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HABITAT AND SALMON SUBCOMMITTEE MEETING

SUMMARY

Four working papers were reviewed by the Pacific Scientific Advice Review Committee's (PSARC) Habitat and Salmon Subcommittees on April 6-7, 2004 at The Grand Hotel in Nanaimo, BC. Topics covered by these papers included results of the Pink Salmon Action Plan Marine Monitoring Program (MMP) in the Broughton Archipelago in 2003, an evaluation of candidate marine protected area site selection methodologies, and a proposed Central Coast Integrated Management (CCIM) boundary.

The two MMP papers assessed 1) distribution and relative abundance of juvenile pink and chum salmon (and other marine fish species) and 2) prevalence and infection rates of sea lice on juvenile salmon in the Broughton area. The analysis indicated that juvenile pink and chum salmon were spatially distributed throughout the Broughton area in the 2003 sampling period. No significant adverse effects of sea lice on juvenile salmon growth and condition factor were observed for the period studied. Sampling was terminated, however, about the time the intensity of the sea lice motile stages were increasing. The subcommittee agreed that the base-line juvenile salmon distribution data collected in 2003 will be useful in providing the foundation for more deductive-type studies in the future. Future studies should be designed to identify potential sea lice sources/reservoirs and factors affecting sea lice prevalence and infection rates including fish density and physical and chemical oceanographic steady-state variables.

The paper entitled "Evaluation of site selection methodologies for use in marine protected area network design" identified and compared different methodologies used for the selection of candidate marine protected areas (Areas of Interest). The report also referred to two case-specific applications of these algorithms currently being used in Canada. These projects, by Living Oceans Society and World Wildlife Fund Canada, were highlighted with regard to their potential applicability to future DFO studies.

The final paper presented "A science-based Boundary for the Central Coast Integrated Management Area" as a proposed modification to the current Central Coast 'working boundary'. The boundary modifications proposed in this document represent a relatively new approach to boundary definition based on a more comprehensive consideration of scientific and ecosystem information. The boundary is intended to define the Large Ocean Management Area (LOMA) for BC's Central Coast as a pilot area for integrated management. The main criteria used to define the proposed modifications of the boundary were physical environment (e.g. habitat, bathymetry, substrate, oceanography) and biological information.

SOMMAIRE

INTRODUCTION

The PSARC Habitat and Salmon Subcommittee met April 6-7, 2004 at The Grand Hotel in Nanaimo, British Columbia. The Habitat Subcommittee Chair, B. Antcliffe, opened the meeting by welcoming the participants. During the introductory remarks the objectives of the meeting were reviewed, along with the protocol to be observed by external participants and observers. The Subcommittee accepted the meeting agenda.

The Subcommittees reviewed four Working Papers. Summaries of each are in Appendix 1. The meeting agenda appears as Appendix 2. A list of meeting participants, observers and reviewers is included as Appendix 3.

DETAILED COMMENTS FROM THE REVIEW

H2004-01: Sea lice on juvenile salmon and on some non-salmonid species caught in the Broughton Archipelago in 2003.

Simon Jones and Amanda Nemec.

H2004-02: Abundance and distribution of juvenile salmon and other fish caught in the Broughton Archipelago, Knight Inlet and Muchalat Inlet, B.C. in 2003.

Brent Hargreaves, Doug Herriott and Vic Palermo

<u>Subcommittee Discussion</u> (H2004-01 and H2004-02)

The Subcommittee (SC) agreed that the objectives of the two working papers as described in the PSARC working paper requests were largely met. Although some reviewers commented on the lack of a specific study design for hypothesis testing that linked captive fish in farms, wild fish and sea lice, the authors noted that the study objectives were not designed to examine cause and effect relationships among sea lice infection rates and fish farm site location or farm management practices. The SC agreed with the reviewers, however, that the design was not appropriate to address this relationship, or allow interpretation beyond the descriptive analysis of the data as presented in the working papers. The authors commented that additional analyses are ongoing to further explore the data collected in 2003.

The SC also acknowledged that the 2003 Marine Monitoring Program (MMP) was an important first step in gathering important base-line information and data on distribution of juvenile pink and chum salmon and current state of sea lice infection rates in the Broughton Archipelago. This information would form the basis of the experimental design of future sampling where hypothesis can be established and tested.

The SC discussed the potential sources of sea lice infection, including captive farmed salmon, wild adult and juvenile salmon as well as non-salmon species, and agreed that there are potentially multiple sources of sea lice. It has been hypothesized that the captive farmed salmon could act as reservoirs in addition to natural sources. A senior author (H2004-01) commented that non-salmon species such as smelt and herring could be a source of infection for *Caligus* species, but not for L. *salmonis*.

The principal focus of the study was on juvenile pink and chum salmon, thus some of the reviewers queried why so much of the analytical effort was devoted to sticklebacks. They also noted that herring and smelt were more abundant than pink and chum salmon or sticklebacks, based on survey catch data, and they represent species that could be important sources for some species of sea lice, compared to sticklebacks. Most SC members agreed that the data for non-salmonid species were a valuable contribution to the report. The SC agreed with a reviewer that the sampling information from Muchalet and Esperanza inlets contributed little to the assessment of juvenile sea lice and juvenile salmon in the Broughton Area.

Part of the rationale for the study, as identified in the Request-for-Working Papers, was to determine if there was a significant main migration corridor for juvenile salmon migrating through the Broughton area during the sampling period, as hypothesized in 2002. The MMP study was not definitive with respect to the null hypothesis that the bulk of juvenile salmon from the Broughton Archipelago and Knight Inlet do not migrate seaward via the hypothesized "migratory channel". Reviewers suggested further analysis of fish size variation, spatial and temporal fish distribution and oceanographic variables be carried out to enhance the interpretation of the migration corridor hypothesis. The authors noted that they had carried out such analyses, but the findings were inconclusive. The senior author (H2004-02) suggested that a mark-recapture experiment was the only direct way to confirm the existence of a migration corridor.

Although the methods used to collect the samples are well established sampling techniques, one reviewer recommended that the authors provide information on whether the techniques that they used for copepod collection may have led to underestimates of some species of sea lice such as *Caligus clemensi*.

Statistical and sampling design was debated. Some participants cautioned that the authors may be unable to separate the effects of salinity, weight and fish size from the effects of fish farms in any future data analysis as these are co-variables and thus not independent (i.e., salinity increases as fish move to and beyond fish farm sites). Although it was noted that other software (e.g. SatScan) may be useful for analyzing spatial and temporal dynamics of louse infections, participants cautioned that all sources of infection, including captive farm salmon and natural sources and factors, would need to be assessed. There was a suggestion that researchers may need to find a reference area elsewhere on the Central Coast to study these natural factors in non-farmed waters. Additional analyses of the new data obtained by the authors in 2003 from Muchalat Inlet, prior to the installation of the first fish farm in August, may prove to be valuable in this regard. It was also suggested that the authors should conduct a more detailed statistical analysis using non-averaged data to assess within-zone effects of factors influencing sea lice prevalence.

It was the view of one external expert that louse nauplii are planktonic for up to seven days prior to molting to the infectious copepodid stage. This expert further concluded that any study trying to identify the source of lice in the Broughton or elsewhere must be cognizant of the fact that nauplii distribution is dependant on tidal and other current patterns for their dispersal. Any future studies attempting to link cause and effect should take this complex relationship into consideration.

Although it was stated in the paper that "the study was not designed to answer questions relating to the origins of parasitic copepods on wild juveniles", one reviewer and some SC members acknowledged that the authors should make greater efforts to compare their data to that collected in other sea lice studies in the Broughton area. This reviewer stated that the sea lice numbers reported in the 2003 MMP were generally lower and the proportions of sea lice species present were reportedly different than the results of an independent research sampling in 2002 in this area. It was suggested that the differences among years may indicate that there is large annual variability in the species of sea lice present and their numbers. As mentioned by the authors and reviewers, further research on the oceanography of the area, the abundance of wild hosts and the variability in sea lice populations among years may be valuable.

An invited expert stated that the most striking difference between the findings of this study and other studies on sea lice infestations on *Salmo* species was that fish growth and condition seemed little (if any) affected by sea lice. This expert indicated that other studies show significant differences in *Salmo* growth and condition factor responses to lice infestation. The results further emphasize the need for caution in comparing studies on sea lice on different salmonid species and from different geographic areas.

The SC deliberated over making a conclusion with respect to impact of sea lice on juvenile salmon based on these two papers. Although the analysis suggested that in 2003 there was no observed impact (i.e., differences between infected and uninfected juvenile salmon) based on the variables examined (condition factor or fish size) in the available samples, the authors emphasized the work is on-going. The authors cautioned against making a definitive conclusion regarding sources of sea lice because the study did not examine all factors that affect sea lice infection, including information from the fish farms in the Broughton area with respect to numbers of farmed fish, stocking densities, farmed salmon sea lice loads (species, number and developmental stages), chemical treatments on the farms to reduce lice levels, and other natural factors and sources affecting sea lice prevalence and infection rates.

There was considerable discussion on the need for continued studies. All were in agreement that the 2003 MMP provided a single-year of sampling and that multi-year sampling over a variety of conditions, including salmon abundance which was low in 2003, was required to understand the causal factors that produce inter-annual variability. The reviewers also suggested that it should be possible to reduce future monitoring efforts to fewer sites and the capture of smaller numbers of fish, and to move the research into the deductive phase, i.e. hypothesis testing. No specific direction on future sampling could be provided without a better description of the short and longer term objectives of the research.

It was agreed that the two papers should be published as stand-alone papers, however, they should be part of a series and cross-referenced in the title with the H2004-02 as Part I and H2004-01 as Part 2.

The SC discussed further analysis and additional information for expansion of the discussion during each paper's revision. One author stated that H2004-02 was purposely written for the public given the general interest in the issue. There was consensus among participants that the papers should have a technical focus. It was suggested that the revisions should consider the following points:

1. Locations of salmon bearing streams on maps and, where possible, links to salmon escapement data, linked to salmon abundance;
2. Oceanographic data (e.g., currents, salinity and temperature, river discharge, timing of runoff, winter precipitation);
3. Additional discussion on the life cycle of sea lice and aging of parasites allow for the tracing of infection source;
4. More detailed temporal and spatial analysis of the data including differences among zones and variation among catches in sets within zones;
5. Focus on CPUE rather than total catch as a measure of relative abundance;
6. More detailed analysis of spatial and temporal patterns in the fish size data;
7. Comparison of results with other published studies, the inclusion of the analysis/figures that were provided in the presentation; and
8. The inclusion of the analysis/figures that were provided in the presentation of H2004-01.

Subcommittee Conclusions (H2004-01 and H2004-02)

1. Both papers were accepted subject to revisions.

2. No significant adverse effects of sea lice on juvenile salmon growth and condition factor were observed for the period studied, though collections terminated about the time the intensity of the sea lice motile stages were increasing.

3. The base-line data collected in the 2003 MMP will be most useful in providing the foundation for more deductive-type studies in the future.

Subcommittee Recommendations (H2004-01 and H2004-02)

1. Further research is required to confirm or reject the observations in 2003 that showed little impact of sea lice on juvenile salmon.

2. If the impact of sea lice on juvenile salmon is found in future studies to be significant to adult recruitment, then source(s) of sea lice and factors affecting sea lice prevalence and infection rates, including fish density and physical and chemical oceanographic steady-state variables, should be determined.

3. The study design for future studies requires both careful consideration of key questions and hypotheses formulation, and where necessary, the use of controlled experiments.

H2004-03: Evaluation of site selection methodologies for use in marine protected area network design

S.M.J. Evans, G.S. Jamieson, J. Ardron, M. Patterson and S. Jessen

Subcommittee Discussion

SC members expressed concerned that first reviewer's comments should not be considered because of a personal involvement with the development of the MARXAN model. This reviewer also raised comments that were not directly related to the purpose or were outside the scope of the paper. The second review was deemed a very satisfactory review on its own by all SC members, and thus the SC used only the second reviewer's comments.

Most SC members were supportive of the working paper and concluded that it was a good comparison of methodologies. They noted that any of the models reviewed could be used by DFO to bring stakeholders together to discuss and assess candidate MPA site selection. It was noted that the selected model could also be used to address not only ENGO concerns, but those of industrial stakeholders such as aquaculture, fisheries, etc. DFO is currently working with other federal partners, which provides a forum where the utility of these models can be further discussed. One SC member noted that Parks Canada is in the process of evaluating MARXAN for site-selection in the proposed NMCA in the Strait of Georgia. To address management needs, authors were urged to include a few words in the WP on the existing DFO MPA establishment process, and where and how the chosen model would be used.

The authors were encouraged to give due consideration to the following two key points made by the reviewer: that a retrospective analysis be carried out to compare the outputs of the techniques; and connectivity, a most important criteria in planning a network of MPAs, be considered and addressed to the extent possible. Connectivity is indirectly determined by proximity and other factors; functional connectivity algorithms do not presently exist. These tools are step towards attaining what we ultimately want, which is a network with connectivity relationships also optimised.

It was agreed that “network” should be removed from the title as the paper does not deal fully with the connectivity issue.

Key terms, including connectivity, network, and other terms, will be defined in the glossary along with a flow diagram. An appendix with a flowchart describing the methodologies is also recommended, and the paper needs to be simplified.

Reviewers and SC members indicated that the shortcomings of MARXAN, their preferred model, should be better enunciated in the paper. These include: lack of transparency as to why or when (during the selection process) a given site or place is selected because this technique is attempting to evaluate the ‘set of sites’ rather than individual sites; 2) uncertainty and variability in results associated with the removal or locking in of any given site; 3) area (or currency) goals that must be pre-established; and 4) MARXAN and its predecessors are very flexible, with the potential for numerous user inputs that can create markedly different selection results. This flexibility and the lack of fixed methods of using this tool may create variation in outputs.

The “user-friendliness” of the authors recommended method – MARXAN – was discussed. The authors stated that MARXAN is indeed “user friendly” and that specialists would not have to be hired to run it. The challenge is in the formatting of the input data. For example, World Map had a good front piece which included a map. The author stated that a couple of the models tested were not easy to use.

The reviewer stated that this paper only generically reviewed the techniques and did not review the programs with respect to DFO’s needs. However, the authors clarified that this was not the intent of the paper, and that there were a series of different DFO considerations identified, including spatial constraints, development of a systematic and transparent system, and the incorporation of socio-economic and environmental data consistent with IM. The need for a role by the public in MPA determinations was noted, including the desirability of public consultation and stakeholder buy-in.

One SC member inquired whether MARXAN, with all the variables and assumptions involved, leaves too much to chance. The authors suggested that if one defines the goals and objectives of the exercise well, then the "chance" element is much reduced. There was discussion as to whether MARXAN was a "probabilistic" model or a "stochastic" model, and the authors pointed out that because it uses randomly chosen information in each run, it is stochastic, but because it is run hundreds of times in any analysis, it also produced a probabilistic distribution. It was also pointed out that the weighting function does to some degree dictate results, which on one hand is desirable as there is a need to weight options with project values in mind but on the other hand makes the final result somewhat subjective.

The SC discussed how a sensitivity analysis might be conducted. The Living Oceans Society has used the model in BC waters, and had also verified some outputs and has done some sensitivity analysis. In operation, the model produces a "report card" that allows one to determine how well its output is meeting defined objectives. Model tuning is carried out via weighting factors. The authors agreed to add more information on verification and sensitivity analysis considerations.

Concerns regarding data values and weightings were also discussed, and it was agreed it is appropriate to set values and explore the implications of different value and weighting options. Weightings can be assessed and adjusted after the model is run based on the output score sheet produced by MARXAN.

The value in using optimisation models to explore different goals and objectives of different agencies was discussed. Defining DFO management needs and objectives will be critical to the evaluation and selection of a methodology, and the evaluation framework in the report allows for this process to occur.

The context of conservation planning processes within DFO need to be addressed and where the methodologies discussed here fit in should be elaborated on. The Department is moving forward in the direction of multi-agency collaboration for marine planning and establishing MPA in conjunction with Parks Canada, Environment Canada and others. The Canada BC MPA strategy is also an important context for this paper. Parks Canada is looking at using MARXAN as part of its Southern Strait of Georgia study. MARXAN was selected base on a review of the literature. It was noted by the SC that a multi-agency approach has a better chance of success overall in functional MPA network establishment, and planning at multiple scales (e.g., LOMA, Coastal Management) is desirable.

Subcommittee Conclusions

1. The paper was accepted subject to revisions.

2. A better understanding of ecological processes would help determine baseline data requirements, which are key to the success of any site-selection methodology.

3. Data needs and weightings need to be established in a multi-agency forum.

4. MARXAN can accommodate multiple data sets from various agencies and stakeholders.

Subcommittee Recommendations

1. MARXAN is an appropriate and available decision support tool for MPA site-selection.

2. DFO and partners should conduct a case study to evaluate the utility of this method for BC situations that incorporate multiple values from different stakeholders.

3. The output of MARXAN must be analyzed to determine whether the goals of DFO and other stakeholders are being achieved.

H2004-04: A Science-based Boundary for the Central Coast Integrated Management Area

Duncan Johannessen, D. Haggarty and J. Pringle

Subcommittee Discussion

Oceans Managers and the SC were satisfied that the revised paper meets the objectives of the working paper request and management needs. The revised document incorporates and defines scientific criteria used to consider changes to the existing CCIM working boundaries. There were no external reviews of this paper as it was reviewed externally at a previous PSARC meeting, where it was declared a work-in-progress.

The relation with the CCIM and Pacific North Coast Integrated Management Area (PNCIMA) area was discussed, with PNCIMA being a larger management area for management of issues such as offshore oil and gas, aquaculture, and turning point First Nations consultation. However, this paper provides valuable information relative to the existing CCIM boundaries and it proposes a new management boundary that is aligned with scientific criteria.

There was discussion about the ecological rationale for setting of the Brooks Peninsula boundary. Water currents were considerations, along with oceanographic conditions, as the northern waters are more oceanographically similar to and they are influenced by the Alaska currents. Fisheries information was specific to the northern boundary, as groundfish data relative to substrate type were available. Other data indicate that the Brooks peninsula area is a dividing line between southern and northern fish species. Biological communities (e.g., plankton communities) also indicated a difference between the southern and northern boundary, and ecologically important features such as Scott Islands were are not separated by using Brooks Peninsula.

The continental slope was put with the shelf rather than abyssal plain because the gullies which are characteristics of Queen Charlotte sound make it difficult to define the top of the slope. Also ground fish come off the shelf onto the slope but not onto the abyssal plain. The biological slope is also quite a biologically active area, and the biology is more closely related to that on the shelf, rather than the abyss. However, it was also noted that the abysal plain is very diverse from a meiofauna perspective

It was noted by one SC member that killer whales are divided between northern and southern resident killer whales and the borders they use is the proposed inland waters line but on the west coast, it would be further south of Brooks Peninsula. Different species thus have different spatial distributions, making oceanographic data better criteria for boundary definition then species spatial distributions.

The SC agreed that there were northern boundary options around the mainland islands, including taking into account the freshwater influence of the Skeena River (i.e., the freshwater-saltwater interface). The science is uncertain in this area and hence the revised paper will suggest possible variations on this northern boundary around the coastal mainland islands.

Discussion could be expanded to include some recent literature on large ocean management areas to put initiatives in BC in a broader perspective. It was also suggested that the criteria used for setting of the proposed new boundaries will be outlined in table format.

It was pointed out that the CCIM/offshore boundary, the Johnstone Strain boundary and the Brooks Peninsula boundary were also ecoregion boundaries identified at the recent DFO Ecoregion Working Group national meeting.

The author concluded that the proposed boundary changes be considered in the final development of a Central Coast Large Ocean Management Area (LOMA) boundary along with management, economic and social factors.

Subcommittee Conclusions

1. The paper was accepted subject to revisions

Subcommittee Recommendations

1. The boundaries identified provide an ecological rationale that might be used for establishing boundaries relevant to a LOMA for central and northern BC waters.

APPENDIX 1: Working Paper Summaries

H2004-01: Sea lice on juvenile salmon and on some non-salmonid species caught in the Broughton Archipelago in 2003

Simon Jones and Amanda Nemec

Copepods of the family *Caligidae (*Siphonostomatoidea: Copepoda) are parasitic on the skin, fins, gills and buccal cavity of marine fishes. In British Columbia (BC) coastal waters these niches have been exploited by 11 species belonging to the genus *Lepeophtheirus* and one species of *Caligus*. There is little historic data on sea lice infection rates of juvenile salmonids in the Broughton Archipelago. In addition, prior to 2001, juvenile pink and chum salmon in the Broughton Archipelago had received virtually no scientific attention. Annual variations in the number and condition of out-migrating smolts from specific streams had been relatively poorly documented and their migratory routes through this region were speculative. The present study was an effort to systematically survey juvenile *Oncorhynchus* spp. for caligid copepods throughout their nearshore marine migratory phase following seawater entry. The overall objective of the study was to describe patterns of spatial and temporal variations in the prevalence and intensity (or abundance) of sea lice infections on juvenile pink and chum salmon in a limited area of coastal BC: the Broughton Archipelago and Knight Inlet. For the purpose of this study, it was hypothesized that the prevalence and intensity (or abundance) of infections on salmonid and non-salmonid fishes would be uniformly distributed temporally and spatially throughout the study.

Approximately 25% of juvenile pink and chum salmon were infected with two species of sea lice: *Lepeophtheirus salmonis* and *Caligus clemensi*. On both salmon species most infections consisted of a single chalimus stage and most of these were *C. clemensi.* The prevalence of motile *L. salmonis* increased towards the end of the study and was coincident with a decline in the proportion of *L. salmonis* chalimus stages. Prevalence of sea lice infections on juvenile salmon varied significantly in time and space was this variation was significantly associated with sea water salinity and temperature and with size of salmon. There was no evidence that infection with sea lice adversely affected size or condition factor of juvenile pink and chum salmon during the time that was monitored. *Caligus clemensi* and an unidentified *Lepeophtheirus* sp. were found on approximately 60% of sticklebacks. *Lepeophtheirus hospitalis* and *C. clemensi* were also found on herring.

The paper made three major recommendations: 1, to initiate and coordinate field and laboratory studies to better understand the impact of sea lice and other infectious diseases on wild juvenile salmon; 2, to establish mechanisms for sharing relevant disease information between industry and DFO for example by initiating collaborative research programs to better understand local factors influencing prevalence, distribution and sources of sea lice infections on juvenile salmon and 3, to initiate studies to improve knowledge of the morphological characteristics of the chalimus stages of *Lepeophtheirus* species.

H2004-02: Abundance and distribution of juvenile salmon and other fish caught in the Broughton Archipelago, Knight Inlet and Muchalat Inlet, B.C. in 2003.

Brent Hargreaves, Doug Herriott and Vic Palermo

During 2001 and 2002 intense public concern was raised about the infection of wild juvenile pink salmon by parasitic sea lice in the Broughton Archipelago area of the B.C. coast, and the possibility that commercial salmon aquaculture farms might be the source of these sea lice. In February 2003 the Minister of Fisheries and Oceans Canada announced DFO's Pink Salmon Action Plan (the "Action Plan") that focused on the Broughton Archipelago. This Action Plan had several components, including a marine monitoring program (MMP). The main objective of this MMP was to obtain samples of wild juvenile pink salmon (*Oncorhynchus gorbuscha)* from marine areas throughout the Broughton, to assess the incidence and severity of infection by sea lice by location and time. A secondary objective was to regularly monitor the abundance of wild juvenile pink salmon at many locations during the early sea life period, to obtain additional information about the migration routes of juvenile pink salmon in the Broughton. A third objective, subsequently added in March 2003, was to conduct a separate marine sampling program to assess the prevalence and intensity of infection by sea lice on wild juvenile salmon in Muchalat Inlet. It was anticipated that these two marine sampling programs would allow baseline assessment of sea lice infection of wild juvenile salmon in areas both with (Broughton) and without (Muchalat Inlet) commercial salmon farms, and before and after the first salmon farms were installed in a new area (Muchalat Inlet).

This PSARC Working Paper describes the results for the field sampling portion of the 2003 MMP in the Broughton area and Muchalat Inlet, including the fish catch, abundance and size information. The results from the analyses of sea lice infections of these fish are documented in a separate PSARC Working Paper (Jones and Nemec 2004).

The 2003 MMP was very ambitious. The PSAP was announced by DFO on February 20, 2003 and by March 2 fish sampling began in the Broughton. The program utilized two main DFO vessels (Walker Rock and Clupea), four smaller DFO skiffs, and contracted three commercial salmon seine vessels and their crews. More than 43 people directly participated in the field sampling, including 15 volunteer DFO staff, 19 First Nations people and 4 additional commercial fishermen hired under contract. Four additional biologists were provided by the B.C. Province and one person was also provided by the salmon aquaculture industry (Stolt and Heritage Aquaculture Ltd. and Stolt Sea Farms).

In the Broughton Archipelago and Knight Inlet fish samples were collected 5 days each week, for 15 weeks. A total of 1472 sets were made with purse seines and beach seines, and more than 1.1 million fish (all species) were captured. A total of 105,00 juvenile pink salmon, 89,000 juvenile chum salmon, and 82,522 three-spined stickleback were captured. This PSARC report focuses on the results for juvenile pink and chum salmon, but also includes results for stickleback because this species was observed in the field to be heavily infected with sea lice.

In Muchalat Inlet a total of 206 beach seine sets were completed from March 26 to June 11, 2003. A total of 38,465 fish (all species) were captured, including 19,587 juvenile chum salmon and 1 juvenile pink salmon. An additional 4 beach seine sets were also done on one day (June 4) in Esperanza Inlet, to obtain some fish samples from an area with active fish farms that was closest to Muchalat Inlet. A total of 39 fish were caught, including 11 juvenile chinook and 12 juvenile chum salmon. To minimize costs, no purse seining was done in either Muchalat Inlet or Esperanza Inlet.

This PSARC paper provides extensive analyses of the catches, abundances (CPUE), and size of juvenile pink and chum salmon, and stickleback, for the Broughton and Knight Inlet. In general, juvenile pink and chum were caught throughout the Broughton and Knight Inlet in all time periods, and frequently these two species were found together. The abundances of pink and chum remained low throughout the study area during March, then gradually increased during April. The peak abundances of both pink and chum salmon occurred in Knight Inlet in mid-to-late April, about two to three weeks earlier than in the Broughton. The average size of both pink and chum remained low (30 – 40mm fork length range) during March, then increased steadily to 70-80 mm by mid-June. Stickleback were caught throughout the study area but there were no clear patterns in either stickleback abundances or sizes.

This PSARC paper also provides some new information on migration routes and timing of juvenile pink and chum salmon in the Broughton and Knight Inlet. The primary question was the “main migration corridor” for juvenile pink salmon that was proposed in 2002 by an independent biologist (Alexandra Morton). In 2003 the B.C. Province required that all commercial salmon farms along this route be fallowed (cease production) to protect juvenile pink and chum salmon. The results from the

2003 MMP show that juvenile pink and chum salmon were widely distributed throughout the Broughton and Knight Inlet, and do not provide confirmation or even strong support for the existence of a “main migration corridor” in the Broughton. However, these results represent only one year and the conclusion may be different in other years when the abundances of pink or chum are substantially higher or lower. Determining the migration routes and timing for juvenile pink and chum was not the primary objective for the 2003 MMP, and the sampling program was not optimal for resolving these questions. The authors suggested that if more definitive answers to these questions are required then a different approach will likely be required (e.g. mark and recapture experiments conducted over several years).

The prevalence and intensity of infection by sea lice of juvenile pink salmon, juvenile chum salmon and three-spined by sea lice that were captured in the Broughton and Knight Inlet in the 2003 MMP is assessed in a separate PSARC Working Paper (Jones and Nemec 2004. However, the sea lice data for the fish sampled in Muchalat Inlet and Esperanza Inlet have not yet been fully analyzed and are not included in the Jones and Nemec 2004 PSARC Working Paper. Preliminary analyses indicates that the infection rates of juvenile salmon in Muchalat Inlet generally remained at zero percent or very low (maximum 3.0% at one location) during March – May, then suddenly increased in early June. In the final sampling period (June 09-11) the percentage of juvenile chum infected with at least one sea louse ranged from zero to a maximum of 19% for chum captured at various locations in Muchalat Inlet. A total of 10 of the 11 juvenile chum that were caught in Esperanza Inlet on June 04, 2003 were infected with sea lice.

The authors provided several recommendations and conclusions. Regarding any additional DFO research on juvenile salmon and sea lice in the Broughton, they recommended that: 1) if the MMP is repeated in 2004, that only beach seines be used prior to mid-April to minimize costs. After mid-April, both beach seines and purse seines should be used, 2) the total number of pink and chum kept for sea lice analyses likely can (and should) be reduced without reducing the reliability of results, and 3) extending sampling to include the head of Knight Inlet should be reconsidered. Regarding juvenile salmon migration routes, the authors concluded that “main migration corridor” hypothesis was not clearly supported by the 2003 MMP results, but cautioned that this conclusion may be different in other years. The authors recommended that tagging and recapturing juvenile pink and chum would likely be the most conclusive method of confirming this.

Regarding sea lice and wild juvenile salmon marine research more generally, the authors concluded that continued progress towards resolving the concerns and debate surrounding the sea lice - wild salmon - fish farm interaction issue likely will require a multi-year research program. This research will be most effective if it is planned and conducted with the full cooperation and participation of DFO, the B.C. government and the B.C. finfish aquaculture industry.

H2004-03: Evaluation of site selection methodologies for use in marine protected area network design

S.M.J. Evans, G.S. Jamieson, J. Ardron, M. Patterson and S. Jessen

This report identifies and compares different methodologies used for the selection of (candidate) marine protected areas. It is hoped that this will provide DFO with the necessary information to evaluate which selection methodology would be most effective in furthering it's MPA objectives within the IM framework.

Choosing the most appropriate methodology depends on the underlying goal for establishing the set of marine protected areas. Clearly defining the purpose and the overall conservation goal is an important first step that must not be overlooked.

There are two main approaches to selecting AOIs; scoring/weighting (non-systematic) and systematic.

Scoring methods assign a rank of relative importance to all sites based on some user-defined criteria and then add those sites with the highest rank to an existing reserve. The product from this type of reserve site selection is not able to identify how each site relates to the others in the system beyond it's 'score' which is not indicative of what is being captured by the sites. While the objective nature of a scoring selection process is preferred to subjective or opportunistic decision-making, it is not very rigorous, it is not able to efficiently select a set of complementary sites and does not have the spatial capacity to create a network.

Systematic methods of reserve selection make use of algorithm-based decision support tools. Systematic selection of MPAs is based on the concept of 'complementarity' in which new sites contain features that are not currently captured in the reserve system and thus augment the overall diversity and representivity of the system. Of the systematic methods there are 4 main types of algorithms used; linear integer programming (ILP), simple iterative algorithms (heuristics), iterative simulated annealing and explicitly spatial population based models.

The advantage of the ILP methodology over other complementarity methods is its ability to find an optimal solution. However, if there are too many constraints or the problem is too complex (non-linear) this method will often fail to produce a solution. Thus it is best applied when there are only a few constraints to be optimised.

Heuristics are much faster than the ILP methods, but may arrive at a solution which is considerably less efficient than the theoretical minimum. These programs can manage conservation problems comprised of large datasets and several constraints. In some cases spatial constraints can be incorporated into the method via additional programming.

The simulated annealing method is considered superior to the other methodologies for selecting priority areas for conservation reviewed here. This algorithm can produce multiple solutions for a given scenario unlike heuristics which only provide one solution. It can produce more efficient solutions compared to heuristics in terms of minimising total area needed to meet the desired conservation objectives. There is a random component of this algorithm that allows for the search of the 'global minima'.

The last systematic method reviewed in this paper, explicitly spatial programs, specifically address the issue of species persistence through the application of environmental variable models (those which influence the distribution of biodiversity) or metapopulation models that will direct the selection of a 'connected' set of sites. These programs can only select sites for a limited number of species and require detailed data sets regarding either environmental parameters or species population dynamics. Thus, they are often most appropriately applied at smaller scales for which this type of data exists, or as a post-selection tool (see section 3.3) to choose among candidate sites in the development of a network that ensures a particular species persistence.

This report also reviewed two case specific applications of the systematic algorithms to identify priority areas for conservation currently being used in Canada. These projects, by Living Oceans Society and World Wildlife Fund Canada are highlighted with regard to their potential applicability to DFO.

Upon review of the methodologies we recommend that DFO consider the use of a site selection methodology in its IM program. From our analysis we concluded that MARXAN (a software package which employs simulated annealing) would be most appropriate tool to assist DFO in furthering its mandate and MPA objectives under the Oceans Act.

Other recommendations include;

- do multi-scale planning in MPA network design;
- perform analyses with multiple MPA objectives and datasets
- determine if MPA networks created using multiple agency mandates requires less area than performing the analyses separately specific for each agency
- improve our understanding of the usefulness of the various frameworks and approaches to applying Marxan, especially those ongoing in Canada;
- investigate current selection analyses used to date in Canada to provide DFO with compiled data and information on lessons learned in applying MARXAN and developing ecological planning frameworks for both coasts
- determine the ecological attributes for cells in terms of parameters reflective of criteria used by different agencies to rationalise their mandates to establish MPAs;
- undertake a pilot MPA selection analysis in some relevant geographical area, as DFO has the mandate among federal departments to show leadership in marine protected area studies;

Although spatial optimisation offers a powerful solution to MPA network design and while these programs make a contribution to improving rigour, transparency and efficiency of what is a complex process, they only contribute to part of the process. Other decision support tools (such as GIS and Delphic approaches – see Lewis et al. 2003) may need to be employed when fine-tuning boundaries, developing zoning plans, or when choosing among candidate sights that are of interest to several stakeholder groups.

H2004-04: A Science-based Boundary for the Central Coast Integrated Management Area

D. Johannessen, D. Haggarty and J. Pringle

The Science Branch of Fisheries and Oceans Canada's Pacific Region was asked by the Central Coast Integrated Management (CCIM) Working Group to propose modifications to the Central Coast 'working boundary' based on scientific and ecosystem information. Traditionally, marine boundaries have been based on one type of criteria such as political information, management requirements, or ecosystem-based information. Thus, Canada's Pacific waters can be politically bounded by the Canada-US border to the north and south and by the 200 nautical mile limit of national jurisdiction. Canada's Pacific waters have also been bounded by a number of different administrative systems, such as Fisheries and Oceans Canada (DFO) management areas, as well as smaller polygons used to manage specific fisheries. Boundaries have also been developed that attempt to define marine ecosystems at various scales, as described in section two of this paper. Section three reviews the latest work by the British Columbia (BC) provincial government using GIS analysis to define marine ecosystems at two scales. Section four lists some of the existing boundaries in the Central Coast Area. Section five describes the criteria used to define the proposed changes and discusses in detail the reasoning behind each portion of the boundary.

The boundary modifications proposed in this document represent a relatively new approach to boundary definition. The boundary is intended to define the Large Ocean Management Area (LOMA) for BC's Central Coast as a pilot area for integrated management. According to the *Oceans Act*, these areas are to be drawn using a mix of ecological consideration and administrative boundaries (Fisheries and Oceans Canada 2002). Boundaries developed in Australia for the purpose of marine management have ostensibly been created using only ecological criteria (IMCRA 1998). What is unclear from this work is how various State and Commonwealth jurisdictions and interests will be integrated into this system of boundaries, particularly as much of the boundary development work was done by individual states using different data and criteria. Furthermore, political jurisdictions, such as state versus commonwealth waters, were clearly used in the boundary definition. This illustrates the fact that if resource management is the end purpose of the area, then the definition of the area cannot ignore political boundaries. The definition of the area must also consider whether the area is suitable for management. For example, the intertidal zone could be defined as a single ecosystem for the entire BC coast, but that would create a very long, thin, convoluted area which would be unsuitable for management as a single area.

The definition of an ecosystem is also problematic. Watson (1998) reviews a variety of these definitions and it is clear that they can range from purely scientific, to mixtures of scientific and management criteria. Canada's Oceans Strategy (based on the *Oceans Act*) defines an ecosystem as: "The system of interactive relationships among organisms (e.g. energy transfer), and between organisms and their physical environment (e.g. habitat) in a given geographical unit." (Fisheries and Oceans Canada 2002).

Given the difficulty and subjectivity in defining an ecosystem, and given that the question put to Science Branch is to propose modifications to an existing boundary, this paper does not attempt to define a single Central Coast ecosystem. Instead the general Central Coast area is taken as defined by the working boundary (Figure 1) and modifications to that boundary are proposed wherever there exists scientific information to support an alternative to the working boundary. Since the general area is based on management considerations and the proposed modifications are based on science, the resulting area fits the *Oceans Act* recommendation for defining LOMA boundaries based on a mixture of management and scientific considerations (mentioned above).

The main criterion used to define the proposed modifications of the boundary is evidence for a clear and defined change in the physical environment (e.g. habitat). A sharp change (as opposed to a diffuse or gradational change) is the most desirable because it can more reasonably be represented by a boundary line. During the course of the project two specific factors, bathymetry and substrate material, were most often found to have readily available data, and to provide a sharply defined marine boundary. Whenever possible, biological information was also used to inform the proposed boundary modification. Although all of the proposed modifications in this paper are based on scientific information, where these modifications also make sense politically, culturally, or managerially, those factors are mentioned.

APPENDIX 2: PSARC Habitat and Salmon Subcommittee Meeting Agenda April 6-7, 2004

AGENDA
PSARC HABITAT SUBCOMMITTEE

April 6 & 7, 2004
Grand Hotel Nanaimo
4898 Rutherford Road
Nanaimo, B.C.

April 6, 2004 Start time: 09:00

1. Introductions and PSARC meeting procedures
2. Review agenda
3. Review of WP# H2004-02: Abundance and distribution of juvenile salmon and other fish caught in the Broughton Archipelago, Knight Inlet and Muchalat Inlet, B.C. in 2003. (Brent Hargreaves, Doug Herriott and Vic Palermo)
4. Sub-Committee Review – Conclusions and Recommendations - WP#2
5. Preliminary results of the study examining the impacts of sea lice on juvenile salmon: "The health of juvenile salmon in August 2003 in the Broughton and associated areas".
6. Review of WP# H2004-01: Sea Lice on juvenile salmon and on some non-salmonid species caught in the Broughton Archipelago in 2003. (Simon Jones and Amanda Nemec)
7. Sub-Committee Review – Conclusions and Recommendations - WP#1

April 7, 2004 Start time: 08:30

8. Review of WP# H2004-03: Oceans Strategy – Evaluation of site selection methodologies for use in marine protected area network design. (Glen Jamieson, Susan Evans, J. Ardron, M. Patterson and S. Jessen)
9. Review of WP# H2004-04: A Science-based Boundary for the Central Coast Integrated Management Area. (Johannessen et al.)
10. Sub-Committee Review – Conclusions and Recommendations - WP#3 and 4
11. Next meeting – Fall 2004

APPENDIX 3. List of Attendees

Subcommittee Chair: Bonnie Antcliffe
PSARC Chair: Alan Cass

NAME	Tuesday	Wednesday	AFFILIATION
EXTERNAL PARTICIPANTS			
Ennis, Gordon	X		Pacific Fisheries Resource Conservation Council (PFRCC)
Hon. John Fraser	X	X	PFRCC
Atkinson, Mary-Sue	X	X	PFRCC
LeBlond, Dr. Paul	X		PFRCC
Constantine, Dr. Joanne	X		BC MAFF
Harrower, Bill	X		BC MAFF
Groves, Dr. David	X	X	Sea Spring Salmon Farms Inc.
McKenzie, Peter	X		Heritage Salmon
Lawrie, John	X		
Fearon, Merrill	X	X	
Observers:			
Grydeland, Odd	X	X	BC SFA
Ardron, Jeff		X	Living Oceans Society
Blackbourn, Dave	X		Consultant – Observer
Morrison, Dr. Diane	X		Marine Harvest
Backman, Clare	X		Stolt Sea Farm Americas
Peet, Corey	X		Biology student

NAME	Tuesday	Wednesday	AFFILIATION
Hunter, Lynn	X		BC Coast Alliance for Aquatic Reform
Invited Experts			
Healey, Mike	X		University of BC
Routledge, Rick	X		Simon Fraser University
Johnson, Stewart	X		IMB, NRC
DFO MEMBERS (* Subcommittee Members)			
Cass, Al*	X	X	PSARC
Hargreaves, Brent*	X		
Irvine, Jim*	X		
Tompkins, Arlene*	X		
Van Will, Pieter*	X		DFO STAD
Foreman, Mike*	X	X	
Francis, Kelly*		X	
Jamieson, Glen*	X	X	
Johnston, Tom*	X	X	WLAP
Levings, Colin*		X	
Pringle, John*	X	X	DFO
Robinson, Clifford*	X	X	Parks Canada
Ross, Peter*	X	X	DFO, MEHS, IOS
Russell, Rob*	X		Habitat Management/SCD
Taccogna, Gary	X		Area Chief Oceans
Neville, Chrys	X		DFO
Thomson, Andrew	X		A/Senior Aquaculture Officer
Ladwig, Aleria	X	X	CA, DFO-CC
Mathias, Jack		X	Sr. Policy Advisor, Oceans Directorate
Riddell, Brian	x	X	DFO

NAME	Tuesday	Wednesday	AFFILIATION
Trudel, Mark	X		DFO
Cote, Christiane	X		Communications Advisor – RHQ
Jones, Simon	X		DFO – PBS
Sweeting, Rustin	X		DFO – PBS
Stucchi, Dario	X		DFO, IOS
Palermo, Vic	X		DFO, FR. STAD
Herriott, Doug	X	X	DFO, STAD
Nicolson, Midora	X	X	DFO, Oceans
Bravender, Bev	X		DFO, Science Branch
Jewsbury, Gail	X		DFO, STAD
Evans, Susan		X	DFO, RHQ
Johannessen, Duncan		X	DFO
Pellegrin, Nicole		X	DFO - intern

Reviewers for the PSARC papers presented at this meeting are listed below in alphabetical order. Their assistance is invaluable in making the PSARC process work.

Philip Bloch	Washington DNR, Aquatics Division
Professor Hugh Possingham	University of Queensland, Australia
Michael Healey	University of British Columbia
Marc Trudel	Pacific Biological Station
William Heard	NOAA Fisheries Auke Bay Laboratory, Juneau, Alaska