untried, review options but *recommend preferred option*, data
- Discussion Section could include:
  - Recommended Steps to implement classification to Macro Habitats (Level 4) – this is for other practitioners
  - Validation Examples
  - Potential strategies, data for implementation to Micro Habitat level (5)
  - Implications to MPA Planning
  - Next steps (specific would be most helpful, top 1 or 2 would be most helpful)
- Conclusions
  - Suggested Approach

Application to MPA Planning
Next Steps

PACIFIC WORKING PAPER REVIEW

Reviewer: C. Robinson

Consultant, Nanaimo
Date: 22 September 2015

Working Paper: Rubidge, E M.., K. Gale, J.M.R. Curtis, E. McClelland, L. Feyrer, Karin Bodtker, Carrie Robb. 2015. Methodology of the Pacific Marine Ecological Classification System and its Application to the Northern and Southern Shelf Bioregions CSAP Working Paper 2014OCN02a

Instructions received from CSAP:

The primary issues to consider in the working paper (WP) were:

1. Are the methods and results appropriate given data availability and the intended purposed of applying the conceptual classification framework?
2. What are the uncertainties and consequences associated with the data availability and classification decisions (e.g., number, boundary, type, etc.) in the application of the conceptual framework, and what guidance can be developed for future applications?
3. What types of analyses are appropriate to classify areas at spatial scales not completed as part of this application?

Questions considered in this review:

- Is the purpose of the working paper clearly stated? Yes.
- Are the data and methods adequate to support the conclusion? No. See comments below.
- Are the data and methods explained in sufficient detail to properly evaluate the conclusions? Yes. See comments below
- If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or processes? No. See comments below.
- Can you suggest additional areas of research that are needed to improve our assessment abilities? Yes. See below.

Key points from review

The WP is a good start for examining the issue of biodiversity representation and implementing PMECS on the Pacific coast of Canada. The WP also represents great and necessary strides in assembling georeferenced species data from a variety of sources for the BC coast. This was a key first step in further developing and applying the PMECS framework. At this time however, there are several short-comings and limitations in the WP approach and analysis that need to be addressed before the results can be implemented. These can be briefly summarized as follows:

1. consider using best available biodiversity data on a bioregion basis only to initiate down-scaling,
2. consider analyzing fish and invertebrate data separately by bioregion,

3. consider using only "biomes" at level 4 of PMECS,
4. compare results of clustering with additional analytical methods to more fully understand biodiversity representativity,
5. better describe the fish/invertebrate biodiversity represented (or not) within the proposed biomes, and
6. consider evaluating fish/invertebrate diversity in relation to proposed geozones to better understand the utility of the latter.

Each of these considerations is discussed in greater detail below.

Detailed Review

Context: From the National Framework for Canada's Network of Marine Protected Areas (Section 9.2, Government of Canada. 2011): Ecological Representation (or Representativity) at its most basic, broad scale, this means protecting relatively intact, naturally functioning examples of the full range of ecosystems and habitat diversity found within a given planning area such as a bioregion. Establishing a network of MPAs that captures examples of habitat types within the bioregion will ensure that the finer-scale elements of biodiversity (e.g., species, communities) and physical characteristics (e.g., oceanographic conditions, bathymetry, geology) are also protected. The different habitat types in a bioregion can be identified and delineated using habitat classification schemes based on the best available physical and biological information.

DFO (2009) identified four major bioregions representing a maximum scale that can be subdivided into smaller units that are ecologically meaningful at smaller scales. The intent of the Canada-BC MPA MOU was to develop a network of MPAs within each bioregion. The implicit assumption is that biodiversity differs among bioregions and that sub dividing each bioregion will capture the inherent distributional differences in biodiversity that will support the development of a network or marine protected areas (MPAs).

The Pacific Marine Ecological Classification System (PMECS) was recommended because of the need to consider biological data in a biodiversity representation assessment and to not simply rely on habitat-biodiversity surrogacy. Further, classification levels and biodiversity results of PMECS were intended to be spatially nested. Ultimately, one of the first steps in applying PMECS to the BC coast was down-scaling or sub dividing biodiversity in the four larger Pacific bioregions. A key question remains as to what level(s) of PMECS will be used to identify MPAs for the network within each bioregion.

The stated goal of the working paper was to apply the conceptual PMECS framework towards implementation for use in MPA network design. Mapping biodiversity patterns and understanding the environmental drivers of those patterns is a critical first step in conservation planning.

The approach taken in the WP was to select 'appropriate layers' to develop a marine ecological classification system that can be used to underpin marine spatial planning. The cluster, indicator species and random forest analyses considered a combination of fish and invertebrate data sets for both the northern shelf bioregion (NSB) and the southern shelf bioregion (SSB) simultaneously.

Key points:

A. Changes to PMEC

1. One of the first steps taken in the WP was to modify the proposed PMECS framework. The authors indicate that the spatial extent of ecosections and bathomes were similar and not spatially hierarchical and that the biological relevance of ecosections was not supported by results of the cluster and PEMANOVA analysis; hence the ecosection level was dropped from PMECS. I think dropping the ecosection level could be premature because it is based on the results from only one benthic analysis (that has some limitations). Recall that there is a pelagic diversity component of PMECS that may be consistent with the ecosection level but this also requires testing.
2. The bathome level of PMECS was renamed and essentially broken into two sub levels namely "super-biomes" and "biomes". The WP authors may have misunderstood the term bathomes in PMECS but it was not intended to rely on predefined depth zones, but rather required results from an analysis of biotic data to define depth zones. Last et al (2010) state that while primary bathomes provide a useful way of categorizing biota, they can be further subdivided, based on their biological composition, to reflect finer scale, depth-related substructure. Last et al (2010) proposed bathomes instead of biomes to avoid confusion with other classification systems.
3. Regardless of the renaming of bathomes to biomes, the results presented in the WP were used to justify splitting level 4 into super-biomes and biomes. The authors should provide further justification and explanation for this split and how it relates to better representation of biodiversity. For example, the identification of biomes seems to be somewhat subjective based on "cutting the tree slightly lower" at a dissimilarity value of 0.55. Why stop there? Ultimately, my concern is how 'useful' is the super-biome level in a biodiversity representation analysis or classification framework when sites are only 35% similar?

B. Analysis across bioregions

1. The main approach of the WP includes analysis of fish and invertebrates data along the coast, covering both the NSB and SSB. This approach is not consistent with the assumption that each bioregion harbours a subset of coastal diversity and that each bioregion should be considered separately. At present, the super-biome extends coast-wide and implies that slope (shelf) fish/invertebrate assemblages off Haida Gwaii are equally representative of those assemblages off southern Vancouver Island? This conclusion ignores the potential for species turnover with latitude and more analysis is required to support the result.
2. The analysis performed in the WP partially supports the recommendation made in Robinson et al (2015) that "Research and analysis is required to understand how (if) marine species diversity differs among these (four) bioregions." I recall that the four bioregions for Pacific were initially derived from known differences in oceanographic processes and did not necessarily include any substantial biodiversity information. Differences in diversity among bioregions have rarely been tested (but see Robinson et al. 2013) and remain a weak link in the upper levels of PMECS.
3. The approach used in the WP considered species datasets that occurred coast-wide over both NSB and SSB. There were a few more datasets available for the NSB and this may have biased results of the cluster analysis more towards these species. Is there any analysis to refute this?

C. Analysis across taxa

1. The inclusion of both fish and invertebrate taxa within the same cluster analysis is not an approach commonly used in the marine literature. Is there any a priori reason to assume that demersal fish and invertebrates would share a similar distributional pattern to warrant 'lumping together' in a cluster analysis? One key issue of this approach is the potential for one group of taxa to mask the distributional patterns observed in the other. For example, 96 species of fish and 78 species of invertebrates were included in the analysis. However, the 'indicator' species for super-biomes only resulted in the selection of 7 of 78 invertebrates, and 35 of 96 fish species. The classification might be dominated by the greater frequency of occurrence of fish species. I think it would be more informative to consider fish and invertebrates separately.

D. Issues related to data

1. To adhere to the assumption that the data are representative and independent and to reduce sampling bias, the authors selected data that met the following criteria: multispecies surveys, North-south spatial coverage across the study area and localized or patchy data sets were excluded. I would argue that localized or patchy data can still potentially be useful in identifying species assemblages in the modeling process. The role then of the diversity-environmental modeling is to identify relationships and then project into areas with no biotic data.
2. Removing 111 'rare' species from the analysis is probably not helpful when the goal of the MPA network is biodiversity representation. Alternatively, species that are wide spread in their distribution will tend to dominate the cluster analysis and should be removed. Henderson et al. (2011) for instance note that relatively few fish species dominate fish assemblages and don't contribute as much as occasional species to assemblage richness. Ultimately, 'hot spot' areas with occasional species may contribute meaningful information for identifying MPAs.
3. There was no discussion or justification for using a cell size of 4 km2, and no analysis presented to understand how cell size might influence the identification of assemblages.
4. If the concern is that there are too many species to consider in the cluster analysis, many benthic marine invertebrate diversity studies role up species to the genera or family level; The 96 fish species used in the present analysis would roll up to 57 genera. Was this considered?
5. Perhaps at the higher levels of PMECS such as biomes, a coarser resolution of taxa like genera or families should be considered, while species resolution data are reserved for delineating finer scale levels of PMECS.

E. Nearshore diversity

1. The WP indicated that all sites (4km2) that intersected land were removed from the analysis. It was unclear in the WP what the minimum depth of analysis was but this approach effectively eliminates nearshore areas in the biodiversity representation assessment. It also excludes some of the best available biodiversity datasets (BC museum and UBC) on fish and invertebrate species distribution in the shallow nearshore areas. How/when do the authors propose to evaluate biodiversity in the nearshore and how will this 'mesh' with the slope-shelf-bank biome level assessment?

F. Cluster analysis

1. Section 3.1.1. The authors indicate that they used similar methodologies to Lyne et al. (2006), specifically cluster analysis. The only reference to cluster analysis that I could find in Lyne et al. was in their Table 3: "identified 3 sub biomic units from a cluster analysis of informative fish species". In this WP, the inclusion of both invertebrates and fish into the same cluster analysis is unconventional. I would strongly recommend that a cluster analysis/ordination be completed independently on each taxa and results compared to inform the identification of species assemblages within a bioregion.
2. The authors state that the only assumption of a cluster analysis is that the input data are representative of the larger population. It is also well known that clustering is typically less useful where there is a steady gradation in community structure across sites in response to environmental gradients (e.g., range of water depths; see marine benthos studies of Clarke and Warwick). Ordination methods (such as nMDS) are usually preferable in these situations. In fact, cluster analysis is often best used in combination with ordination to understand assemblage clusters, and agreement between the two representations strengthens 'belief' in the adequacy of the assemblage. For a local example employing both methods that should be considered refer to Fargo et al. (2007). Note also that Horn et al (2006) used both cluster and ordination in their assessment of California fish diversity.
3. The use of Simpson's index is an unusual choice for a cluster analysis of marine fish assemblages, and I could not find any previously published work. Why have the authors moved away from the use of conventional dissimilarity metrics?
4. The 'indval' identifies species that are more prevalent in a particular cluster but we don't know how prevalent the species were in the other biome or super biome clusters. This was briefly discussed for Dungeness crab and the dogfish bank biome but should be considered for other indicator species. Perhaps a summary table of species by biome and the relative percentages of occurrence would be most informative.
5. What is the utility of the indicator species analysis from a biodiversity representation perspective? I would think that a similarity percent analysis would be more relevant because it evaluates which species are most responsible for the dissimilarity among clusters/groups (and it typically excludes common species).
6. The criteria for dendrogram cut-off (Figure 4) seem to be mainly driven by site-level (mapping) properties (e.g., spatial coherence of sites) rather than diversity information. Please provide additional rationale.

G. Level 4 Results

1. The authors refer to communities that are somewhat stable over time and thus base the analysis on more common species. There was no assessment of assemblage stability over time, even though this could be accomplished with the existing dataset. See Fargo et al. (2007) for a discussion of temporal stability in Hecate Strait fish assemblage membership. Also consider that in some of our recent work with fish assemblages in eelgrass meadows the common species remain quite persistent and stable over time (10 years) but occasional species come-and-go at a meadow mainly through changes in frequency of occurrence (driven by abundance). Ultimately, it is the latter that are most tightly linked to species richness and thus may be most informative in a biodiversity representivity assessment.
2. How do the biome-level fish assemblages compare to those identified by Fargo (2012) for Hecate Strait?

3. Section 3.1.2.4 and Figure 7. "Sampling effort does not appear to be strongly correlated with species richness at each site". It is well known that higher sampling effort and sampling method can greatly influence species richness. A more detailed analysis is required to understand sampling effort implications on invertebrate and fish species richness separately.
4. I am not familiar with random forest methods but will only comment that the method is not frequently used in the marine literature to evaluate biodiversity in relation to environmental data. Many other multivariate methods have been commonly used (e.g., CCO) and the authors should discuss why this approach was taken. Ideally, it would benefit our understanding if several models were evaluated and results compared before settling on one approach (See recommendation in Robinson et al. 2015).

H. Geozones

1. This section gives a good methodological overview of the benthic terrain modeller tool as applied to the BC coast.
2. Why was the continental shelf off Vancouver Island excluded from the analysis?
3. Section 4.2.5. 'the scale of features should determine the scale factor of the BPI' Couldn't this be based on an 'analysis' of multi-beam imagery and identification of the scale of key features on the seabed, and or through discussion with CHS/NRCAN experts?
4. The most surprising part of this section was the absence of an analysis between the assembled fish and invertebrate diversity data sets and the resulting geozones. This would be relatively 'easy' to do and the results of such an analysis would further dictate the refinement or utility of geozones as surrogates for benthic diversity.

I. Level 5 and 6 of PMECS

1. I agree that Gregr et al (2013) offers a method for mapping potential biodiversity at this spatial scale of PMECS, and that it will take time to develop a more comprehensive substrate layer for nearshore regions. What’s another decade or two?

J. General

1. It would be helpful to re-organize the approach section for the level 4 of the WP as follows: cluster analysis and assumption with supporting studies, indicators species analysis and then random forest approach. It is not necessary to include a description of random gradient forest approach if it was not used in the WP.
2. Section 3.3.2 "our analysis assumes that they are representative of the benthic communities found in our study area". This assumption requires testing.
3. Section 3.3 "the added benefit of our community approach is that ability to provide a list of species associated with each ecological unit". The issue here is that the indicator species are not necessarily associated with only one biome. This aspect requires more description and discussion.
4. The RF model does not perform well in "transition zones where species composition is changing across environmental gradients". It wasn't clear to me how the analysis/results in Appendix E addressed this issue of changing species composition across environmental gradient at 'transition sites'. This could however be tested using nMDS, ANOSIM and SIMPER analyses; also see approaches in Anderson et al. (2011) for beta diversity turnover analysis suggestions.

5. The variable performance plots for super biomes and biomes were similar and indicate depth, salinity and temperature range were the three most important environmental parameters evaluated. Again, nothing is really gained from considering both super biomes and biomes.
6. It should be re-iterated that Robinson et al. (2015) recommended that a pilot region be identified with best available biodiversity and environmental data to best provide a focused and fulsome analysis to operationalize PMECS. One main reason for this recommendation was because of the well-known complexity and overwhelming amount of biodiversity and environmental data and available analytical approaches. Given some of the shortcomings of the coast-wide analyses as discussed above, I would strongly advocate for a larger scale analysis in one bioregion as the most pragmatic approach for developing methods and ultimately implementing PMECS.

K. Additional analyses

1. Two key gradients to consider for marine biodiversity representation on the BC coast are depth and latitude. To some extent the bioregion level of PMECS is intended to consider latitudinal gradients in diversity (but yet untested) and presumably the biome/bathome level was intended to consider biodiversity in relation to depth gradients. I think additional analysis is required to clearly understand these gradients on the BC coast. See Anderson et al. (2011) for a discussion of species turnover in marine systems and suggestions for beta diversity analyses along gradients.
2. One analysis worth considering is to resample a fixed number of sites without replacement, re-calculate the cluster tree, repeat numerous times and then determine the consistency of particular dendrogram branches using bootstrap probabilities or the 'alternative unbiased index'.
3. In evaluating biodiversity data sets, simple but informative histogram plots for data used in the cluster analysis would help to interpret the results. For example, number species X depth, effort X depth, and species X effort.

Additional References

Anderson MJ, Crist TO, Chase JM, Velland M, Inouye BD, Freestone AL, Sanders NJ, Cornell HV, Comita LS, Davies KF. 2011. Navigating the multiple meanings of beta diversity: a roadmap for the practicing ecologist. Ecology Letters 14:19-28.

Fargo, J.J. 2012. Dynamics of marine fish assemblages in Hecate Strait, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2996: iv + 65 p.

Gregr, E.J., Lessard, J., and Harper, J. 2013. A spatial framework for representing nearshore ecosystems. Prog. Oceanog. 115: 189-201.

Henderson, P.A., R. Seaby and R. Somes. 2011. Community level response to climate change: The long-term study of the fish and crustacean community of the Bristol Channel. J. Exp. Mar. Biol. Ecol. 400: 78-89.

Robinson, CLK. and J. Yakimishyn. 2013. The persistence and stability of fish assemblages in relation to environmental variability within eelgrass meadows (*Zostera marina*) on the Pacific coast of Canada. Canadian Journal Fisheries and Aquatic Sciences 70:775-784.

HIGH LEVEL REVIEW

Reviewer: John Roff

22 September 2015 as requested to review:

1. **Rubidge, E M.., K. Gale, J.M.R. Curtis, E. McClelland, L. Feyrer, Karin Bodtker, Carrie Robb. 2015. Methods for applying the Pacific Marine Ecological Classification System (PMECS) to Northern Shelf Bioregion. CSAP Working Paper 2014OCN02a**
2. **Greenlaw, M.E., Smith, K., Martin, R. 2015. A subtidal ecological classification system to represent species diversity and distribution patterns in the Maritimes Region. CSAP Working Paper 2014OCN02b**

Terms of reference from John Holmes:

The primary issues to consider in this paper are:

1. Are the methods and results appropriate given data availability and the intended purpose of applying the conceptual classification framework?
2. What are the uncertainties and consequences associated with data availability and classification decisions (e.g., number, boundary, type, etc.) in the application of the conceptual framework, and what guidance can be developed for future applications?
3. What types of analyses are appropriate to classify areas at spatial scales not completed as part of this application.

We have asked technical experts in each Region to review these papers to ensure that the appropriate datasets were used and the results are consistent with local expert knowledge (i.e., issue 1 above), specifically they are asked to determine:

1. Whether the appropriate regional datasets been included in the analysis and whether there other datasets that should be considered.
2. Whether the results seem consistent with expected outcomes, given their experience and expertise.

We have also solicited a review of each paper from an expert in marine ecological classifications focused on issues 2 and 3 identified above.

The two working papers represent two implementations of the same conceptual classification system, driven by data availability and other decisions. Should you agree, we hope that you can provide a high level review of the strengths and weaknesses of the marine ecological classification system tool that was developed and guidance for marine spatial planning going forward.

Of course, I do not want to limit your review so addressing the following kinds of issues will be helpful to everyone, although it is not necessary to constrain your review to these questions:

1. Is the purpose of the working paper clearly stated?
2. Are the data and methods adequate to support the conclusions?
3. Are the data and methods explained in sufficient detail to properly evaluate the conclusions?
4. If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or process?
5. Can you suggest additional areas of research that are needed to improve our assessment abilities?

JCR Report September 2015

Preliminary and general comments

These are both impressive and well written reports. The authors are to be congratulated. I am very pleased to have been asked to comment on them. I cannot promise that I have caught all useful points or relevant ideas, but I hope to contribute at the meeting itself.

Although a 'high-level' review was requested, I have interpreted this phrase rather broadly., while concentrating on the issues numbered (by me) above.

Please also note that I may well have missed some points in reading these complex reports.

1. **Are the methods and results appropriate given data availability and the intended purpose of applying the conceptual classification framework?**

Briefly – yes.

2. **What are the uncertainties and consequences associated with data availability and classification decisions (e.g., number, boundary, type, etc.) in the application of the conceptual framework, and what guidance can be developed for future applications?**

These issues have been covered well at the Biome level by the Pacific report. They are less well examined by the Maritimes report. This should be a major point of discussion at the meeting since these points are scale and purpose dependant.

3. **What types of analyses are appropriate to classify areas at spatial scales not completed as part of this application.**

To be discussed at the meeting.

4. **Whether the appropriate regional datasets been included in the analysis and whether there other datasets that should be considered.**

I leave this issue to others who know the data available better than I do, with one major exception.

The Pelagic realm is mentioned 8 times in the Maritimes report and 24 times in the Pacific report. Both reports seem to acknowledge that a separate hierarchical classifications are required for benthic and pelagic realms, and indicate that some data is already at hand for such classifications.

Is this classification for the Pelagic realm to be a separate task?

5. **Whether the results seem consistent with expected outcomes, given their experience and expertise.**

Broadly speaking –yes, results seem consistent with expectations.

6. **Is the purpose of the working paper clearly stated?**

The primary purpose of each report is planning to aid in the location, selection and designation of MPAs. However, this could be much more clearly stated, especially in the report Titles and Introductions.

Specifically, the concept of Representation (or Representativity, see below) does not seem to have been adequately defined in either of these reports.

Both reports should indicate the OVERALL planning process of designation of Networks of MPAs (i.e. the various steps and processes involved), and clearly state that the purpose of the PRESENT report is to provide the framework for mapping only of representative areas for MPA planning. Actually, given that the mandate for marine conservation is split between DFO and Environment Canada (Parks Canada), and that Parks has the mandate for Representation, I find it rather ironic that DFO is doing the representation planning. No matter – good to see the initiative!

Parks Canada's interpretation of Representation, in its NMCA program is very different from the DFO analyses presented in these two reports. Some discussion of the integration of DFO and Environment Canada mandates (Parks and CWS) is warranted at the Nanaimo meeting.

The Maritimes report does address the issue of purpose, in fact it states that spatial planning can address several issues (purposes) related to EAM (e.g. p2 and p25). However, the emphasis in the Introduction is on the spatial planning process rather than its application. Most useful in this report is the summary Table 5, that begins to show the relationships among spatial scale, extent and resolution of data, and the purposes for which they can be applied to make management decisions. The purposes (not a single purpose) of the report are therefore present but not emphasised and not well reflected in the Title of the report or the Introduction. Also, the subject of purpose is scattered throughout the report, e.g. on p15, with policy and management statements on p16.

The Pacific region report clearly states its purpose as "Hierarchical Marine Ecological Classification … for… MPA Planning and Ecological Representativity". The emphasis in this report is on development of (and comparisons among) classification systems, and data requirements for MPA Network planning. The report does not mention the broader concepts of EAM or indeed EAF, but in later sections it does indicate the various uses of spatial planning at various scales of data.

Thus although the titles of the two reports indicate that they are attempting essentially the same thing, their stated purposes are not identical, and the comments on utility of the techniques are scattered throughout the reports.

The Zonal Peer-Review (RPR) meeting therefore needs to consider whether these differences are significant, and whether or how the differences in the two reports should/ could be reconciled.

This is important, because planning for Networks of MPAs should be a multi-stage process. It involves not only the concept of habitat representation, but also Distinctive areas – EBSAs, fisheries management etc.

DFO has the lead mandate for several aspects of ocean conservation and management including: fisheries management; individual species management; EBSA planning; climate change impacts etc. These different (and sometimes competing) interests lead to different purposes, data requirements and analyses, at different levels of the ecological hierarchy. These DFO responsibilities are clearly indicated, but are somewhat lost in both reports. Table 5 of the Maritimes report clearly indicates the broader mandate here (which is not reflected in the title of that report). This is a most useful contribution, on which both reports could capitalize and emphasize, beyond the present agenda of representation. I realize that the present purpose of the reports is representation, but the utility and potential of the techniques described to the broader DFO responsibility, should be more strongly and clearly presented. This would address not just PURPOSE, but also CONTEXT of the present studies and reports (as better indicated in the Pacific report).

The broadest context is marine conservation – including sustainable fisheries exploitation and biodiversity preservation.

In terms of biodiversity preservation the main purpose here is mapping and planning for preservation of representation – primarily at the levels of habitat and communities. Other aspects of marine biodiversity (see below for definition) are NOT adequately covered (and are not part of the present mandate?).

Species richness (or species diversity – see below) is NOT adequately covered.

EBSAs are NOT adequately covered but have been addressed in other DFO surveys and meetings as a sort of Delphic process.

Ecosystem level processes are NOT addressed.

Genetic level of the hierarchy is not addressed.

7. **Are the data and methods adequate to support the conclusions?**

This can really be incorporated with the following question.

8. **Are the data and methods (adequate and) explained in sufficient detail to properly (support and) evaluate the conclusions?**

Data sources and methods in the Pacific report are generally well described, and the methods are explained in sufficient detail (e.g. p27 section on data sources is comprehensive, but the section on uses of data should be in the Introduction under Purpose; p28 careful data screening and consideration of uncertainties and errors; p36).

This is not always the case for the Maritimes report. I can provide examples if needed, and I cite some in other sections of this report. However the section of the report starting on p26 "Parallel process… is very thoughtful.

The section on Biomes in the Pacific report is a very fine example of data and methods reporting, and a good example of how to verify biological and geophysical data. This section was also very thoughtful on how to extrapolate probable biological community types from geophysical data. I hope the authors will publish this in the primary literature. I am sure that Aquatic Conservation would be pleased to take it.

In the Maritimes report a similar kind of 'sensitivity' analysis was done for factors in a Gradient Forest Analysis, but other sections on PCA analyses were not so comprehensive, and I was not convinced of the differences in their 'inductive' versus 'deductive' analyses.

In my opinion, these are the kinds of analyses that should be done for data at each level of the hierarchy - where possible. This sort of analysis removes any suggestion that the hierarchy and its supporting (deciding) factors have been arbitrarily selected. Where such analysis is not possible, explanation should be given.

Arguments for selection of the uppermost levels of the hierarchy are not easy to supply. Realms and Provinces are rationalized (NOT analyzed) in Spalding et al. (2007). As Longhurst has noted "Biogeography is generally a mess". Canada's Bioregions have also been previously rationalized.

The Scale of each level of the hierarchy has been addressed in one form or another in each report, and the relevance of each scale is best presented in Figure 5 of the Maritimes report.

The issue of 'aliasing' of data worries me. It is not mentioned in either report, but the concept may be hidden under another term I did not find. Basically, how certain can we be that biological and geophysical data correspond precisely (for calibration or extrapolation purposes) over time and spatial scales. I would like to be re-assured on this issue.

Correlations between sampled biological and geophysical variables have, of course been examined multiple times in the literature. In the UK Seamap data, correspondence is mixed (David Connor pers. comm.) almost certainly due to data aliasing and environmental heterogeneity.

Some mention needs to be made of the sampling biases of the various gear types used, and how this has been considered or treated in the data.

Also some mention of the smaller types and taxa of invertebrates (those not sampled in any of the gears or studies), and how they may be distributed.

9. **If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or process?**

The Maritimes report summarises previous advice to decision makers (p4), but otherwise does not use this term in the report. However the report does indicate the significance of spatial planning and how such classification systems can be used (e.g. p25 and Table 5). It would be highly desirable to expand on this aspect of the report, though not necessarily IN THIS report. Table 5 for example could well form the basis of recommendations in a highly useable form.

In the Pacific Region report p14 states: "this working paper aims to support the development of science advice.."

Table 13 of the PMECS report gives a series of recommendations from CSAS (DFO 2015/065) and notes how those have been addressed. However the report does not itself provide advice, although it cites DFO and other sources of advice 16 times.

So – the answer to this extended question appears to be NO.

10. **Can you suggest additional areas of research that are needed to improve our assessment abilities?**

Fish Guilds and Macro-Invertebrates

O'Boyle paper then K. Zwanenburg analyses of ground fish surveys and water masses. See next section.

Also, were the various analyses of fish communities and invertebrates conducted on presence-absence data only, or were the abundances and biomasses considered?

Areas of high Species Richness

Species richness (or species diversity) are mentioned several times in each report. However there is no data or analysis of such locations and occurrences. Surely it is important to know this. Was this not a part of the mandate for these studies?

Water Masses

I was very surprised to find no analysis of water masses in either report. There is one brief mention of water masses in the Maritimes report (p8), and one entry in the Pacific report (Table 2).

The data to calculate and spatially visualise water masses (as combinations of temperature and salinity and depth) are available for both coasts. I am not as familiar with data for the west coast, but it must historically at least be available from trawl surveys and physical oceanography surveys.

Water masses correlate VERY strongly with the distribution of fish guilds (as shown by Kees Zwanenburg, DFO Bedford – 'who owns the real-estate'?) in unpublished reports (see Roff and

Zacharias). Unpublished analyses of benthos and water masses on the Scotian Shelf (Lewin and Roff unpublished) also show clear relations to macro-benthos distributions. Such analyses (based on water masses, depth and species guild relationships) can be highly revealing, and would serve to indicate primary and secondary biotopes DIRECTLY at least for the fish community and macro benthos community (as sampled by trawl surveys), as a combination of geophysical and biological data.

Water masses also indicate the origin of plankton, including ichthyoplankton, and the propagules of benthic species. In addition, temporal variations (inter-annual and seasonal) can be calculated for several years. This also raises the point that primary and secondary biotopes may be (probably ARE) different for fish guilds and macro-invertebrates. Combining them together (as e.g. in the Pacific report) therefore likely loses information. This could be important for separate management of groundfish and invertebrate fisheries.

In the Indo-Pacific region, the Coral Triangle has the highest recorded marine species diversity (among a variety of taxa) in the world. It is fascinating to note that this is also the region of the globe that has the highest variability in water masses (V. Lynne unpublished analyses of NOAA data).

In the Maritimes at least, the inter-annual and seasonal variability of water masses, can be clearly demonstrated, and areas of high variability may correspond to elevated species richness. This would probably be seen more readily on the west coast. Such variability could be traced to oceanographic and meteorological forcing – for example in the kind of analysis carried out on relationships between fish stock recruitment patterns and variability of Gulf Stream Rings (by Ram Myers). Such analyses could lead to understanding of variability as opposed to simple description.

Biological Valuation Maps (BVMs)

The study conducted by DFO on EBSAs on the Scotian Shelf was a Delphic process not an analytic one. However the location and characteristics of EBSAs can be determined (at least in one way and in one context) by conducting an analysis and summation of all available data at all levels of the ecological hierarchy (NOT the same as the spatial planning hierarchy in the present reports). One process for doing this is given by Derous et al. (see chapter 15 in Roff and Zacharias, and attached Table 1).

Analysis of Geomorphic Features (Geosomes)

One analysis of geomorphic features would be to follow the idea of Ken Frank who correlated fish species richness and bank size on the Scotian Shelf (following the concept of Island Biogeography Theory). All geomorphic features could be examined in this way, including: banks, basins, fjords, bays etc.

EBSAs

EBSAs have barely been considered in the present reports. However, since they are by nature non-hierarchical this is understandable. Nevertheless, since EBSAs are a central part of the DFO mandate for marine conservation, I trust that they will be considered at some time, by examination of the processes that generate or support them.

Ecological Hierarchy

The Ecological Hierarchy (which is not the same as a spatial planning hierarchy) has not been considered (see Tables 1 and 2 attached). The Ecological Hierarchy spans from Genes, through Species and their Communities and Habitats to Ecosystems. Such a Table, which could be revised and improved with some thought, provides a useful checklist of whether the significant environmental factors and processes have been accounted for during the various approaches to marine conservation planning.

Spatial Analysis of Fishing Effort

This topic is not directly relevant to present considerations, however I include it here so that it will not be forgotten. At such time as further decisions are made with respect to selection of MPAs, some analysis of the 'naturalness' of locations will be required. One of the most environmentally destructive practices for the benthos, is bottom trawling. Several years ago David Kulka made an inventory of fishing tracks, and I am sure that this is constantly updated by DFO. This (combined with substrate data) will be indispensable information.

Comparisons of Benthic and Pelagic Hierarchies

Both reports clearly have the benthic realm as their prime interest, although both reports mention the pelagic realm also (e.g. p8 Maritimes, p24 Pacific). There seems to be general agreement that the benthic and pelagic realms should be treated and classified separately (I strongly agree), but the pelagic is not considered further. Is this expected to be a separate series of reports?

11. **Levels of the Hierarchy**

Comparison of Hierarchies in Maritimes and Pacific

The hierarchies proposed in both regions are quite comparable (Contained in summary in Table 2 Maritimes and Table 4 Pacific). The main differences lie between the upper levels and the level of biological facies (Level 3 in the Maritimes versus Levels 4a, 4b, and 5 in the Pacific), though even here the factors used for classifications are essentially identical.

Terminology and the whole classifications should be standardized between Maritimes and Pacific regions. There is no fundamental reason that the levels of a hierarchy should be different on the two coasts. There is also no reason to proliferate terminology.

Importantly it is necessary that inshore and offshore areas should be considered separately. Both reports acknowledge the need for this and have their separate analyses, but neither report provides a separate complete hierarchy table for the inshore areas (see Figure 7 Maritimes and references to Gregr in Pacific).

Upper levels are: REALMS (not mentioned in Maritimes report) **Level 1 Pacific**.

PROVINCES, ECOREGIONS (or Bioregions). Level 1, 2 Maritimes. Levels 2, 3 Pacific

Are equivalent in both reports. Both reports should note the correspondence (or rationalize the lack of correspondence) between the MEoW ecoregions (Spalding et al.) and Canada's Marine Bioregions.

Level 3 Maritimes PHYSIOGRAPHIC REGIONS, and Levels 4a, 4b and 5 Pacific (SUPER BIOMES, BIOMES, GEOZONES)

At this level of the hierarchy, essentially the same array of geophysical factors was examined on both coasts. The various levels of the hierarchies MAY be expected to contain somewhat different combinations of geophysical factors (which should be rationalized), but there is no reason why the hierarchies themselves, OR the names of the levels, should be different between the two coasts. In both cases, biological data were also used either to classify and/ or to verify/ calibrate geophysical/ biological relationships. In the Pacific report, it may have been useful for analysis to separate factors at the Biome and Geozone levels, however, now that this has been done, I see no reason to not combine these levels again to condense the hierarchy as per the Maritimes report. Certainly I see no reason to have two levels of biotopes.

The relative importance of the factors was well explained.

MARITIMES Level 3 FACTORS USED	PACIFIC Levels 4a, 4b, 5 FACTORS USED
Physiographic Regions	Super Biomes, Biomes, Geozones
Benthic Temperature	Temperature Range
Chlorophyll a	Not Used (?)
Salinity	Salinity
Benthic Current Stress	Tidal Velocity
Geomorphic Units	Geomorphology
Bathymetry	Depth (Bathymetry

Pacific GEOZONES again

Several points here, primarily concerning the Pacific Geozones level.

First, I would have thought that this level of the hierarchy would precede the analysis of 'Biomes' or at least be combined with that level.

Second, since depth is included as a factor in level 4 (in fact it ranks as a dominant factor), why is it being used again here in a separate level?

Third, what is the utility of Geozones? As presented, geozones appear to describe only: consistent slope, ridge, and depression. This is not a measure of Rugosity, nor have these factors or derivatives been correlated to biotic data. However, Analysis of the biota of geomorphic structures as a whole, can be very revealing with respect to overall species diversity (see above – Ken Frank study).

Levels 4 Maritimes 1o BIOTOPES / 6 & 7 Pacific 1° and 2° BIOTOPES.

Note that a Biotope is a particular COMMUNITY of organisms, associated with a DEFINED TYPE of habitat.

The Maritimes report includes Primary Biotopes only. The examples cited in Table 2 of that report (mussel beds, seagrass beds, kelp forest), are good examples of Biotopes (but see below under Biological Facies). At this level of the hierarchy, substrate characteristics are the dominant variable, but the authors note that oceanographic data is lacking for the inshore areas. However it is not clear whether the classification derived at this level applies ONLY to inshore areas, or to both inshore and offshore. Indeed is the offshore classified at this level of the hierarchy?

The Pacific report again uses substrate characteristics as the dominant variable, along with associated biota. This level relies heavily on the model of Gregr of bottom patch types. Could this model also be applied, for consistency of approach, in the Maritimes? Again it is not clear if this level of the hierarchy has ONLY been applied to inshore areas, or whether the offshore has not been considered at this level of the hierarchy. Why two levels of biotopes in the Pacific and only one in the Maritimes?

Both reports note that MPAs would be expected to be larger offshore and smaller inshore. Perhaps I missed a statement corresponding to hierarchy level?

I also note again that separate analyses of fish and invertebrates Probably at this Primary Biotope level) should be done, rather than combining them together.

Level 5 Maritimes / 8 Pacific: BIOLOGICAL FACIES. These levels are essentially equivalent in both reports. Note that this includes 'foundation' and/ or 'engineering' and/or (substrate) biogenic species. As noted in the Pacific report, data for this level is very incomplete. However it is also important to note that there is a significant degree of confusion between what constitutes a Primary Biotope and what constitutes a Biological Facies. For instance, seagrass beds and kelp forests are cited as examples at BOTH the Primary Biotope Level AND at the Biological Facies Level. This confusion needs to be addressed, but it essentially resolves into the difference between thinking of a biotope as a COMMUNITY PLUS its HABITAT, while a Facies refers ONLY to a SET of SPECIES.

Lowest levels MICROCOMMUNITIES and GENETICS will also be essentially equivalent in Maritimes and Pacific.

Offshore vs Inshore Classifications.

Both reports acknowledge that Inshore and Offshore areas warrant separate treatment. However a number of important points should be raised.

First, it is not clear from either report whether separate entire hierarchies are required, or whether the inshore areas would branch off from the offshore areas at the biome, geozone or physiographic level, or even at the bioregion level, then develop their own short hierarchy at the biotope level, and then re-connect with the offshore from the biological facies to the genetic levels.

Second, the Maritimes report separates the inshore at the 110m isobath (WHY?), while the Pacific separates the inshore habitats at the 50m isobaths WHY?). This difference needs to be reconciled. Functionally the coastal zone might be defined as the limit of fringing communities (euphotic zone depth), or pragmatically as the shoreward limit of commercial trawling operations.

Third: In the Maritimes, coastal physiographic units were created using a combination of substrate characteristics (exactly how the data is derived is not clear) and oceanographic data (again, source not clear). In the Pacific region, inshore areas were separated according to: depth, substrate type and tidal energy following Gregr et al. (2013).

It seems to me that a common system should and could be developed, OR if it cannot be we should have an explanation as to WHY coastal regions and their habitats are differently structured on the east and west coasts of Canada. Reasons might include the greater variability of temperature on the east coast, greater range of salinity on the west coast, presence of fjords on the west coast etc. However none of these factors that I have suggested feature in either classification.

12. **Further comments and questions**

Non-hierarchical systems of classification

I completely agree that systems such as those popular in Europe (e.g. EUNIS and Natura 2000 Marine Habitat types) are generally not workable in the Maritimes. Not only is the relevant kind of data generally not available, but in addition, these systems confuse levels of the hierarchy from the geomorphic level to species (i.e. levels 3, 4 and 7 at least).

I found no reference to EUNIS or NATURA systems in the Pacific Region report. Although, at least in the inshore regions such a system could potentially be developed in BC, I do not think this is worth pursuing because of the issue of confusion among levels of a hierarchy in the EUNIS and NATURA systems.

Global classification systems

There are four important global systems of marine ecological classification:

Longhurst 'Marine Ecological Geography' – which deals exclusively with the upper pelagic zone and is not applicable for present purposes.

Sherman et al. – a series of volumes on Large Marine Ecosystems – again not applicable to present requirements.

Spalding et al. The MEoW system (Marine Ecoregions of the World), which IS relevant. Both reports should note the correspondence (or rationalize the lack of correspondence) between the MEoW ecoregions and Canada's Marine Bioregions.

The IUCN GOODS report for classification of the High Seas and Deep Ocean is not yet applicable or sufficiently developed.

13. **Terminology**

Without wanting to sound pedantic ….

Bathomes

I looked up this term but the closest I could find was BAT HOMES. Bathymetric zones?

Biodiversity

This term is used repeatedly in both reports (24 times in the Pacific, and 38 times in the Maritimes), but not always in its proper sense.

Biodiversity has now come to mean all life forms on the planet, and the environmental structures ecosystems and habitats) that support them. This is sometimes the sense in which it is used in these reports, but frequently it is used as synonymous with species richness or species diversity. Both reports ONLY deal with habitats (and/or species/ communities and their surrogates), NOT with the broader issue of biodiversity as a whole (see Table 1). Authors should examine their use of this term carefully; it is a more inclusive term than covered by their use.

The analyses presented in these reports are one component of what could be produced as important BVMs (biological valuation maps), that would encompass ALL known components of marine biodiversity on both coasts. Such BVMs can then be used for a variety of management purposes e.g., as indicated in Table 5 of the Maritime report.

Biome

This term has a specific ecological meaning and is not used appropriately in the Pacific report (it is used once in the Maritimes report in reference to the Pacific report).

Biomes are spatially defines regions of the globe (at Ecosystem level) of similar climate and edaphic (i.e. geophysical) factors that support ecologically and functionally similar sets of species and communities at all trophic levels, in comparable habitats. BUT: Biomes are NOT taxonomically defined, and they are non-hierarchical (like ecosystems).

The best marine example of biomes is given by Longhurst in his book 'Ecological Geography of the Sea'.

As used in the Pacific report, biomes ARE taxonomically defined, and do NOT have comparable geophysical features.

If the Pacific region insists on the use of this term, then it should be used to compare ecological units between the Pacific and the Maritimes. In fact, this would be its proper use. Such units would be defined by e.g.: salinity, temperature ranges, depth intervals, productivity regimes, and the presence of similar taxonomic assemblages (communities) performing equivalent ecological functions.

Representativity or Representation (?)

Working definition of this term/ terms, as applied to marine conservation (which seem to be missing from the reports where they are used frequently and apparently interchangeably), is needed.

Rugosity

Bottom topography (as rugosity) is a major factor in the distribution of species diversity (as a function of habitat diversity See Buzeta-Innes reports).

It is not mentioned at all in the Maritimes report.

Rugosity is mentioned 14 times as a factor in the Pacific report, but with no apparent rationale for the interest in it.

However, given the interest by DFO in EBSAs or distinctive areas, this is a major omission. There have been separate meetings by DFO to consider the location of EBSAs (at least in the Atlantic region as Delphic opinion surveys).

Species Diversity (Richness)

This term is used 15 times in The Maritime report where species richness is actually meant (species richness is mentioned once).

Both terms are used once or twice in the Pacific report (and its Appendix) - usage here given the benefit of the doubt!

In the Maritime report, the title says “species diversity”; however, the subject of the report is predominantly species community types, their distributions and representation (or representativity).

The Pacific report (and Appendix) both mention areas of high species diversity and what they could be related to (areas where ‘biomes’ intersect – i.e. ecoclines).

NEITHER report adequately addresses the issue of species diversity (or species richness) and what it may be related to (ecoclines, habitat heterogeneity, rugosity etc.). It may be that this should be considered as a separate planning issue: if so, this should be explicitly stated in each report.

What are these EBSAs related to geophysically (oceanographically, topographically, habitat heterogeneity, gyral systems etc.)?

14. **PMEC Appendices**

I have not spent much time on these appendices, except to note the very nice statistical analysis of the BC Govt. Ecosection data. Others may want to comment further on the dropping of this category.

One question: were the data always treated as presence/ absence or as numerical or biomass data? This can make a good deal of difference for some analyses.

Additional References

Roff, J., Zacharias, M., and Day, J. 2011. Marine conservation ecology. Earthscan, London, U.K. xx + 439 p.

Spalding, M.D., Fox, H.E., Allen, G.R., Davidson, N., Ferdaña, Z.A., Finlayson, M.A.X., Halpern, B.S., Jorge, M.A., Lombana, A., Lourie, S.A., Martin, K.D., McManus, E., Molnar, J., Recchia, C.A., and Robertson, J. 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. Biosci. 57: 573-583.

Table E 1. The components of Biodiversity in the Marine Environment. Note that a Seascape level could also be included

GENETIC LEVEL		**SPECIES POPULATION LEVEL**		**COMMUNITY LEVEL**		**ECOSYSTEM LEVEL**	
STRUCTURE	**PROCESS**	**STRUCTURE**	**PROCESS**	**STRUCTURE**	**PROCESS**	**STRUCTURE**	**PROCESS**
Structure	Mutation	Structure	Migration	Structure	Succession	Watermass	Currents
Genotypes	Differentiat.	Abundance	Dispersion	S.Diversity	Predation	Temp	Tides
Fitness	Drift	Distribut	Retention	S. Richness	Competit.	Salinity	Disturban.
Haplotype D	Flow	Focal Spp	Mig/ Drift	S. Evenness	Parasitism	Properties	Gyres
Stocks	Nat. Select	Keystone	Growth	Abundance	Mutualism	Boundaries	Retention
	Inbreeding	*Ind. Cond.*	Reprod.	Represent.	Disease	Depth/Pres	P-B couple
	Mating	*Ind. Comp.*	Recruit	Distinctive	Production	Light	Entrain.
	Dir. Select	*Umbrella*		Biomes	Decomp.	Stratificat.	B-G cycles
	Stab. select	Charismat.		Biocoenos.		Topograph	Seasonal.
	Dis. select	Vulnerable		S-A relns.		Substrate	Product.
	Micro. Evol.	Economic		Transitions		Represent.	H-A equil.
	Erosion	Phenotypes		Fun.groups		Distinctive	H-L equil.
	Speciation	Fragments		Heterog.		Anomalies	Turbulence
	Macro. Evol	Meta-pops		Endemism		Exposure	Mixing
				Alt. S.Stats		Patchiness	Upwelling
				Symbioses		Nutrients	Divergence
				Biomass		Dis. Gases	Ecol.Integ.
						Anoxia	Erosion
							Dessication
Expanded from Zacharias & Roff (2000).							

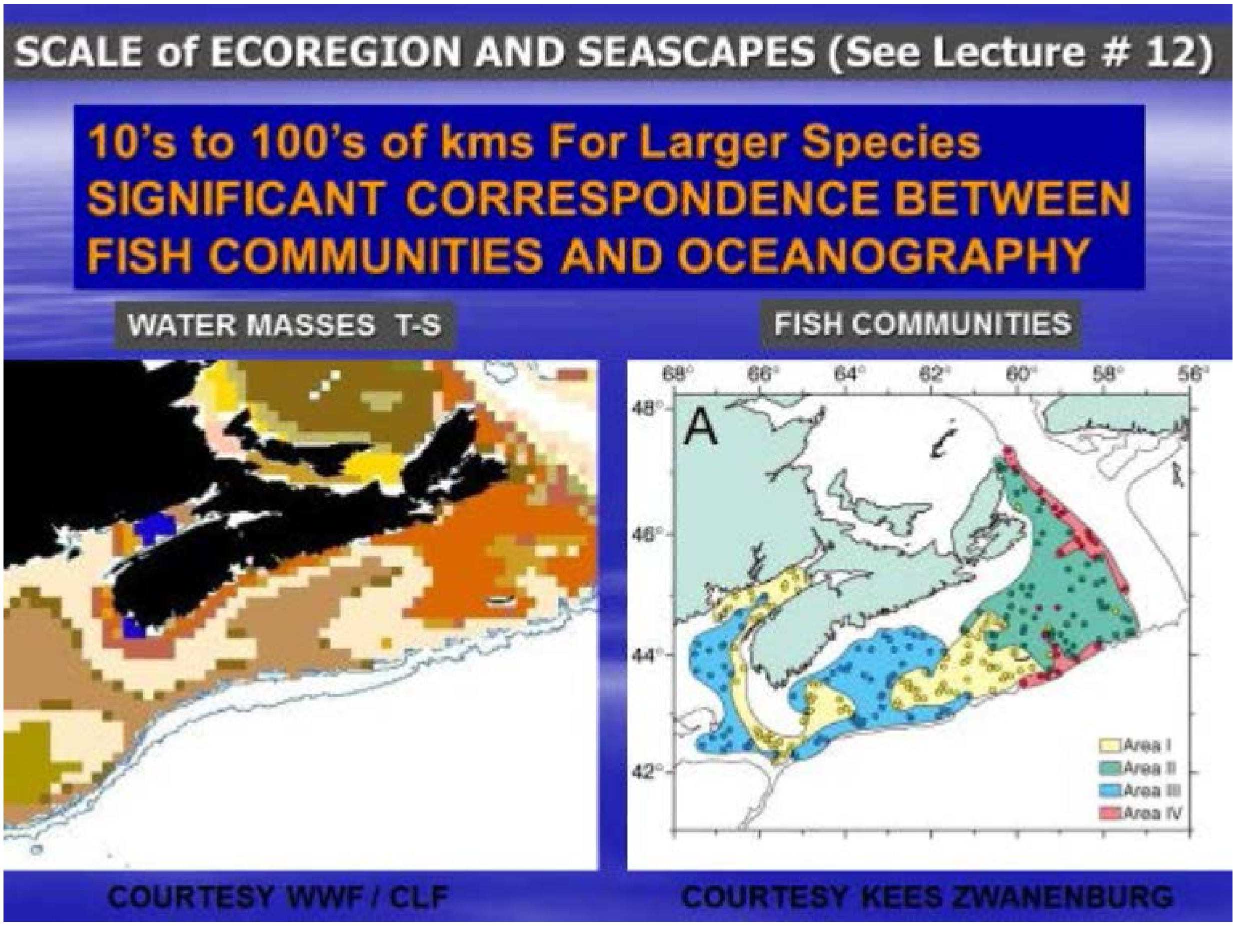

Figure E 1. Spatial Relationships between Water Masses and Demersal Fish Guilds.

APPENDIX F: CROSSWALK OF MECS IN MARITIMES AND PACIFIC WORKING PAPERS

Table F 1. Crosswalk of conceptual and operational marine ecological classifications and recommended harmonized marine ecological classification developed during the meeting.

Conceptual MECS Framework (DFO 2013)					Pacific Operational MECS			Maritimes Operational MECS			Recommended Harmonized MECS		
Level	**Unit**	**Spatial extent**	**Spatial resolution**	**Benthic description**	Level	Unit	Benthic Description	Level	Unit	Benthic Description	Level	Unit	Benthic Description
0	Realm	10,000's km	1,000 km^2	Broad-scale geographic units such as the north Pacific Ocean.	0	Realm	Broad-scale geographic units such as the north Pacific Ocean.	0	Realm	Broad-scale geographic units such as the north Pacific Ocean.	1	Realm	Broad-scale geographic units such as the north Pacific Ocean.
1	Province	1,000's km	~100 km^2	Broad-scale geological units such as continental blocks, basins and abyssal plains.	1	Province	Broad-scale geological units such as continental blocks, basins and abyssal plains.	1	Province	Broad-scale geological units such as continental blocks, basins and abyssal plains.	2	Province	Broad-scale geological units such as continental blocks, basins and abyssal plains.
2	Bioregions	1,000's km	~10-100 km^2	Distinctive, recurring and small-scale physical oceanographic processes (e.g., separation between California Current and Alaska Current regions). Four major bioregions in Pacific marine waters. Research and analysis is required to understand how marine species diversity differs among these Bioregions.	2	Bioregions	Distinctive, recurring and small-scale physical oceanographic processes (e.g., separation between California Current and Alaska Current regions). Research and analysis is required to understand how marine species diversity differs among these Bioregions.	2	Bioregions	Distinctive, recurring and small-scale physical oceanographic processes (e.g., separation between California Current and Alaska Current regions). Research and analysis is required to understand how marine species diversity differs among these Bioregions.	3	Bioregions	Distinctive, recurring and small-scale physical oceanographic processes (e.g., separation between California Current and Alaska Current regions). Research and analysis is required to understand how marine species diversity differs among these Bioregions.
3	Ecosections	100's-1,000's km	~10-100 km^2	Ecosections are primarily related to abiotic pelagic oceanographic processes; relation to benthic ecosystems requires further research.	3	Ecosections	NOT USED – probably more value for pelagic ecosystems.		Oceano-graphic Domains	Unique biotic composition driven by oceanographic process that physically and physiologically affect fauna	4	Bio-physical	Distinct physiographic and oceanographic conditions/processes, including bathymetry, related to biotic composition if data are available or evidence in the literature.
4	Bathomes	100's-	~10 km^2	Nearshore and littoral	4a	Super-Biome	Units characterized	3	Physiographic				

Conceptual MECS Framework (DFO 2013)					Pacific Operational MECS			Maritimes Operational MECS			Recommended Harmonized MECS		
Level	**Unit**	**Spatial extent**	**Spatial resolution**	**Benthic description**	Level	Unit	Benthic Description	Level	Unit	Benthic Description	Level	Unit	Benthic Description
		1,000's km		zone, continental shelf, continental slope, abyssal plain.			primarily on bathymetric distribution of biota		Regions				
					4b	Biome	Level 4a further divided into biomes based on hierarchical clustering of biological assemblages		Bathomes	Unique biotic distribution driven primarily by bathymetry			
5	Geozones	100s km	1-10 km^2	Mappable areas with similar seabed geomorphology and usually with distinct biota (e.g., seamounts, canyons, rocky banks, inlets).	5	Geozones	based primarily on geomorphology and defined by abiotic characteristics; Unique geomorphological structures assumed to have distinctive biological assemblages		Geomorphic Units	Unique geomorphological structures assumed to have distinctive biological assemblages	5	Geomorphic	Discrete geomorphological structures assumed to have distinctive biological assemblages; Individually defined by shape, size and topographic variation. May span other levels of hierarchy. *** Recommend nomenclature consistent with Hab Codes (Gary Green) for naming structures.
6	Primary biotopes	10's-100's km	<1km^2	Nested within Geomorphic Units are soft, hard or mixed substrate-based units, together with their associated substrate-based units and their associated biological communities.	6	Primary biotopes	Spatial elements combining both the concept of physical and biological communities. Based on key biogeophysical processes such as sediment mobility, availability of infaunal habitat, retention of biotic resources, and the availability of surfaces for microbial activity and filter	4	1^o habitats/ biotopes (Seascapes)	Substrate - Unique categories of physical substrate Biology - Associated biological components Oceanographic Units - Unique biotic composition driven by oceanographic process that physically and physiologically	6	Biotopes (Habitats and Communities)	Discrete taxonomic assemblages characterized by associated substrate and environmental factors. ***Requires in-situ sampling

Conceptual MECS Framework (DFO 2013)					Pacific Operational MECS			Maritimes Operational MECS			Recommended Harmonized MECS		
Level	**Unit**	**Spatial extent**	**Spatial resolution**	**Benthic description**	Level	Unit	Benthic Description	Level	Unit	Benthic Description	Level	Unit	Benthic Description
							feeders.			affect fauna			
7	Secondary biotopes	100's-1000's m	100's m^2	Smaller-scale abiotic and biotic sub structural units characterized by specific types of substrate (e.g., seapen beds, sponge reefs).	7	Secondary biotopes	Nested within primary biotopes are smaller-scale, abiotic and/ or biotic sub-structural units of the seafloor						
8	Biological facies	100's m	<10 m^2	Fundamental unit for management of biodiversity. Mappable units that act as surrogates for all levels below. (e.g., species of seagrass, group of hard corals or sponges).	8	Biological facies	Mappable units characterized by groups of species. Identifiable by one or more indicator species that act as surrogates for the broader biological assemblage to which they belong	5	Biological facies	Characterized by groups of particular species	7	Biological Facies	Groups of biogenic or foundation species identified by one or more indicator species. BFs are patchy and nested within biotopes. Most examples are biogenic habitats, e.g., glass sponge reefs, cold-water corals, eelgrass beds, kelp forest. ***Overlap in concept between biotopes and biological facies.
9	Micro-communities	10's m	< 1 m^2	Assemblages of species that depend on member species of the Biological Facies, e.g., holdfast communities in giant kelp.	9	Micro-communities	Small scale assemblages of often highly specialized species that depend on member species of biological facies	6	Micro-communities	Small-scale assemblages of often highly specialized species	8	Micro-assemblage	Distinct assemblages of often highly specialized species. For example, tide pool assemblages. ***Will be associated with biotope but may not or may not be associated with a biological facies
								7	Species	Species-level taxa, operational taxonomic units, and evolutionary significant units	9	Species	Operational taxonomic units
								8	Populations	Sub-species, phenotypes, and	10	Populations	Spatially structured subgroups of a species;

Conceptual MECS Framework (DFO 2013)					Pacific Operational MECS			Maritimes Operational MECS			Recommended Harmonized MECS		
Level	**Unit**	**Spatial extent**	**Spatial resolution**	**Benthic description**	Level	Unit	Benthic Description	Level	Unit	Benthic Description	Level	Unit	Benthic Description
										monospecific assemblages of geographic and extralimital isolates			includes phenotypes, evolutionary significant units, CUs
								9	Genes	Alleles and DNA sequences	11	Genes	Alleles and DNA sequences

APPENDIX G: SUGGESTED DATA SCALES FOR DFO DECISION-MAKING

Table G 1. Suggested data scales for DFO decision-making. The management issues shown here are not an exhaustive list of marine spatial planning needs. Specific objectives related to decision making will determine necessary spatial level. Dark grey indicates that spatial information at a particular level is expected to be used in decision making and light grey indicates that there is less certainty among meeting participants in the use of spatial information for decision-making. White indicates that a level is not expected to be used in decision-making.

	Level	Unit	Spatial Extent	Spatial Resolution	MPA Network Planning	Representation Criterion – MPA Network Design	Environmental Assessment for Project Siting[1]	Delineating Critical Habitat (SARA)	Ecological Restoration	Species Management	Marine Spill Response	Cumulative Effects for Planning
ECOSYSTEM-BASED	1	Realm	10,000s km	1,000s km^2	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
	2	Province	1,000's km	~100 km^2	High certainty will be used	High certainty will be used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
	3	Bioregion	1,000's km	~10-100 km^2	High certainty will be used	High certainty will be used	Not Used	High certainty will be used	Not Used	Not Used	Not Used	Not Used
	4	Biophysical	100s-1,000s km	~10-100 km^2	High certainty will be used	High certainty will be used	Not Used	High certainty will be used	Not Used	Not Used	Lower certainty will be used	Lower certainty will be used
	5	Geomorphic	100s km	1-10 km^2	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	Not Used	Not Used	High certainty will be used	Lower certainty will be used
	6	Biotope	100s m-100s km	<1 km^2	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	Lower certainty will be used
	7	Biological Facies	10s – 100s m	<100 m^2	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	Lower certainty will be used
	8	Micro-assemblage	10s m	< 1 m^2	High certainty will be used	Not Used	Lower certainty will be used	High certainty will be used	High certainty will be used	Not Used	High certainty will be used	Lower certainty will be used
SPECIES-BASED	9	Species	-	-	High certainty will be used	Not Used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	Lower certainty will be used
	10	Populations	-	-	High certainty will be used	Not Used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	High certainty will be used	Lower certainty will be used
	11	Genes	-	-	High certainty will be used	Not Used	Not Used	Lower certainty will be used	Lower certainty will be used	High certainty will be used	Lower certainty will be used	Not Used

[1] Environmental Assessments for Project Siting includes, but areas not limited to, aquaculture sites, liquid natural gas terminals, log dumps and other facilities for which Fisheries Protection Program review or approval may be required.

APPENDIX H: WORKING PAPER REVISIONS

Both Working Papers

Clearly state that the papers related to benthic systems only

Increase prominence of context perspective - clearly describe overall objective - purpose of the current effort and future applications- highlight that this is a first and essential step which allows to get started with network planning (or similar), then provide clear indication of what next.

Consider using a more general term (Marine spatial planning versus MPA planning)

Define hierarchy (notes in table – sublevels, potential overlap , hybrid... make clear in text, that they do not have to be perfectly nested)

Geomorphic units have not been correlated with biological structure for this region (P or P and Mar??), however links are shown to exist in other regions of the world ocean. Provide info/refs in the WP.

Include consistent level hierarchy and nomenclature

Make sure terminology is consistent – include glossary (see below)

Write a paragraph on the methods to be used under given data availability. => add evaluation confirming the validity of the abiotic process (PMECS)

PMECS Paper

Clarify variable selection for cluster analysis

Clearly summarize reasoning for dendrogram cutting: predictability goes down, survey patterns become more visible, makes ecological sense, sensible with respect to objective.

Add note on sensitivity study supporting no split between fish and invertebrates

Evaluate oceanographic conditions for reasonable stability for the time period of the data set.

Look at oceanographic evaluation of interannual/decadal variability see if this was a reasonable averaging time period for data used, cite references (Info from website – ENSO-PDO, Crawford references.

Add (??) TS diagrams and/or recommend TS diagram analyses for pelagic and possibly future benthic inclusion.

Spatial autocorrelation ? Clarify in text that spatial AC is kind of inherent to the procedure used (back up with refs)

Recommend that future work should include testing a few methods on a restricted/smaller region (method used is appropriate – yes, are there others, but it is not needed to change the method for this WP.)

At some spatial scale we actually need to define ecologically meaningful groups, add sentence in SAR and short paragraph in PMECS WP.

Language: talk about environmental drivers as being correlated to bio not driving bio, since we do not talk about processes

For L6/7 population /bottom-patch model recommendation include statement that no other option known to date and that the application needs to be tested and approved.

MMECS Paper

Needs major revisions with respect to text and structure – need to clarify procedure (see Harper review) – include uncertainty section.

Perform correlation-sensitivity test to assure taking SST out of the equation is valid. - review by oceanographic reviewers.

Separate layers and show figures with separated units

Methods for substrate model are insufficiently published/reviewed and can only be included as recommendation for L6&7 , include statement that no other option known to date and that the application needs to be tested and approved.

Some Suggested Glossary Entries for Both Working Papers:

- representativity
- species distribution
- species richness
- biodiversity
- biotope
- habitat
- hierarchy
- morphology
- topography
- rugosity