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Pacific Region

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Science Advisory Report 2014/026

PILOT APPLICATION OF AN ECOLOGICAL RISK ASSESSMENT FRAMEWORK TO INFORM ECOSYSTEM-BASED MANAGEMENT IN THE PACIFIC NORTH COAST INTEGRATED MANAGEMENT AREA

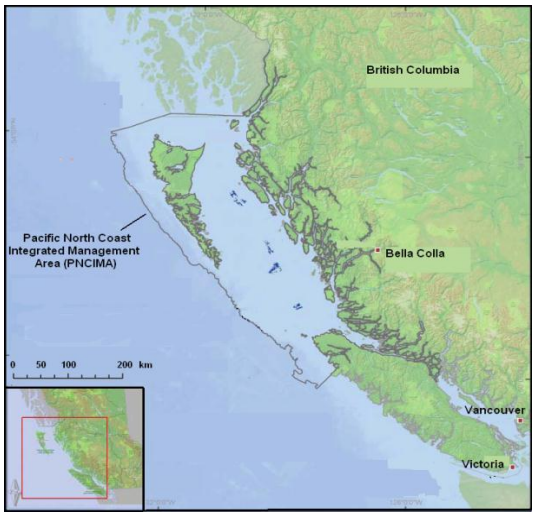

Figure 1. DFO's Pacific North Coast Integrated Management Area (PNCIMA) spatial boundaries. Map taken from PNCIMA Initiative (2011).

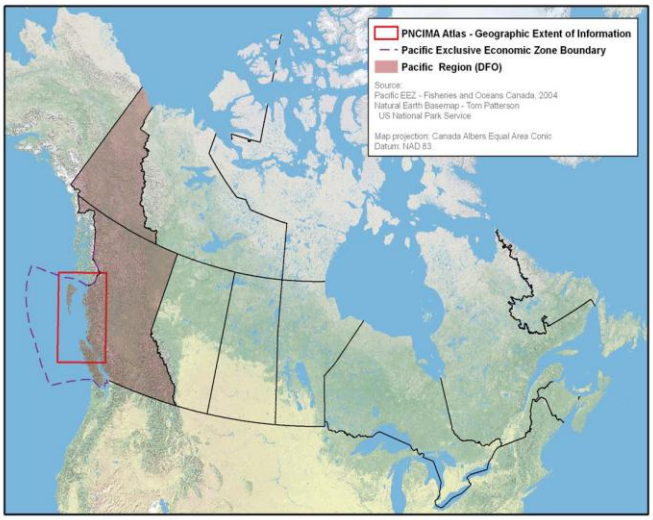

Figure 2. Geographic location of the Pacific North Coast Integrated Management Area (red box) relative to the Canadian Exclusive Economic Zone (dashed line) and DFO Pacific Region (brown area).

Context

Canada's Oceans Act and Oceans Strategy commit Fisheries and Oceans Canada (DFO) to leading the development and implementation of a sustainable, precautionary and integrated ecosystem approach to oceans management. An Ecological Risk Assessment Framework (ERAF) was developed and reviewed at a Canadian Science Advisory Secretariat-Pacific (CSAP) Regional Peer Review (RPR) meeting in May 2012 (DFO 2012), representing an important step toward meeting these commitments. This risk-based framework provides managers with a process and tools to inform the development of conservation objectives, management strategies, and action plans for the implementation of DFO's ecosystem-based integrated oceans management in large ocean management areas (LOMAs), such as the Pacific North Coast Integrated Management Area (PNCIMA), and Pacific Region Marine Protected Areas (MPAs).

During the May 2012 RPR meeting it was recommended that a pilot project to test the ERAF prototype and a performance review of the ERAF ranking of risk to significant ecosystems components (SECs) that result from human activities and stressors before broader implementation is contemplated. The present document summarizes discussion and guidance on key modifications to the ERAF prototype that were made during a pilot application of the Level 1 risk assessment in PNCIMA. The results of this pilot application are intended to further the development of the ERAF as a tool for identifying and assessing the relative risk of harm to SECs. The relative risk scores estimated in this test are not intended to be used for further management action or to inform decision-making around PNCIMA conservation objectives or priorities.

SUMMARY

- A pilot application of the ecological risk assessment framework (ERAF) methodology (DFO 2012) was reviewed at an RPR meeting in June 2013. The pilot test was conducted with a subset of significant ecosystem components (SECs) and activities/stressors in the Pacific North Coast Integrated Management Area (PNCIMA) to evaluate operational modifications to the Level 1 ERAF methodology and to assess the performance of the ERAF in providing a relative ranking of SECs (formerly called valued ecosystems components, VECs) and activities/stressors. The SEC terminology is recommended because it is a better descriptor of the components addressed by the ERAF and is consistent with international usage. The results of this pilot application further the development of the ERAF as a tool for identifying, and assessing the relative risk of harm to SECs from human activities and their associated stressors.
- The relative risk rankings and raw scores estimated in this pilot application are not intended to be used for further management action or to inform decision-making around PNCIMA conservation objectives or priorities since the results are based on scores from a small group of experts working on a subset of activities, stressors, and SECs chosen for the test based on perceived data availability.
- A Level 1 risk assessment is a triage method/approach best suited to assessing relative risk at large ocean management area (LOMA) spatial scales, where the list of potential SECs and activities/stressors is large and broad-scale data availability may be limited.
- The semi-quantitative Level 2 risk assessment is best suited to local or regional scales within PNCIMA, or on specific SECs of interest. The data requirements (quantity and quality) are much higher in a Level 2 assessment than for a Level 1 assessment.
- The operational modifications to the ERAF methodology reviewed at this RPR are suitable for conducting Level 1 risk assessment in the PNCIMA.
- Two methods of estimating risk to SECs were tested in the pilot: Binned Exposure and Uncertainty Propagation. Incorporating uncertainty directly into the risk calculation (Uncertainty Propagation) is the recommended approach to estimating relative risk for a Level 1 risk assessment.
- Peer-reviewed pathways of effects (POE) models should be used to identify SEC-stressor interactions and impacts in a Level 1 assessment when they are available. However, the absence of peer-reviewed POEs should not stall the process; rather the strength-of-evidence tables used in the pilot application are a suitable substitute until a peer-reviewed POE for a specific activity is available. Developing a library of activity-based POE models in collaboration with other agencies is recommended to facilitate future applications of the ERAF.
- The exposure term in the risk estimate was scored for the activity and the stressor it produces and thus a common value was applied across all SECs that interact with the given stressor. This approach to scoring the exposure term is appropriate for Level 1 risk assessments applied at a PNCIMA spatial scale, but Level 1 risk assessments applied to smaller scales should consider an individual SEC scoring approach to increase the accuracy of results.
- Individually scoring uncertainty for each subcomponent in the exposure and consequence terms of the risk equation and the implementation of a method to account for a lack of

consensus in the scientific literature are important modifications in the pilot application that address uncertainty in biological data inputs. It is recommended that a Comments section be added to the scoring table to record information about the factors driving uncertainty, especially for subcomponents that are data deficient or lack scientific consensus concerning impacts since these variables are given a high uncertainty score.

- The ERAF allows for assumptions to be clearly stated and raw data scores available in tables for inspection. Individually scoring each subcomponent in the risk equation was designed to provide information to the user as to the main driver(s) of risk to a SEC.
- Scoring guides are clear and explicit. However, ERAF performance would be improved with input from subject-matter experts (including scientists from DFO, other agencies and non-governmental organizations, and stakeholders who can provide local knowledge) to the scoring process, either directly in conducting the scoring or indirectly in reviewing the assigned scores. More experience is needed in the application of the ERAF to enhance its repeatability, since the pilot application was conducted by a small group of experts.
- The Level 1 risk assessment performed well in identifying relative risk to SECs in that it can distinguish SECs with high and low risk profiles, and it provides considerable information on the drivers of risk.
- The selection of SECs is critically important to providing useable output from the ERAF. The absence of a suitable list hampered the pilot application of the ERAF in PNCIMA. Finalized lists of SECs and existing activities/stressors will be needed to support the full implementation of a Level 1 risk assessment in PNCIMA.

INTRODUCTION

Canada's Oceans Act and Oceans Strategy commit Fisheries and Oceans Canada (DFO) to leading the development and implementation of a sustainable, precautionary and integrated ecosystem approach to oceans management. The development of a risk-based framework to identify and prioritize management issues for Large Ocean Management Areas (LOMAs) and Marine Protected Areas (MPAs) represents an important step toward meeting these commitments.

An Ecological Risk Assessment Framework (ERAF) was developed by a team of DFO Oceans and Science staff in Pacific Region (O et al. unpublished manuscript)[1] and reviewed at a Canadian Science Advisory Secretariat-Pacific (CSAP) Regional Peer Review (RPR) meeting in May 2012 (DFO 2012). The ERAF is a framework for assessing single and cumulative risks to significant ecosystem components (SECs), and for ranking the significance of activities and stressors based on the relative risks to SECs. The aim of developing this risk-based framework is to provide managers with a process and tools to inform the development of conservation objectives, management strategies, and action plans for the implementation of DFO's ecosystem-based integrated oceans management in large ocean management areas (LOMAs) such as the Pacific North Coast Integrated Management Area (PNCIMA) and Pacific Region Marine Protected Areas (MPAs).

Carrying out an ecological risk assessment for PNCIMA and the suite of monitoring indicators that will ultimately be derived from this information are critical components of ecosystem-based

[1] O, M., Martone, R., Hannah, L., Grieg, L., Boutillier, J., and Patton, S., in press [2014]. An Ecological Risk Assessment Framework (ERAF) for Ecosystem-Based Oceans Management in the Pacific Region. Draft Research Document.

management. The results of an ecological risk assessment will provide managers with the ability to make informed decisions based on an understanding of the links between ecosystem health and human activity. A review of the outcomes of the risk assessment will ensure that future management decisions appropriately consider ecosystem components, resulting in effective conservation of biodiversity while supporting economic prosperity.

The May 2012 RPR meeting reviewed the ERAF methodology (O et al. unpublished manuscript)[2] and recommended a pilot project to test and develop operational modifications to the ERAF prototype and a performance review of the ERAF through a future RPR meeting (DFO 2012). The present report summarizes discussion and guidance from DFO Pacific Region Science on key modifications to the ERAF prototype methodology that were made in a pilot application of the Level 1 risk assessment using a subset of 17 SECs, and associated activities and stressors in the PNCIMA and the performance of the ERAF with respect to ranking SECs and/or activities and stressors included in the pilot application. The results of this pilot application are intended to further the development of the ERAF as a tool for identifying and assessing the relative risk of harm to SECs from human activities and their associated stressors. The risk scores and relative rankings estimated in this test cannot and were not intended to be used for further management action or to inform decision-making around PNCIMA conservation objectives or priorities because they are based on results from a small group of experts working on a subset of activities, stressors, and SECs chosen for testing based on perceived data availability.

ANALYSIS

The Ecological Risk Assessment Framework has two phases: Scoping and Risk Assessment. Scoping and the Level 1 Qualitative Risk Assessment were completed for the current pilot application to PNCIMA. It is emphasized that the Level 1 assessment estimates relative risk to SECs and that comparing cumulative risk estimates between SECs is not appropriate.

Scoping

Identification of Activity/Stressors and SECs

A subset of activities and stressors were evaluated in the current pilot project. An activity was not considered if it was not currently occurring within PNCIMA, or if spatial information was unavailable. In order to identify stressors associated with each activity, the framework calls for Pathway of Effects (POE) models to be employed. Relevant POEs were under development and unavailable at the time of the pilot project and, therefore, the description of associated stressors from MacConnachie et al. (2007) was used and weight of evidence tables produced. A subset of these stressors was included in the pilot project.

The second stage in the Scoping phase of the ERAF is the identification of SECs. The PNCIMA ecosystem is composed of a large number of SECs, therefore the pilot application is based on a selected subset of the potential SECs in PNCIMA. Thirteen SEC subcategories were selected from candidate lists of SECs identified by Lucas et al (2007) and Clarke and Jamieson (2006) and 17 example species were chosen from each of these subcategories based on data availability to test the ecological risk assessment framework.

[2] O, M., Martone, R., Hannah, L., Grieg, L., Boutillier, J., and Patton, S., in press [2014]. An Ecological Risk Assessment Framework (ERAF) for Ecosystem-Based Oceans Management in the Pacific Region. Draft Research Document.

Level 1 Qualitative risk assessment

SEC-Stressor Matrix

The first step in the Level 1 risk assessment is to identify the activities and stressors that interact with each SEC. The potential interaction between the pilot SECs and stressors was evaluated using an expert judgment exercise. These relationships were then used to define which activities' stressors were subsequently assessed for their risk to each of the 17 SECs.

The Research Document accompanying this report (Clarke Murray et al. unpublished manuscript)[3] comprehensively reviews and describes the risk variables and calculations used to estimate relative risk in the pilot Level 1 risk assessment. The Research Document provides a complete description of the variables, risk equations, and scoring guidelines. Here we describe the important modifications to the prototype methodology that were tested in the PNCIMA pilot project.

Qualitative Risk Variables

Risk is a product of the SEC's exposure to a stressor and the consequence of that exposure to the SEC. Each activity may produce multiple stressors and, as a result, risk is estimated for exposure to each stressor independently.

Risk to SECs from stressors was assessed using two methods in the PNCIMA pilot project. Method 1 uses the Binned Exposure approach developed by O et al. (unpublished manuscript)[4]. The *Exposure* score is binned (by dividing by 6) to equate it to the *Consequence* score (which had a maximum score of 6). The goal of this approach is to give equal weight to both the exposure and consequence components of the risk score. Uncertainty related to data or lack of knowledge is not directly incorporated into the risk score estimated by the binned method, but it is recorded in the scoring table.

Method 2 incorporates uncertainty into the risk score by random sampling within a normal distribution, with the mean of the distribution corresponding to the variable score and the shape of the distribution (standard deviation) defined by the assigned uncertainty score. Each distribution was bounded by the minimum and maximum scores for the risk variable and the score of each risk variable was then randomly sampled 100 times. A final risk score array of 100 values is generated and the mean and 10% and 90% quantiles are reported. Method 2 differs from Method 1 in that it propagates uncertainty into the risk estimate, the *Exposure* component scores of the risk calculation were not binned, and the *Consequence* score is squared to ensure that both terms are given equal weight in the risk score calculation.

Scoring Exposure and Consequence

Regardless of the method used to estimate risk, qualitative scoring of the risk variables used the same methodology defined by O et al.[5]. *Exposure* is the product of three variables: *Temporal Scale (TS)*, *Spatial Scale (SS),* and *Load (L)* of a stressor on a SEC*.* Each variable is assigned an uncertainty score.

[3] Clarke Murray, C., Mach, M.E., and O, M. 2013. Pilot ecosystem risk assessment to assess cumulative risk to species in the Pacific North Coast Integrated Management Area (PNCIMA). Draft Research Document.
[4] O, M., Martone, R., Hannah, L., Grieg, L., Boutillier, J., and Patton, S., in press [2014]. An Ecological Risk Assessment Framework (ERAF) for Ecosystem-Based Oceans Management in the Pacific Region. Draft Research Document.
[5] *Ibid.*

1. Temporal Scale (TS) refers to the frequency of the event, rather than its duration. Consideration is given to how often the stressor occurs, rather than how long the effect is felt by the SEC.
2. Spatial Scale (SS) is the scale or spatial extent of the impact from the stressor.
3. Load (L) is a measure of the amount or strength of a stressor (e.g., quantity or concentration of a pollutant or harmful species, rate of change for climate change) and its persistence through time across the entire study area (in this case, PNCIMA).

The ERAF prototype (O et al. unpublished manuscript)[6] scores each *Exposure* variable individually for each SEC-stressor relationship. In contrast, the scoring of *Exposure* variables in the PNCIMA pilot project was specific to the activity and the stressor it produces and thus common across all SECs that interact with the given stressor. For example, *Exposure* for sedimentation from trawling was scored and this score was used for birds, marine mammals, and other SECs that interact with this stressor because in practice, *Exposure* scores were assigned based on the characteristics of the stressor itself.

Consequence is the impact of the stressor on the individual SEC and was scored for each SEC-stressor combination. *Consequence* is scored from 1 to 6 and is an indicator of the impact of a stressor on an individual SEC, ranging from negligible to intolerable. *Consequence* scoring is based on the subcomponent (population size, geographic range, behaviour, etc.) but most commonly *Consequence* is scored on the population size or geographic range subcomponent Uncertainty was also included for the *Consequence* score. In contrast to *Exposure* scoring, *Consequence* is scored specifically in relation to the stressor's risk to the particular SEC, *i.e*., *Consequence* varies according to the SEC.

Scoring Uncertainty

An uncertainty score is assigned to each risk variable analyzed during scoring; one uncertainty score for each of *Temporal, Spatial, Intensity* and *Consequence*. These uncertainty scores are based on five categories outlined in Therriault and Herborg (2008) and Therriault et al. (2011). In addition, an important modification applied during this pilot application of the ERAF is to capture uncertainty associated with a lack of scientific consensus about the ecological impact of a stressor. The uncertainty score is increased by one when there was no consensus about impact (i.e., no consensus = higher uncertainty).

Calculation of Risk Method 1: Binned Exposure

In accordance with the framework developed by O et al.(unpublished manuscript)[7] *Exposure* is calculated as the product of *Temporal Scale, Spatial Scale* and *Intensity. Exposure* is then binned by finding the integer of 1+(*I***TS***SS*)/6. Total risk for each SEC-stressor relationship is calculated as the product of *Exposure and Consequence*. Cumulative risk to each SEC was calculated by adding the total risk scores from each SEC-stressor relationship.

Calculation of Risk Method 2: Uncertainty Propagation

An "uncertainty propagation" exercise was completed to incorporate the uncertainty of the qualitative risk scoring in the final and cumulative risk scores. Each risk variable score (*Temporal Scale, Spatial Scale, Intensity* and *Consequence*) is assigned as the mean of a normal distribution with standard deviation set according to the level of uncertainty assigned as

[6] O, M., Martone, R., Hannah, L., Grieg, L., Boutillier, J., and Patton, S., in press [2014]. An Ecological Risk Assessment Framework (ERAF) for Ecosystem-Based Oceans Management in the Pacific Region. Draft Research Document.
[7] *Ibid.*

described in O. et al (unpublished manuscript)[8]. The score of each risk variable is then randomly sampled from this distribution 100 times using Monte Carlo simulation. The final risk score for each SEC-stressor relationship was a product of the four risk variable arrays ($Risk = SS \times TS \times I \times C^2$), where the first score generated from each variable array is multiplied across all four risk variables, followed by the second, and others for all 100 replicates, resulting in a final risk array of 100 scores. Cumulative risk to each SEC was calculated by adding the total risk score produced for each SEC-stressor relationship, where the first score generated from the first SEC-stressor relationship is added to the first score from the second SEC-stressor relationship, and so on for all SEC-stressor relationships. This procedure is repeated for up to 100 scores for that SEC producing a final array of 100 cumulative risk scores. The results are reported as the mean and the 10^{th} and 90^{th} quantiles of the final array of cumulative risk scores.

Sources of Uncertainty

Cumulative risk from multiple stressors on a SEC is estimated based on the assumption that adding risk from each stressor individually is a reasonable first approximation of cumulative risk. However, interactions among multiple stressors could also produce synergistic, compensatory or masking effects. Since existing knowledge concerning the effects of these different interactions is limited, they were not addressed in the pilot application of the ERAF. Alternative methods to estimate cumulative risk should be explored (e.g., non-additive approaches).

The risk estimated in this pilot application represents only direct risks to SECs. Indirect risks associated with ecological interactions were not considered in the pilot application, although the ERAF has the capacity to capture these kinds of risks.

The consequence of not having peer-reviewed POEs available for a Level 1 risk assessment is a high potential for the mis-characterization of the risk profile to a SEC since low risk stressors that are important to cumulative risk may be missed.

Spatial overlap is not considered when assessing the exposure term in the risk estimation procedure of a Level 1 risk assessment.

CONCLUSIONS AND ADVICE

The operational modifications to the ERAF methodology reviewed at this RPR are suitable for conducting Level 1 risk assessment in PNCIMA.

Incorporating uncertainty directly into the risk calculation is the recommended approach to estimating risk for a Level 1 risk assessment.

A Level 1 risk assessment is a triage method/approach best suited to assessing relative risk at LOMA spatial scales (e.g., PNCIMA), where the list of potential SECs and activities/stressors is large and broad-scale data availability may be limited.

The semi-quantitative Level 2 risk assessment is best suited to local or regional scales within PNCIMA or to specific SECs of interest. The data requirements (quantity and quality) are much higher in a Level 2 assessment than for a Level 1 assessment.

[8] O, M., Martone, R., Hannah, L., Grieg, L., Boutillier, J., and Patton, S., in press [2014]. An Ecological Risk Assessment Framework (ERAF) for Ecosystem-Based Oceans Management in the Pacific Region. Draft Research Document.

Recommendations

The development of a library of activity-based POE models in collaboration with other agencies is recommended to facilitate future applications of the ERAF.

The development of complete lists of SECs and existing activities/stressors is recommended to support the full implementation of a Level 1 risk assessment in PNCIMA. The lack of finalized lists was problematic for the pilot application of the ERAF.

It is recommended that the term significant ecological components (SECs) be used rather than valued ecosystem components (VECs) because the SEC terminology is a better descriptor of the components addressed by this ERAF and it is consistent with international usage.

It is recommended that alternative approaches to estimating cumulative risk be explored (e.g., non-additive methods).

It is recommended that a Comments section be added to the scoring table to record information about the factors driving uncertainty, especially for *Exposure* and *Consequence* subcomponents that are data deficient or lack consensus in scientific literature as these categories are given a high uncertainty score.

OTHER CONSIDERATIONS

This pilot application of the ERAF is a science process focusing on ecological SECs and is part of a broader iterative process in DFO's ecosystem-based integrated Oceans management. This broader process will bring together science-based SECs along with social and economic dimensions to derive objectives, strategies and actions for PNCIMA. However, there are other ways to identify SECs that include socio-economic dimensions at the outset, including The Open Standards (Conservation Gateway), the British Columbia Conservation Data Centre (CDC) stress assessment, and the Natural Capital Project's Integrated Valuation of Environmental Services and Tradeoffs (InVEST) tool.

SOURCES OF INFORMATION

This Science Advisory Report is from the June 25-27, 2013 Regional Peer Review on the Pilot Application of an Ecological Risk Assessment Framework to Inform Ecosystem-based Management in the Pacific North Coast Integrated Management Area. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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