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Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals

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Fisheries Centre, University of British Columbia, Canada

Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems As Future Policy Goals

Edited by

Tony J. Pitcher

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BACK TO THE FUTURE: ADVANCES IN METHODOLOGY FOR MODELLING AND EVALUATING PAST ECOSYSTEMS AS FUTURE POLICY GOALS

Edited by Tony J. Pitcher

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'Back to the Future: the Restoration of Past Ecosystems as Policy Goals for Fisheries'

Supported by the Coasts Under Stress 'Arm 2' Project
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Director's Foreword

Big Catch for Humans

The *Draught of Fishes*, painted in 1515 by Raphaello Sanzio (1483-1520). Towards the end of his short life, Raphael moved briefly but spectacularly to Rome, where he initially helped to redecorate apartments vacated by the unsavory and detested Borgia Pope (Alexander 6th). Ten full-size cartoons were commissioned from Raphaello by the urbane Medici Pope, Leo 10th, as designs for tapestries to hang in the Sistine chapel. The subsequent tapestries by Pieter van Aelst in Brussels (1519) were revolutionary in their use of light and shade, and can be seen today in the Vatican Museum. Note that the Vatican is visible on the lake shore, transposed by virtue of our painter's benefactor to the shores of the Sea of Galilee in biblical times. Cranes in the foreground symbolize vigilance, while seagulls allude to the apostasy of the former regime.

Victoria & Albert Museum, London, tempura on canvas, 399 x 440cm.

The fishers were not catching much when Jesus, sitting in one of the boats, encouraged Peter to cast the nets again in deeper water. Such a large amount of fish was caught that both boats began to sink. The disciples were astonished, but Jesus said to Peter "Do not fear, from now on you will be catching men."[1] Some might hold that this 'parable of the draught of fishes' is an early example of overfishing. There is a catch, so to speak, in sinking the darn boat, not to say in depleting all those Galilean fishes. But in fact, the parable means that if you fish in the right place with the right gear and information (divine in this case), your catch may surprise you. And indeed, Christianity, a really bright and shiny new idea at the time, ended up with an unexpectedly large catch of humans. (Yes, yes, there was a catch - a lot went very wrong later on!)

Back-to-the-Future (BTF), an integrative approach to restoration ecology of the oceans, is today another bright and shiny new idea, needing more supporters, that attempts to overcome the catch of overfishing. BTF uses past ecosystems as policy goals for the future. It harnesses an understanding of ecosystem processes and whole ecosystem simulation to insight into the human dimension of fisheries management. It includes new methods, reported in substance here, for quantitative descriptions of past ecosystems, for designing fisheries that meet criteria for sustainability and responsibility, and to evaluate the costs and benefits of fisheries in restored ecosystems. Alternative policy choices involve different trade-offs between conservation and economic value. Automated searches maximise values of objective functions, and the methodology includes analyses of model parameter uncertainty. Participatory workshops attempt to maximise compliance by fostering a sense of ownership among all stakeholders. Some challenges that have still be met include improving methods for quantitatively describing the past, reducing uncertainty in ecosystem simulation techniques and making policy choices robust against climate change. Critical issues discussed here include whether past ecosystems make viable policy goals, and whether desirable goals may be reached from today's ecosystem.

This report, covering new and adapted methodology devised to support Back-to-the-Future analyses and policy procedures, has been rather a long time in the making. This foreword has been in draft for over a year, and, in the event, turns out to be the last Director's foreword (of 40 since 1993) that I have written for *Fisheries Centre Research Reports*.

The *Fisheries Centre Research Reports* series publishes results of research work carried out, or workshops held, at the UBC Fisheries Centre. The series focusses on multidisciplinary problems in fisheries management, and aims to provide a synoptic overview of the foundations, themes and prospects of current research. *Fisheries Centre Research Reports* are distributed to appropriate workshop participants or project partners, and are recorded in the *Aquatic Sciences and Fisheries Abstracts*. A full list appears on the Fisheries Centre's Web site, www.fisheries.ubc.ca. Copies of the reports are sent to meeting participants, and all papers are available for free download from our web site as PDF files. Paper copies of reports are available on request for a modest cost-recovery charge.

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[1] Bible, Luke 5: 1-11.

Introduction To The Methodological Challenges In 'Back-To-The-Future' Research

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Abstract

Many of the concepts in the Back-to-the-Future research process are new and so new methods, and modifications to existing methods, have been required for analysis, modelling and prediction of marine ecosystems and their fisheries. Methodological issues have been encountered in describing and modelling past ecosystems, in devising an ecosystem approach to determine sustainable fisheries, in devising a rational basis for choosing appropriate restoration goals and in attempting to maximise consent and compliance through encouraging a sense of ownership of policy by stakeholders. This paper summarises these issues, and introduces each of the new methods later to be described in detail in papers in this report. Results from case studies of the BTF process are contained in a separate report.

Introduction

Back-to-the-Future (BTF) is a science-based restoration ecology aimed at the creation of truly sustainable food and wealth from capture fisheries and aquatic ecosystems (Pitcher *et al.* 1999). The fisheries are embedded in aquatic ecosystems that, by quantitative analysis and with the agreement of stakeholders, trade-off wealth and food with a specified degree of retention of their unexploited biodiversity and trophic structure. Hence, BTF uses past ecosystem states as candidates for adoption as policy goals for the future (Figure 1, Pitcher 2001). In practice, the policy goals are subject to a number of practical constraints from species, habitat and climate changes (Haggan *et al.* 2003). The six logical steps in the BTF process are outlined in Table 1 (Pitcher 1998, 2004a, Pitcher *et al.* 2003).

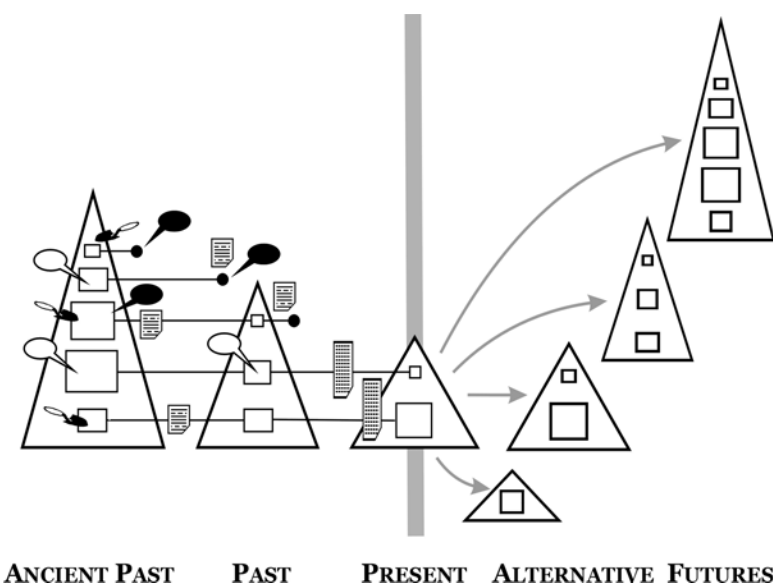

Figure 1. Diagram illustrating the 'Back to the Future' concept for the restoration of past ecosystems. Triangles at left represent a series of ecosystem models, constructed at appropriate past times, where vertex angle is inversely related and height directly related to biodiversity and internal connectance. Time lines of some representative species in the models are indicated, where size of boxes represents relative abundance and solid circles represent local extinctions. Sources of information for constructing and tuning the ecosystem models are illustrated by symbols for historical documents (*paper sheet symbol*), data archives (*tall data sheet*), archaeological data (*trowel*), the traditional environmental knowledge of indigenous Peoples (*open balloons*) and local environmental knowledge (*solid balloons*). Alternative future ecosystems, restored 'Lost Valleys', taken as alternative policy goals, are drawn to the right. (Diagram modified from Pitcher *et al.* 1999 and Pitcher 2001.)

Many new concepts have been developed as a part of the BTF research sponsored by *Coasts Under Stress* (CUS), and so it is not surprising that existing methods have not been adequate to express them. This report contains descriptions of the new methods that have been developed, along with papers of a general methodological nature from CUS research partners. BTF case studies and results are the subject of a separate publication.

The new methods can be divided into four groups: methods required to describe and model past ecosystems, ecosystem-based methods to determine sustainable fisheries, methods that set out a rational basis for choosing appropriate ecosystem restoration goals, and finally, practical techniques that attempt to secure compliance and consent through participation.

1. Methods of Modelling Past Ecosystems

The present-day ecosystem is represented by mass-balance and dynamic simulation modelling (at present using *Ecopath* with *Ecosim*; Walters

Pitcher, T.J. (2004) Introduction to the methodological challenges in 'Back-To-The-Future' research. Pages 4–10 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

Table 1. Stages in the 'Back to the Future' process for the restoration of fisheries and aquatic ecosystems. Workshop phases are in italics. Modified from tables in Pitcher (1998) and in Pitcher *et al.* (2003).

Stage	Goals	Steps
1	Model construction of past and present aquatic ecosystems	Assemble present-day mass-balance and ecosystem simulation model Assemble preliminary past models using compatible structure and parameters Search and score data archives, historical documents, archeological information *Workshop of scientists knowledgeable about system* Interviews for traditional environmental knowledge, and for fisher's opinions and behaviour Assemble and standardize historical and interview scores database Assemble and test suite of ecosystem simulation models *Workshop of scientists and managers to compare and standardise ecosystem models* (may need to return to this step after preliminary results)
2	Evaluation of ecological, economic and social benefits that could be gained from each system	Determine sustainable fisheries with which to exploit reconstructed ecosystems ('Opening the Lost Valley') Challenge model scenarios with uncertainty Challenge model scenarios with climate changes Ecosystem simulation scenarios under anticipated conditions *Workshops to evaluate policies with fishing communities* Critique and evaluate 'Lost Valley' fisheries scenarios and adjust where required Searches for optimal mix of fishing gears Determine Optimum Restorable Biomasses (ORBs) for 'Lost Valley' scenarios Quantify risks to ORB policies
3	Choice of system that maximises benefits to society	Identify trade-offs among economic, ecological and social criteria Ecological economic evaluations including analysis of risks *Workshops with communities, managers, scientists, NGOs, and government* Participatory policy choice
4	Design of instruments to achieve this policy goal	Model exploration of MPAs, effort controls, acceptable quotas, times and places for fishing Evaluation of costs of the desired management measures
5	Participatory choice of instruments	Community and stakeholder discussion and choice of instruments to achieve policy goals *Workshops with communities, managers, scientists, NGOs, and government* Participatory policy choice
6	Adaptive management: implementation and monitoring	On-going monitoring, validation and improvement of model forecasts using adaptive management procedures On-going participatory guidance on instruments and policy goals

et al. 1997) using techniques that have received a degree of approval by marine ecologists (e.g. Whipple *et al.* 2000). This modelling is a far from trivial task, especially if fitting to time series of fisheries and survey data is undertaken. Moreover, highly migratory species like salmon, that exhibit lifetime shifts between different ecosystems, are included in ecosystem models with difficulty (see Martell 2004, this volume).

Models for past ecosystems are assembled using scientific archival data, archeological data, historical information, and local and traditional environmental knowledge. Scientific data derive mainly from published scientific papers, although material from unpublished reports and archives can often be valuable. Archaeological data has a similar set of sources (see Orchard and Mackie 2004, this volume). Historical information is gathered mainly from relevant books, letters, trade accounts and other historical documents, although, unlike science and archaeology, where searchable databases are the norm, finding and locating historic material can be quite hard. In some cases, translations are required. Local and traditional environmental knowledge, on the other hand, is rarely published and often has to be derived largely from oral sources through interviews and discussion held in coastal communities (see papers by Ainsworth, Simeon and Pitcher *et al.* 2002c, this volume).

Once found, all these data have to be assembled into a relational database together with evaluations of its scope and quality, to ease retrieval of relevant information for the models. (The CUS BTF project database will be described by Erfan in a later report.) Even so, a significant task is systematising the way in which information is collated for use in the models. The reason is that, once documented, information has to be expressed in a form that can be used in building ecosystem model structure, in setting parameters, or in shaping dynamic responses to changes. Although presence and absence of a species is easily dealt with, the models require us to know actual biomasses, size and growth parameters, and items in the diet.

Information about the local fisheries, with analyses and surveys, and about local aquatic fauna and flora is relatively easily found, especially as an output of 'science workshops' comprised of research partners and local scientists with expert knowledge of the area and the taxonomic groups. One of the principal problems here is data that has been gathered on either a very small or a very large scale compared to the area of focus (see Haggan 2004, this volume). Another issue often requiring a lot of work is the concordance of measurement units, since specialists on different taxa often work in very different fields. Scientists who generously make the relevant information available, often from a lifetime's work on a group of organisms, are encouraged to publish a paper in one of the BTF reports so that they retain a recognised ownership of material that otherwise would easily vanish into model simulations.

For the CUS BTF project in Newfoundland and British Columbia, the output from an extensive process of consultation with the science community has been presented in detail in four reports (Ainsworth *et al.* 2002, Pitcher *et al.* 2002a, 2002b, Heymans 2003), where information essential to the modelling process, such as geographical scope, biomass, relative fishing mortalities, diets and other ecological information are assembled.

In the absence of local publications on these topics, as is often the case, interviews, conducted under suitable partnership agreements, are the best way to gather LEK and TEK information for use in the modelling. Ainsworth (2004, this volume) reports on methods used in interviews designed especially to gather material that can be used in ecosystem modelling for the CUS BTF project. A report on a community workshop is presented in Pitcher *et al.* (2002c, and see Power *et al.* 2004, this volume).

For ease of comparison, the structure of the past and present ecosystem models should be similar, although of course biomasses and fluxes can be vastly different. Global extinctions of species cause some technical difficulties in modelling. When species have gone locally extinct ('extirpation'), this creates some difficulties (see Pitcher 2004d, this volume). Some practical solutions found in the CUS project are presented by Heymans and Pitcher (2004, this volume).

Another frequent problem is that reconstructions of the ancient past may suggest the presence of large numbers of top predators that are too numerous to be supported by what are thought to be realistic levels of forage organisms (Pitcher 2004c, this volume).

Representing changes in ecosystem structure over long periods of time represents a major challenge. Clearly, the effect of shifts in climate has to be accommodated in the forecasts as much as possible (see Pitcher and Forrest 2004, this volume). But early periods of depletion by human exploitation also had significant impacts on ecosystem structure and function. Recent reconstruction work by Jackson *et al.* (2001) shows what may be possible in this respect.

Ideally, the timing of the series of ecosystem models for BTF may depend on the locality, the dawn of quantitative documentary evidence, and major shifts in resource and ecosystem history such as the introduction of new fishing gears, damming of rivers and collapses of fish stocks. But because of the large amount of work involved in drawing up each ecosystem model, the gaps in time between a series of BTF models may be quite large. So an ideal choice of the time snapshots to use as BTF models is generally constrained by the resources available for the research. This raises a significant methodological problem in that failure to cover important changes that occurred within these time gaps can prejudice the choice of appropriate policy goals at the end of the BTF process. In the event, the choice of the time periods to model in a BTF analysis is something of a compromise.

In many cases, additional informative models might be drawn up for pre-modern humans in the late Pleistocene post-glacial era. Although such ancient ecosystems would be unlikely to ever become practical policy goals, they have the advantage of providing a 'pristine' baseline against which all more recent changes might be assessed. In fact, for some areas of the world only recently colonised by Europeans, such as Australia, New Zealand and the Pacific coast of America (Diamond 1997), models of 'pre-contact' ecosystems may serve this purpose well.

In models of the distant past, the estimation of the size and impacts of ancient fisheries presents many problems. Although the history of fishing technology is quite well known from archaeology and from traditional knowledge, its likely fishing power may be estimated, and ancient diets may be calculated, nevertheless, the size of the human populations that engaged in fishing is often hard to assess. Estimates of ancient human population sizes are often the subject of controversy among archaeologists and anthropologists. In one of the recent volumes from this CUS BTF project, Heymans (2003) presents an example of what may be done with ancient diets and fisheries. It is emphasised, however, that the aboriginal fisheries in the ecosystems are described only to provide an accurate picture of the ancient ecosystem, and they would not necessarily be chosen for a future restoration policy. This issue is discussed in more detail below.

Finally, many of these problems may be eased if we were able to run a past model forward to simulate its change into a more recent ecosystem. Performing this using *Ecosim* requires a great deal of data on fisheries and climate (see Stanford 2004, this volume), but has been possible for some ecosystems that have undergone rapid change, such as the Gulf of Thailand (Christensen 1998). Unfortunately, to date, attempts to do this with both BC and Newfoundland ecosystem models have been only partially successful (Heymans 2003). Heymans and Pitcher (2004, this volume,) summarise the construction of models of the past in relation to the ecosystems researched for the CUS BTF project.

2. METHODS FOR DEVISING SUSTAINABLE FISHERIES

A marine ecosystem restored to some semblance of its past state might be thought of as a 'Lost Valley'[1]: an ecosystem discovered complete with all of its former diversity and abundance of creatures (Pitcher 2004b, Pitcher *et al.* 2004). The BTF process aims to describe a series of such 'Lost Valleys' as a set of potential restoration goals.

Since a 'Lost Valley' has to be fished sustainably, we have to ask how this might be achieved? Using the same fishing fleet as today in order to fish a restored ecosystem is generally not a viable option since massive depletion would soon ensue. Nor is it realistic to expect the fishing gear and methods of former times, including those of aboriginal fisheries, to be re-employed. Of course, some former fisheries might have attractively low by-catch, operating costs or ease of construction and use, so it is evident that some rational criteria for the selection and operation of sustainable fisheries need to be devised. The BTF process aims to devise such criteria. For example, a candidate fishery designed with the criteria could be challenged by assessing its conformity with the FAO Code of Conduct for Responsible Fisheries (FAO 1995) using a rapid appraisal technique (Pitcher 1999).

After applying the criteria in this way to design an 'ideal fishery' for a particular location, ecosystem simulations (using the *Ecosim* policy search interface; Walters *et al.* 2002) can be used to find the relative fishing mortalities that should be used by each gear type in the 'ideal' fishery to achieve sustainable catches over a long time period, usually 100 years.

In addition, we may seek to challenge these results with climate changes that might realistically be expected for the locality in question, and in the face of uncertainty in the simulation modelling (see papers by Ainsworth *et al.*, Pitcher and Forrest 2004, this volume).

3. METHODS FOR CHOOSING ECOSYSTEM RESTORATION GOALS

Once we have snapshot of what a set of alternative restored ecosystems, complete with their sustainable fisheries, might look like, the remaining issue to solve is to find an objective way to choose a rational policy goal from among them. This may be done by comparing the benefits that will accrue to society from each alternative future represented by a fished 'Lost Valley' ecosystem. In order to show the full range of options that may be considered, included in this process is the present day ecosystem (albeit with fisheries designed to be sustainable), and perhaps an ecosystem even further depleted (Figure 1).

One fundamental way to evaluate the benefits of alternative restored ecosystem is the net present economic value of their fisheries, information that is readily estimated from the *Ecosim* simulations mentioned above. A modification more in accord with ecological economics is to estimate present value using intergenerational equity calculations (see Ainsworth and Sumaila 2004a, this volume).

Purely economic considerations, however, are rarely considered sufficient for modern policy making. Therefore, in the BTF process we also estimate the relative impacts on biodiversity (see papers by Ainsworth and Pitcher, Heymans, and Chueng and Pitcher 2004, this volume) and social factors such as the likely number of jobs and their diversity (see Ainsworth and Sumaila 2004b, this volume). For a proper evaluation, the costs of restoration have to be considered alongside the benefits. This part of the evaluation system is not yet completed for the CUS BTF research and the issue is discussed further below.

4. PARTICIPATORY AND ADAPTIVE POLICY IMPLEMENTATION

Implementing a policy goal that has been chosen using any science-based process, including BTF, is, of course a much more difficult matter. When fishing communities and other essential stakeholders actively participate in the policy

[1] We are grateful to Dr Daniel Pauly for suggesting this term in 2001. (See Pitcher *et al.* 2004, this volume)

Table 2. Summary of integral participatory elements from local fishing communities in the BTF process. TEK = traditional ecological knowledge, LEK = local ecological knowledge. All stages are intended to work in concert with science-based decision making.

Model development phase	TEK: in model construction LEK: in model construction TEK/LEK/Community: model credibility and validation
Policy development phase	Community choices: how to rebuild Community choices: choice of best benefits to cost ratio for policy goal Community choices: choice of acceptable and sustainable fisheries
Operational phase	Consent and compliance Monitoring

agenda, compliance and consent may be high (Hart and Pitcher 1998). For example, Haggan (2000) identifies 4 elements as critical to participation: recognition of the scope of the problem and our collective responsibility whether fishers, scientists, managers or policy makers; respect for different systems of knowledge; agreement to share knowledge in the interest of conservation and restoration; and, commitment to share in the benefits of restored systems.

In BTF the aim is to encourage a greater chance of success because a sense of ownership of the process is fostered and developed from the earliest stages of the work. The BTF process includes community participation in building models of the past (see Simeon 2004, this volume), in the choice of sustainable fisheries and in the evaluation of the costs and benefits of alternative restoration goals (see Power *et al.* 2004, this volume, Pitcher *et al.* 2002c). Moreover, the cognitive maps shaped by awareness of past abundance and diversity develop in BTF process may serve to assist consent and compliance with a restoration agenda (Pitcher and Haggan 2003). Participatory elements that are integral to three phases of the BTF process are summarised in Table 2.

Once management aims to make progress towards a specific BTF past state, the use of quantitative adaptive management (e.g., Walters 1986) is the wisest course, in order to try to avoid the disasters that a changing environment and imperfectly understood ecology can throw at any management plan.

CONCLUSIONS

Policy goals that reflect an approach of restoration ecology may be chosen using the BTF procedures outlined here and presented in more detail in subsequent papers in this volume. But a number of methodological challenges raised by BTF remain unresolved at this stage.

The way in which historical information is turned into inputs for the ecosystem modelling could do with considerable improvement. Better semi-quantitative assessment of relative biomass, diet and sizes needs to be devised. Our historical data need a more rigorous and replicable transduction into the quantitative data needed for modelling. For the CUS BTF research, a first step in this respect will be published by Ainsworth (2004) in the forthcoming ‘results’ volume.

BTF has an advantage in not relying exclusively on complex stock assessment (Walters 1998), although such work can help in the tuning of the ecosystem models. At present, the quantitative ecosystem modelling used for BTF to date relies almost exclusively on *Ecopath* and *Ecosim* techniques. Yet many of the assumptions in this modelling system, while plausible, remain unvalidated. Of especial concern are the *Ecosim* ‘vulnerability’ parameters, to which specific results often appear very sensitive (see Ainsworth 2004, this volume). Moreover, these parameters not only shape predator-prey interactions (which they do in an entirely credible fashion for a former evolutionary ecologist), but also pre-determine the scope for further biomass growth in relation to current abundance. For any series of ‘time-shot’ BTF ecosystem models, this creates a conflict between the need to compare the outcomes of various fisheries options while other parameters remain fixed, and setting parameters correctly for biomasses that were closer to unexploited levels in the past. These modelling problems have yet to be resolved.

As pointed out by Heymans and Pitcher (2004, this volume), past ecosystem models may resemble the actual past as a Picasso resembles reality. An important question is whether our comparative restoration policy scenarios can be made robust against such distortions. A deeper insight of the dynamics of ecosystems under change will be required before we can answer this question.

A broad participation by scientists, researchers, stakeholders, government, managers, NGOs and the public is critical for the success of any restoration policy that might be set up under the BTF banner. Yet we have barely scratched the surface of the deep issues raised by the need for this level of participation in the BTF policy searches and analyses. Nor have we enough experience of asking fishing communities to choose what kind of future they might wish to aim for. We are not yet sure how to convey the uncertainty in our work, which to many may seem arcane. Perhaps ‘barefoot ecologists’, the equivalent of rural development generalists for fisheries, as envisaged by Jeremy Prince might be able to help (Prince 2003).

The intention is to give BTF players a clear cognitive map of a future ecosystem that resembles one from the past, to which all may agree and aspire (see Pitcher 2004a). And so, to date, BTF analysis has not considered the costs of achieving each restoration, because this may divert attention from that ultimate goal. (Although it is noted that it may be logically argued that the true policy goal cannot be known until a full cost-benefit analysis is performed.) The fundamental problem here is that estimating the costs of restoration may depend on precisely what techniques are adopted, and the actual instruments may themselves generate conflict (for example, MPAs set up adjacent to a traditional fishing community – see Lucas 2004, this volume - or reduced quotas for some sectors as fisheries are modified to become more sustainable). Again, these important issues remain to be resolved.

The logistics of mounting a quantitative, robust and credible BTF analysis are considerable. The sheer cost, in money and time, of assembling an inter-disciplinary team to gather, validate and analyse the historical, archaeological and ecological information needed for BTF is formidable. Moreover, like other synoptic work involving whole ecosystems, the scope of BTF work appears to be far outside the capacity of one graduate student thesis. In this project, it has therefore been gratifying to see modest financial support from *Coasts under Stress* augmented by enormous enthusiasm and commitment from the team of graduate students, postdoctoral researchers and research partners who have helped with the research reported here.

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SYNOPTIC METHODS FOR CONSTRUCTING ECOSYSTEM MODELS OF THE PAST

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ABSTRACT

This paper gives a brief description of the steps that need to be taken when constructing a model of a past ecosystem. It is important to know what question is going to be asked of the model, as that affects all subsequent steps. To construct a model of the past it is important to know the area, time periods, species to include, what data is available, how to handle the calculation of *Ecopath* parameters for species that have a different age structure from the present day, and finally how to make and test the assumptions needed in such a endeavor. Assumptions that have to be made lead to uncertainty, which may be examined using the emergent properties of the ecosystem.

INTRODUCTION

Models of the past are constructed for comparison with present day models. They provide baselines for the emergent properties of these ecosystems. For the *Coasts under Stress* Back-to-the-Future project we aim to assess the effect of long term trends in the social and environmental health of regional ecosystems on the environment and on human health. The question asked was:

> 'How can local ecological and scientific knowledge help us to understand changes in environmental, community, and individual health in ways that will help develop better strategies for future ecological recovery?'

In this paper the methodology of constructing models of the past will be illustrated by using two examples from the CUS BTF project: Northern British Columbia (including the Hecate Strait and Queen Charlotte Sound), and Eastern Newfoundland /Southeastern Labrador (NAFO Div. 2J3KLNO) (Figures 1 and 2), as defined in Pitcher *et al.* (2002) and Ainsworth *et al.* (2002).

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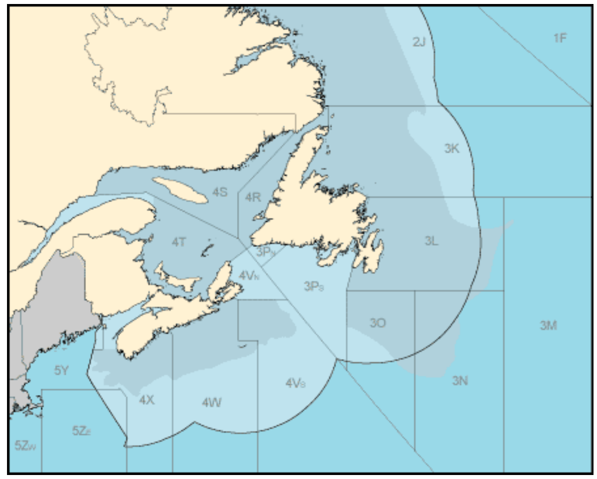

Figure 1. NAFO divisions of the east coast of Canada, showing the areas used in the CUS-BTF study (Divisions 2J, 3K, 3L, 3N and 3O).

METHODOLOGY USED IN CONSTRUCTING MODELS OF THE PAST

The steps involved in the construction of past models include: 1) defining the system, 2) choosing the time periods you want to model, 3) data gathering (on catch and biomass mostly), 4) which species to include, considering extinctions and incorporating species that are not well studied even at present, 5) calculating the energetic ratios for models of the past, and finally 6) making other assumptions for species where we have no better information.

Defining the system

To define a model of the past you have to define the boundaries of your ecosystem. The chosen system should preferably be contained in a natural or oceanographic feature, with a single climate. Generally a larger area is preferable as it increases the chances of having any historical information. By and large the international jurisdiction of the area does not matter, as the jurisdiction would have changed over the course of time. Usually the ecosystem is defined based on current knowledge of the system. For instance, in both the northern BC and Newfoundland models we defined the system based on current knowledge and more recent models constructed for these ecosystems (Heymans and Pitcher 2002a, and Ainsworth *et al.* 2002).

In Newfoundland the area chosen (Figure 1) was similar to that used in prior models of the system (Bundy *et al.*, 2000, and Heymans and Pitcher 2002). The area chosen included the DFO-NAFO divisions 2J3KLNO and incorporated the Labrador Current and the Grand Banks, as they

Figure 2. Map of the West coast of Canada showing the Hecate Strait and Queen Charlotte Sound, both in the study area.

are interconnected and for some species they are managed as a unit. The area chosen for the northern BC model included both Hecate Strait and Queen Charlotte Sound (Figure 2). The area was chosen to answer particular questions, thus some inshore marine waters were included in the model area as salmon had to be included.

Choosing time periods

When choosing a time period it is advisable to choose times pre- and post pivotal gear changes or exploitation levels. Time periods pre- and post the start of formal recorded data are often important, and, finally, the time periods depend on the questions that are asked. For the CUS BTF project the question was to assess the longer term trends in the health of local and regional ecosystems.

The time periods chosen for the northern BC model were 1750, 1900, 1950 and the present day. (Ainsworth *et al.* 2002). The 1750 model was chosen as it was pre-European contact, while 1900 was prior to large scale commercial fisheries and the resumption of whaling. By 1900 the number of First Nations people were drastically reduced, which had a positive effect on Steller sea lions, although the sea otters were already locally extinct by that time. The 1950 model incorporates the large scale purse seine fishery for herring, the collapse of pilchard and the start of DFO's catch data series, while the present day (2000) model was initially based on a model constructed by Beattie (2001) but using more recent data.

In Newfoundland the time periods chosen were 1450, 1900-1905, 1985-1987 and 1995-1997 (Vasconcellos *et al.* 2002). The 1450 model was pre-European contact, 1900 was prior to the large scale Grand Banks fisheries, but after the large scale whaling that took place in that area. The 1985-1987 model was based on the model constructed by Bundy *et al.* (2000) and was prior to the groundfish collapse based on reliable data, while the 1995-97 model was after the groundfish collapse but did not have the same quality of data as the 1985-87 model.

Data gathering

Information on past abundances, catches, etc. are not easy to obtain in normal scientific literature. However, building models of the present day gives a blueprint for models of the past. Information on past abundance and catches are generally found by looking at historical documents, or by using expert opinion of fisheries biologists on virgin population of key species. It is also possible for marine mammal or seabird experts to make 'educated guesses' on how many animals must have been in the system at a certain time. There are also archaeological and anthropological information available to assist with presence/absence of species, as well as the utilization of marine species by First Nations or European settlers. Finally, Traditional and Local Ecological Knowledge (TEK/LEK) can also be useful for models that are within their time frame, i.e. models that go back about 50 years.

Data for building the models of Newfoundland (Heymans and Pitcher 2002a, 2002b, Pitcher *et al.* 2002a) were obtained mostly from historical documents and books that summarize changes in that ecosystem: (Lescarbot 1914, Howley 1915, Lewis and Doutt 1942, Wright 1951, Mercer 1967, Mowat 1984, Reeves *et al.* 1985b, Crosby 1986, Montevecchi and Tuck 1987, Cushing 1988, Pastore 1992, Hewitt 1993, Ryan 1994, Pope 1995, Turgeon 1995, Marshall 1996, Lear 1998, Hiller 2001, Cridland 1998, Whitridge 2001). For the calculation of the pristine population and catch of cod, a reconstructed time series obtained from (Hutchings and Myers 1995) was useful. The Internet was useful for obtaining information on historical populations. In Newfoundland the Heritage Site of Newfoundland and Labrador (www.heritage.nf.ca) contains information on the fishing industry, First Nations and European settlement in the area.

Data for building the models of northern BC (Ainsworth *et al.* 2002) were obtained from historical documents, such as Hudson's Bay Company records (Hammond 1993), as well as other historical records (Lord 1866, Chambers 1872, Anderson 1879, Dawson 1880, Mowat 1886, ANON 1892, Osgood 1901, Freeman 1904, Babcock 1910, Alexander 1912, Thompson 1916, Newcombe 1917, Muir 1935, Carrothers 1941, Akrigg 1975, Kenyon 1975, Jacobsen 1977, DeWhirst 1982, Vancouver 1984, Reeves *et al.* 1985a, Webb 1988, Gregr 1999, 2002, Mackie *et al.*, 2001). Data for building the model of 1950 was also obtained from interviews done in Prince Rupert and surroundings (see report in Pitcher *et al.* 2002). Both historical data and interview data for this system was collected in a database searchable on the web at: www.fisheries.ubc.ca/projects/btf/ (see Erfan, results volume).

Data on sport fish catches are rarely recorded in official 'catch statistics', but can be considerable (e.g., Pitcher 2003, Pitcher and Hollingworth 2002). In Northern BC some estimates have been made using interview and other techniques (Forrest 2002).

Data on catches made by First Nations are generally hard to find (e.g., Irwin 1984). However, in northern BC an estimate of salmon catches by First Nations were made by (Hewes, 1973) and assumptions had to be made for the catch of eulachon and marine mammals. In Newfoundland the catch of marine animals by First Nations was hard to calculate, as the Beothuk people of Newfoundland were extirpated by 1829. Assumptions had to be made about how much the people of Newfoundland would have eaten. With the help of an Ingeborg Marshall, an anthropologist from St. Johns, their consumption of marine resources were calculated by apportioning likely catches between marine mammals, salmon, and other marine resources ((Renouf 1999, Marshall 1996, Heymans 2003).

Which species should be included?

The species to be included usually depends on the question asked, what species have gone extinct, locally or globally, and what species migrate through the system. The question asked implies that some species would be important as single groups in one model vs. being able to combine them in other groups. For instance, in Newfoundland it was necessary to put Greenland cod and lobster into their own compartments, as the question asked pertained more to the human interaction and inshore system than to the offshore system.

Likewise, the importance of migratory species such as migratory salmon and transient killer whales become more important in the northern BC model, as these are important in the policy arena of that system. There are two other important considerations that need to be taken when deciding which species to include, namely extinctions and species that are not well studied.

Extinctions

Local and global extinctions make the inclusion of certain species very difficult. For comparison between emergent properties of ecosystem models it is important for the groups to have the same number of compartments. Similarly, simulations that span two different models would need all the compartments to be included in both models. Thus, it is important to include species that have become extinct during the course of the modeling exercise. These species are usually included by adding a very small biomass ($1*10^{-6}$ $t.km^{-2}$) in the models where they are essentially extinct (see Pitcher 2004, this volume).

An example of a local extinction in northern BC is the sea otter, which became extinct before the 1900 model. Pristine population estimates are given by (Kenyon, 1975), and were used for the estimation of sea otter biomass in 1750, but by 1900 and the subsequent models of 1950 and 2000 biomass was assumed to be $1*10^{-6}$ $t.km^{-2}$.

Three species have become extinct in Newfoundland since European contact: walrus and grey seals have become locally extinct, while the great auk is globally extinct (see Pitcher 2o04, this volume). No estimates of walrus or grey seal biomasses were available for 1450, but estimates of rookery sizes and whelping patches were given in the controversial book by (Mowat, 1984), which had to be used in lieu of any other data. By 1900 both these species were locally extinct in Newfoundland, and their biomass estimates were therefore assumed to be $1*10^{-6}$ $t.km^{-2}$.

The extinction of the great auk was easier to model. Although there were at least 100,000 nesting pairs of great auk in Newfoundland at the time of European contact, they were extinct by 1830 (Burke *et al.* 2002, Sarjeantson 2001, Montevecchi and Kirk 1996). However, seabird biomass and impact is so small that they are usually grouped into functional groups. The great auk was therefore grouped with the piscivorous birds, and as such no assumption had to be made about their biomass, other than the assumptions made for bird biomass in general (see Pitcher 2004, this volume).

Species that are not well studied

In all ecosystem models there are some species that are very poorly studied. Incorporating them is usually problematic, and very little data are usually available for non-commercial species. Examples of these species are the rockfish in northern BC (a guild of over 30 species) and Greenland cod in Newfoundland. There are many species of rockfish in northern BC, but until very recently, very little data was available on these species. In the present day model therefore, they were broken down into inshore rockfish, planktivorous and piscivorous rockfish. (Ainsworth *et al.* 2002, Foulkes in prep.). There are no historical estimates of biomass, production, etc. for these species, or for Greenland cod in Newfoundland, so their biomasses are estimated by *Ecopath* by assuming that their P/B and Q/B ratios would be similar in the past as they are today.

Energetic parameters

The other parameters needed for constructing *Ecopath* models are also be different in models of the past. Parameters such as the P/B and Q/B ratios are often smaller in populations that have many more older fish, that produce and consume less than a population that consist mostly of younger smaller fish.

The P/B ratio is usually assumed to be:

$$P/B = F + M \qquad (1)$$

where F is fishing mortality and M is natural mortality. Fishing mortalities in most models of the past are generally small, but where estimates of catch and biomass are available, they should be added to the estimate of natural mortality calculated below (Palomares and Pauly 1998):

$$\log M = 0.0066 - 0.279 (\log L_{\infty}) + 0.65431 (\log k) + 0.4631 (\log T) \qquad (2)$$

where L_{∞} is the population asymptotic length of the Von Bertalanffy growth function (and is usually greater in populations of the past), k is the Von Bertalanffy growth parameter, and T is temperature in °C.

The Q/B ratio is calculated from an empirical formula published by Palomares and Pauly (1998):

$$\log Q/B = 7.964 - 0.204 (\log W_{\infty}) - 1.965T^* + 0.083A + 0.532h + 0.398d \qquad (3)$$

where T* is the temperature in °Kelvin, A is the tail aspect ratio (generally obtained from *Fishbase*), h = 1 for herbivores and 0 for all other groups, and d = 1 for detritivores and 0 for all other groups.

W_{∞} is estimated from the length weight relationship:

$$W = a+L^b \qquad (4)$$

where the a and b parameters are obtained from *Fishbase*.

Estimating natural mortality and consumption parameters for juveniles are more challenging, therefore in most instances these parameters for juveniles were assumed to be 1.5 x that of the adults. Sometimes it was not possible to estimate both the P/B and Q/B ratios for a group, and then the gross efficiency (GE) was assumed to be 0.2 and the P/B or Q/B was calculated by *Ecopath*.

Assumptions

Constructing models of the past involves making many assumptions for biomass, catch, etc. Also, there is generally no data available on past diets and one has to assume that the diet in the past was similar to that of the present. Usually, when balancing the model the diet is the first parameter that is changed. Thus, starting with today's diet and assuming that most species are generalists that would feed on similar species, the diet of the past is changed to balance the model. The assumption that past diets were not very different is vindicated by a paper showing that, in field studies on Georges Banks (Gulf of Maine), diets of many species changed in proportion as much as would be expected from the change in abundance and species composition (Link and Garrison 2002).

Conclusions

Constructing models of the past is not an exact science. Often the model obtained would seem closer to a Picasso painting than to reality (Figure 3, Heymans and Pitcher 2002a). In an abstract Picasso painting the parts of the whole are all present, but are not realistic in proportion or placement, and this creates the interesting reaction desired by the artist. In a painting by a great Renaissance master like Raphael, in contrast, things look as they do to the eye, although in fact subtle artistic artifice is employed to achieve this effect.

Similarly, an ecosystem model obtained by reconstructing the past incorporates most of the important groups and species that were present at the time period chosen, but the lack of information, and the quality of the available information influences the model. To counteract this problem it is advisable to describe the information and assumptions as well as possible, and to perform uncertainty estimations where possible. Testing for the effect of different input data on the emergent properties of the ecosystem is a valuable way of checking uncertainty. This needs to be done for the models of the *Coasts Under Stress* BTF project. Additionally, putting the errors for the main parameters into the *Ecopath* model can help later when the ecosystem model is used in simulation mode and the effects of parameter uncertainties on alternative polices can be checked. The aim eventually is to have ecosystem models of the past that encourage the familiar comfort of a Raphael rather than the shock of a Picasso.

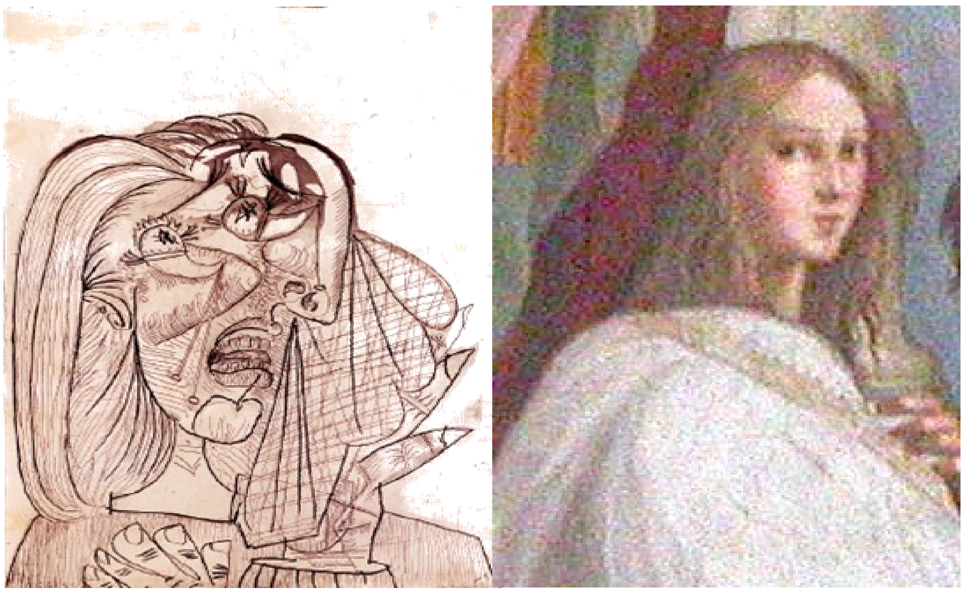

Figure 3. Paintings of attractive young women by Picasso and by Raphael. The Picasso creates a fascinating and shocking effect because all the right elements of the weeping woman (the artist's mistress) appear in a pastiche, but are placed in unexpected locations. The Raphael, on the other hand, appears as a luminous and accurate representation of a smiling young woman (the artist's wife), and whose artifice to deceive the eye is more subtle. The am is for ecosystem models of the past, perhaps initially comparable to a Picasso, to become more like a Raphael. *Pablo Picasso: Weeping Woman, 1937, etching/aquatint/drypoint. 49 x 69 cm, Museum of Modern Art, New York; Raphaello Sanzo: School of Athens (detail), 1510, fresco, 8 x 5.5 m, Vatican Museum, Rome.*

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For discussion following oral presentation of this paper, see page 136.

What Was The Structure Of Past Ecosystems That Had Many Top Predators?

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Abstract

Analyses of the ancient past, from historical sources, archaeology and reconstructions, suggest the presence of large numbers of top predators where few are found today. In mass-balance ecosystem models, these animals are not generally able to be supported by what are thought to be realistic levels of forage organisms. This paper examines the logic of this issue, and suggests that the problem may be resolved by evidence from archaeology and stable isotope analysis. In the past, more species may have occupied the forage fish niches and the diet of top predators near to carrying capacity may have been wider due to intra-specific competition.

Historical sources (e.g., examples in Mowat 1984) and attempted reconstructions (e.g., coastal ecosystems: Jackson *et al.* 2001; predatory fish: Myers and Worm 2003; sharks: Baum *et al.* 2002; whales: Roman and Palumbi 2003) all suggest that past ecosystems had many more large and long-lived top predators than we find today. Analysis of archeological remains also often suggests large predatory species where few are present today, for example, bluefin tuna along the whole western Canadian coast (Tunnicliffe *et al.* 2001, and see discussion page 139 this volume) and the North Sea (Mackinson 2001), and large old individuals of species in regions where they are represented by smaller, younger members today (e.g. cod and saithe at Skara Brae neolithic settlement, Orkney; Barret *et al.* 1999, Childe 1931, Clarke 1977). Moreover, compared to the present day, fishery exploitation was low in the ancient ecosystems (e.g., aboriginal fisheries in Newfoundland, Heymans 2003, Lucas 2004, this volume).

The issue in question here is that, when such large amounts of top predators are inserted into a mass-balance ecosystem model, a very large amount of amount of prey organisms is required as food to maintain all these animals. The

Pitcher, T.J. (2004) What was the structure of past ecosystems that had many top predators? Pages 18–20 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

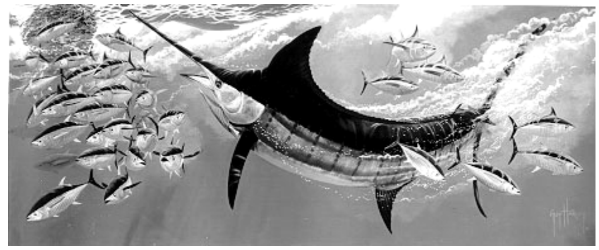

Figure 1. Top predators, like this blue marlin, may have been so abundant in ancient ecosystems that a very large amount of prey forage fish was required to support them. This paper discusses the ecosystem modelling issues raised by this possibility.

resulting biomass of forage animals is thought to be unrealistic compared to present day levels. We may ask if, in fact, this issue is some kind of artifact of the ecosystem modelling method, or a genuine conceptual problem?

On the modelling side, we may note that the P to B ratio of large old individuals of a species is far lower than the ratio characteristic of exploited populations today, and so adjustments in this respect are now routine in the creation of ecosystem models of ancient systems (see Heymans and Pitcher 2004, this volume, and e.g., Ainsworth *et al.* 2002). Nevertheless, even with reduced P/B ratios, surprisingly large forage fish biomasses can still result.

Some simple answers to the problem offer themselves first.

1. There were not so many top predators. The high abundance of top predators may actually be a false impression, based on anecdotes of those impressed by local patches of high abundance? For example, in the accounts of the first European visits to Newfoundland (Pope 1997, Williams 1996) we find what at first sight appear to be exaggerated references to cod so abundant that buckets full of the fish could be scooped up with little effort. Such reports may have been aimed, in part, at reassuring the late 15th Century financiers of expeditions to the New World that future gains would be considerable, as indeed they were. It is, however, a reasonable conclusion from the considerable archeological and documentary evidence that in ancient coastal ecosystems there were indeed large amounts of top predators, both in terms of species and in terms of large, old individuals, numbers and biomass. In addition to the references cited above, the work of Jackson *et al.* (2001) is perhaps the most significant in this respect.

2. A high biomass of forage fish is acceptable. A second simple answer is that a high abundance of

Figure 2. Discovered after a violent storm in 1850, Skara Brae, Orkney Islands, Scotland is the best preserved Neolithic village in northern Europe and offers a unique window into the lives of the fishers and farmers who lived there between 5,100 and 3,450 BP. Photograph shows a house with a stone dresser (rear wall) around which are three tanks for preparing fish bait. Middens from the site contain bones from huge cod and saithe (Barrett *et al.* 1999).

prey needed to feed these top predators may be actually acceptable. Biomasses in excess of 40 tonnes per km^2 are quite possible for small forage fish in upwelling or otherwise highly productive ecosystems (V. Christensen, pers. comm.). These fish may be highly productive, especially after a successful recruitment, feeding directly on blooms of phytoplankton and small zooplankton, with B/P ratios in excess of 3 in some cases. Although very high forage fish biomasses may be sporadic due to volatile recruitment, long-lived predators are presumably buffered against the fluctuations.

In some cases though, these simple answers may not be sufficiently convincing. Two more complex answers are discussed below.

3. *The diet of abundant competing predators was broader in the ancient past*. Populations of fish near their carrying capacity are not only comprised of large old individuals compared to exploited populations, but they are also characterised by high levels of intra-specific competition for food, space and other essential resources. This competition leads them to occupy all suitable habitat including the fringes of their normal range (MacCall 1990). For our purposes, the concept may be extended from the physical habitat to elements of their trophic niche. Competition at high population densities may lead to less successful individuals eating all manner of unlikely prey at the fringes of the normal diet. Hence, for this reason the breadth of the top predator population's diet may have been much wider than under 'normal' exploited conditions under which data on diets has been gathered today. In a mass-balance model of the ancient past, therefore, diet might be broadened to more species of likely prey animals, reducing the high biomasses of any one species required to support the abundant predators.

4. *More forage fish species were present in the ancient past.* A similar argument concerns the number of species of forage fish present ancient ecosystems. Where today forage fish often occur in single-species 'wasp-waist' ecosystems, in the past more species may have been present. According to Odum's ratchet (Pitcher 2001), species with low P/B ratios become locally extinct first under the joint influence of climate and exploitation (Dulvy *et al.* 2003, Christensen and Pauly 1997). Even today, several species of less abundant non-commercial small pelagic fish co-occur with dominant species such as herring, capelin and mackerel. In some areas, the biomasses of small non-commercial forage fish are not even surveyed (e.g. sand-lance in British Columbia). Hence, today's species composition for this group of forage fish may not be a reliable guide to the food web that existed in ancient ecosystems. Since both #3 and #4 entail adjustments to the diet matrix of the mass-balance model, both arguments may need to be taken into account.

How can these issues be resolved? One approach is to look for archaeological evidence of the relative abundance of forage fish species (e.g., van Neera *et al.* 1999). Here, care must be taken to apply a series of strict rules concerning the interpretation of archeological fish bones as being representative of what was present in the wild in ancient ecosystems (see Orchard and Mackie 2004, this volume). For example, values may be distorted by selective fishing, by taphonomic factors affecting relative preservation status, and, since forage fish are generally small, ineffective screening of middens for small bones (see discussion page 138). In some cases, accurate modern analyses based on bone collections that were made in the past may be prejudiced by inadequate preservation, provenance or stratigraphy (i.e., "problems of collection, retention, curation and context", see Leach and Davidson 2001).

Another helpful investigation would be to examine the breadth of ancient fish diets using stable isotope analysis on archeological remains.

Finally, it would be worthwhile to investigate the effect of the structure and breadth of the forage fish diet of top predators more rigorously and systematically using the *Ecopath* auto-balancing facility (Kavanagh *et al.* 2004).

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For discussion following oral presentation of this paper, see page 149.

THE PROBLEM OF EXTINCTIONS

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ABSTRACT

The extinction of species causes problems when, to enable comparison of emergent properties, a series of ecosystem models constructed through time must have a similar structure. Global extinctions are irreversible and approximate representations of such species in models of ancient ecosystems relies on historical and archeological information about their ecology, diet and growth. As a short-cut to preserve model structure, extinct species may sometimes be grouped with species of a similar function in ecosystem models. Local extinctions ('extirpations'), on the other hand, are potentially reversible by natural recolonisation, or by human re-introduction. Ecosystem modelling therefore needs to be able to capture this reversibility by explicitly including such species. Currently, it is especially difficult to model the effects of keystone species, such as sea otters, whose biomass level directly alters habitat structure.

Global extinctions of species, such as the great auk in the North Atlantic (Montevecchi and Kirk 1996), or Steller's sea cow in the North Pacific (Anderson 1995), mean that there is little choice but to eliminate these species from future restoration goals in the Back-to-the-Future process. Local extinctions (= 'extirpations'), on the other hand, are potentially reversible by natural recolonisation or by human re-introduction. But for comparison between the emergent properties of the series of whole-ecosystem models in BTF, it is important for all of the models to have the same number of compartments, although of course biomasses and fluxes can be vastly different. Similarly, ecosystem simulations that span two or more different models need all the compartments to be included in both models. Extinction of species makes this comparison difficult. What can be done in ecosystem modelling, therefore, when species have become locally or globally extinct? How may these factors be accommodated in the suites of ecosystem simulation models used in BTF? Before answering these questions, I review marine species that have become globally or locally extinct in our two CUS BTF ecosystems.

Pitcher, T.J. (2004) The problem of local extinctions. Pages 21–28 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

Figure 1. "Actually, there were three arks. The one with dinosaurs and other extinct forms sank due to overcrowding. The one with marsupials was blown off course and landed in Australia." A brave attempt to explain extinctions and biogeography. See www.christianforums.com/t40474&page=2.

GLOBAL EXTINCTIONS

The great auk, *Alca impennis*, was a large flightless, pelagic species of the *Alcidae* (auks) in the North Atlantic, and the original recipient of the name penguin (pen-gwyn, meaning 'white head', the winter plumage, in Welsh and Gaelic), a name later transferred to an entirely different order of Southern hemisphere birds (*Spheniscidae*). Hunting by humans, usually at island breeding sites, rendered the piscivorous great auk extinct by 1844 (Figure 2). Although the bird had been eaten for thousands of years by coastal peoples, in the late 18^{th} and early 19^{th} Centuries great auks were harvested for food, feathers and eggs on an astounding scale. For example, during the Napoleonic wars, Britain mitigated a blockade of Grand Banks' cod by importing shiploads of great auks from the

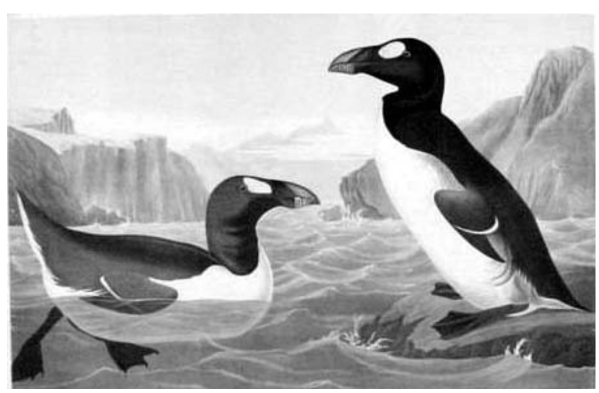

Figure 2. The flightless North Atlantic 'Penguin', Garefowl, Spearbill or Great Auk, *Alca impennis*, a 70cm, 5kg seabird once harvested by the shipload throughout the North Atllantic, and hunted to extinction by 1844. *John J. Audubon, chromolithographic print, The Birds of America, 24 x 36. San Joaquin County Public Library, USA.*

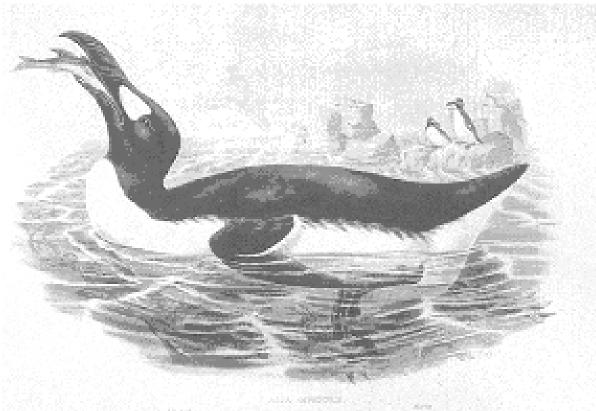

Figure 3. The great auk eating an adult capelin. Few North Atlantic seabirds eat such large prey today. *W. Imp, J. Gould and Whart 1840, coloured lithograph, 38.1 x 54.8 cm, J.H. Fleming Library, Ornithology Collections.*

islands off Iceland. Soon, there was a boisterous and increasingly lucrative international trade in diminishing numbers of great auk eggs, skins and skeletal remains in late Victorian times. Despite unconfirmed reports of sightings up to the early 20th century, the financial incentives brought about by this trade likely ensured that there are no surviving colonies. For example, the last pair of birds seen in Iceland was killed for sale, together with their egg (3rd June, 1844).

The classic study of the biology and demise of the great auk was published by Grieve (1885), and a recent book provides a thorough review (Gaskall 2000). Using data from archaeological remains in middens and from the sites of what appears to have been industrial-scale processing, Sarjeantson (1996) shows how the flightless great auk was wiped out, while the gannet, which was also exploited heavily but can fly, has avoided the same fate. Evidently, there was a population of at least a million birds in the North Atlantic before 1830 (Montevecchi and Kirk 1996), and middens suggest a far greater population over a wide range from Florida to the Bay of Biscay throughout the North Atlantic, and even the Mediterranean, in pre-historic times.

Although there is no quantitative data, fish species eaten by the great auk, which could dive to a depth of at least 10 metres, can be reasonably well deduced from some contemporary descriptions (see Grieve 1885). The diet likely consisted of pelagic fish such as capelin (Figure 3), herring and sandlance offshore, and large sculpins and juvenile cod when feeding inshore during the breeding season. For ecosystem modelling, metabolic parameters for this large bird might be taken as similar to the larger southern hemisphere penguins.

Hence, there is certainly data enough to include great auks explicitly in mass-balance models of ancient North Atlantic ecosystems and to make preliminary biomass estimates based on diet and the other *Ecopath* parameters. But, in most cases, seabirds have such a small biomass and impact in marine ecosystem models that they are usually grouped into functional categories, such as invertebrate eaters, piscivores, inshore ducks and the like (Burke *et al.* 2002). In fact, in the CUS BTF North Atlantic models to date, the great auk has been grouped with other piscivorous seabirds (Heymans *et al.* 2002b, Davoren *et al.* 2002). This means that, provided the great auk's diet and metabolic parameters are represented in the appropriate functional group in the model, no special assumptions have to be made (Heymans *et al.* 2002a). This device also has the advantage that the group structure of the series of BTF ecosystem models remains the same over time. But the trick has the disadvantage that the possible impacts of the great auk's extinction on ecosystem structure cannot be explored. Since the great auk was clearly major predator of medium-sized fish, this would be an interesting topic to explore in the future.

In the 18th Century, the North Pacific was the location of two other dramatic global extinctions. In 1741 on the Komandorski islands at the extreme west of the Aleutian chain, Steller found

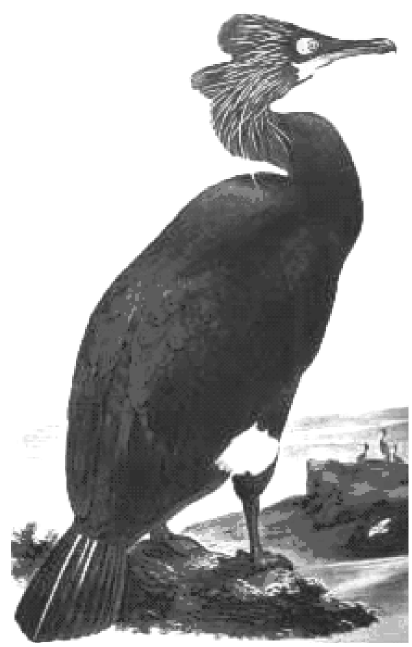

Figure 4. The extinct spectacled (= Pallas') cormorant, *Phalacrocorax perspicillatus* a 5kg flightless bird found by Steller in the Komandorski islands in 1741. Only 7 museum specimens of this North Pacific penguin-like bird survive and very little is known about it.

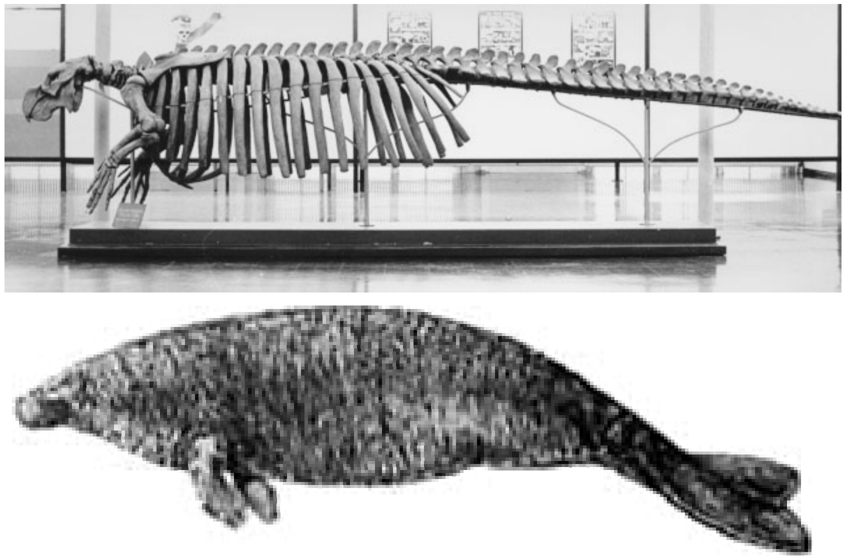

Figure 4. The Sea Cow was discovered by Steller in 1741, all were killed by 1769. *Upper panel:* one of the few extant skeletons in the Helsinki natural history museum. *Lower panel:* likely reconstruction of a Sea Cow (Hans Rothschaur, Germany). These sirenians were 7.5m long, weighed up to 11 tonnes, lived in herds close inshore, and appear to have eaten kelp and red algae.

a flightless spectacled cormorant, *Phalacrocorax perspicillatus* (Figure 4). He also discovered the Sea Cow, or rhytine, *Hydrodamalis gigas*, a large herbivorous sirenian (Figure 5).

Georg Wilhelm Steller, a stern, meticulous German, studied at the University of Wittenberg and then, after a spell as an army surgeon, worked in Russia at the Academy of Sciences in St Petersburg. Steller was 33 years old when he was employed as the naturalist on Janasson ('Vitus') Bering's 1741 expedition from the Tsarina Anna's Russia to the region between Asia and America. Anna had emerged as Empress in 1730 from the turmoil following Peter the Great's sudden death in 1725, and adopted the same expansionist agenda. Bering himself was a Dane serving in the Russian navy. The expedition was a tough call; among the hardships were scurvy, losing the other half of the expedition in a storm, shipwreck, over-wintering on what came known as Bering Island, and having to salvage wood to build a replacement ship[1]. Soon after the shipwreck, Vitus Bering died of scurvy that winter, along with half of his crew. But the tough naturalist Steller impressed the crew by searching out plants to treat scurvy[2]. By the next summer, the survivors began to hunt and eat the sea-cows and they left the island with barrels of salted sea cow meat[3]. They also hunted and ate the large, flightless cormorant of which Steller wrote, "They weighed 12-14 pounds, so that one single bird was sufficient for 3 starving men."

Immediately after the expedition's return, Siberian fur traders flocked to the Komandorski islands, trapping foxes and sea otters for fur. They used the sea cows, said to be similar to almond-flavoured veal, and the flightless cormorants as a living larder. Sea cow blubber was used for cooking and as lamp oil, the milk of slaughtered cows was made into butter, and the tough hide was used for shoes, belts and skin-covered boats. The animal soon became rare, and although an order prohibiting hunting of the sea cows[4] was sent from St Petersburg to the Komandorski Islands on November 27th, 1755 (Domning, 1978), hunting seems to have continued. The last report of a sea cow being killed was in 1768.

The spectacled cormorant lasted longer, its last stronghold until 1850 being the small island of Aij Kamen (Stejneger 1889).

As well as an island, Bering got a sea named after him (on account of a filing error it seems, see Pitcher 1999). Steller ended up lending his name to an eider duck, a jay, a sea-lion, a rock-trout, an eagle and the sea cow. Also, unexpectedly, his name was used posthumously for Stellerite, a kind of silicate crystal found on the Komandorski Islands in 1909. Hounded by the Tsarist bureaucracy for humane treatment of some prisoners, a drunken Georg Steller died a miserable death in a snow storm at Tjumen, a Siberian town to the east of the Ural mountains, in November 1748, only four years after the expedition. Fortunately his notes (written in Latin under the harsh conditions of the island shipwreck) were preserved, and were retrieved, edited and published by P.S.Pallas (1781)[5],

[1] Only one man, Sava Starodubtsov, a Siberian carpenter, thought that he remembered how to build a ship. The 46 surviving crew depended on his knowledge for their lives.

[2] Sven Waxell, one the ship's officers, said that Steller, although stern, was "a great botanist and anatomist, well versed in natural science". Steller saved the life of Waxell and his son. He named over 50 new species of animals and plants on the expedition.

[3] A preserved sea cow carcass, and many other specimens, had to be left behind.

[4] In 1754, an envoy of the Tsar wrote that sea cows were being exterminated at such a rate that they would soon be eradicated. Groups of two or three hunters from Kamchatka, the envoy wrote, were "inflicting huge waste and destruction".

[5] And translated into German (Pallas 1781).

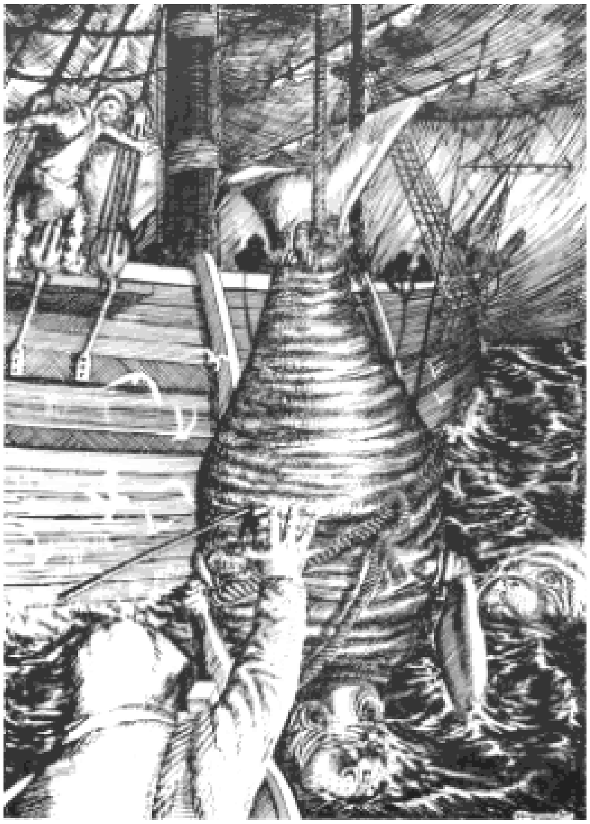

Figure 5. 18th century engraving of a Steller's Sea Cow, *Hydrodamalis gigas*, being captured for food on Bering island by a ship's crew in the mid-1700s.

himself a German naturalist of repute working in St Petersburg, with a cat and several birds, including that flightless cormorant, named after him.

Some believe that small colonies of Steller's Seacows still live in remote areas of the northern oceans. In 1962, the crew of a Russian whaler reported seeing six animals that resembled sea cows, feeding in the Gulf of Anadyr, north of Kamchatka. In 1977, a Kamchatkan fisher reported seeing a drifting animal that matched the description of a sea cow (M. Raynal; http://perso.wanadoo.fr/cryptozoo/dossiers/rhytine.htm). Possible reports of sea cows before Steller might lend support to this idea. For example, in 1609 Henry Hudson reported animals that fit the description of sea cows near Novaya Zemlya. There are also reports from Greenland and other Arctic ocean sites But if these earlier reports from pan-arctic sites are correct, sea cow populations must have undergone a serious range collapse in the 17th Century before being described by Steller, or they would surely have been found by the many North Atlantic expeditions of the time. Sea cows were distinctive, large, impressive animals, forming obvious pair bonds, living inshore in small herds with juveniles, and Steller (1751) even reports them coming to the aid of stricken animals. If their pan-arctic demise was due to recent human predation, there would surely be Traditional Knowledge and Myth concerning these massive social animals among today's native peoples of the arctic.

Archeological evidence places sea cows along the Pacific coasts of Asia and North America as far south as Japan and northern California. Their ease of capture and suitability for providing large amounts of human food would, like other North American megafauna, have rendered them susceptible to the 'clovis' hunting tools of first North Americans 12 to 15,000 years ago (Alroy 2001, Martin 1984). Most of the sites of slaughter and butchering would today lie submerged as a result of rising sea levels after the ice age (see Josenhans *et al*. 1997). It is interesting that the present coastal peoples of the Pacific North-West, whose DNA suggests that they arrived from Asia 6-8000 years ago (Morel 1997), have no knowledge or cultural memory of sea cows. It is likely then, that sea cows were wiped out by hunting very soon after boat-building humans inhabited the Asian shores of the North Pacific 35,000 to 25,000 BP (Erlandson 2001). The abundant food (shellfish, finfish, marine birds – including those flightless cormorants - and mammals) available from North Pacific kelp forests probably attracted early maritime people, and, it is thought, may have facilitated the earliest migrations of people from Eurasia to the Americas. It is possible that the whaling tradition of indigenous people of the North Pacific began with the over-harvest of the predator-naive and defenceless Steller's sea cow, focusing thereafter on cetaceans that were more difficult to harvest (Domning 1972). What Steller discovered on the uninhabited Komandorski islands then, was a living remnant population of one of the Pleistocene megafauna.

There is sufficient historical information about sea cow diet, and reasonable inferences about metabolism may be made from extant sirenians, for us to attempt to model them explicitly in a mass-balance ecosystem model (Stejneger 1886). The animals seem to have lived mainly inshore, near to sources of fresh water (Domning 1976). Steller's account indicates that the sea cow fed mainly on soft brown kelps and red algae, with a little sea grass. Anatomical adaptations to the sea cow's mouth and gut seem to fit with this. The huge sea cow gut seems to have been an adaptation to digest large amounts of poorly masticated algae. There were no teeth, only horny lips and upper palate for rasping algae from the

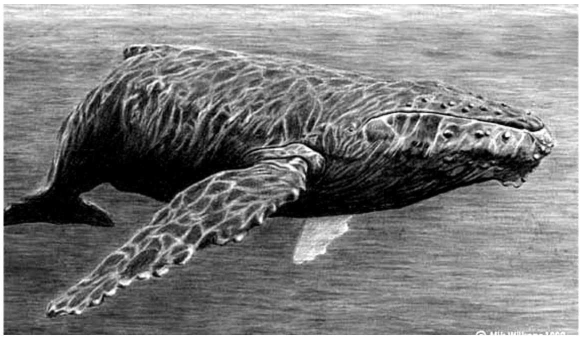

Figure 6. Two hundred Humpback whales, *Megaptera novaeangliae*, were common residents in the Strait of Georgia, BC, before commercial whaling wiped them out early in the 20th century. Nowadays, they may be slowly returning.

rocks. Steller says that large amounts of torn and dislodged kelp floated around sea cow feeding sites. Metabolic parameters for dugongs, 3 metres in length, could be scaled to reflect the slower turnover and larger body size of the sea cow (Pitcher 1998). Sea cow predators would have been mainly killer whales and perhaps cold water sharks. A starting value for sea cow biomass in a model might come from the estimated 5000 population in the area around the Komandorski islands. Assuming an area of 100km by 50 km around the islands, this amounts to an average biomass of about one animal per km^2 in inshore habitats, or about 7.5 tonnes per km^2.

As yet, no-one has attempted to construct an inshore ecosystem model that contains sea cows grazing kelp. In fact, it seems that kelp canopies are remarkably resilient to cropping of the distal fronds (Steneck *et al.* 2002). A multi-million dollar industry of canopy-cropping factory ships sustainably harvest kelp in California with little permanent damage to the kelp forests (Tegner and Dayton 2000). It is therefore unlikely that sea cow grazing of canopies deforested kelp beds. But the large quantities of kelp grazed would have dynamic effect on the kelp forest canopy structure, and would alter strategic cover and hence the survival of many inshore fish and invertebrates. And so, in contrast to most pelagic systems where floating phytoplankton comprises the food of higher trophic levels, these factors would make a sea cow/grazed kelp system structurally similar to many terrestrial ecosystems. Modelling the ecosystems of terrestrial game parks, or even dinosaur ecosystems, would make fascinating work in terrestrial or palaeo-ecology. Changes to the modelling framework to deal with habitat structural elements directly would be required, as discussed below.

LOCAL EXTINCTIONS: ABSENT BUT POTENTIALLY RESURGENT SPECIES

When species have become locally extinct ('extirpation' in conservationist language), one has to allow the possibility that they may return, either through natural migration or though active reintroduction.

An example of natural recolonisation is the humpback whale in the Strait of Georgia, British Columbia. More than 200 humpbacks were resident until wiped out by commercial whaling , a process that was complete by the 1920s (Gregr 2002, Winship 1998, Merliees 1985). Humpbacks now seem to be making a slow return to the Strait (Gregr 2002). Hopefully, simulation models may be able to capture this process of recolonisation. On the other hand, in Newfoundland, almost a quarter of a million walrus were estimated to be resident before exploitation started in 1800 (Mercer 1967), but have shown no signs of returning. Grey seals in Newfoundland have a similar status (see Heymans and Pitcher 2004, this volume). As with the globally extinct species discussed above, estimates of ancient biomass may be based on historical records of breeding sites, or, in the case of whaling, on records of whale kills.

Archeological remains of fish bones in middens show that Bluefin tuna, *Thunnus thynnus*, were at one time distributed along the entire coast of British Columbia and Washington state (Tunnicliffe *et al.* 2001, and see discussion page 139). Traditional Environmental Knowledge concerning weather and seasons for the hazardous spearing of these fast, giant fish

Figure 7. A sea otter, *Enhydra lutris*, eating a sea urchin. Sea otters were common residents along North Pacific coasts before being hunted for fur in the 18th and 19th centuries, and were wiped out in British Columbia. In recent years, sea otters have been re-established on Vancouver Island. Ecosystem modelling of sea otters is tricky because they are keystone species, altering the structure of inshore habitats.

suggest that they were seasonal visitors to coastal habitats depending on weather and conditions (see Lucas, 2004, this volume). However, they appear to be entirely absent from the region today.

Figure 8. Print of an Aleut sea otter hunt at Sanak Island, Alaska. Aleuts have been hunting sea otters for over 2500 years and devised a special whale-bone barbed dart that detaches from a shaft on contact with the otter. (See also Lucas 2004, this volume.)

To accommodate dynamic ecosystem modelling, groups that are present early on, but are later absent, have to be included in some way. As mentioned above, unless the species has been grouped with species of similar function, it is important to include in all time periods species that have become locally extinct over period of the series of ecosystem models. One technique that has been used for the Newfoundland series of CUS BTF models (1750, 1900, 1987, 1995: Vasconcellos *et al.* 2002), is to set biomass for the 'absent' periods to extremely low levels (zero cannot be used as it causes a software failure). For example, a value of $1*10^{-6}$ tonnes/km^2 has been used for walrus in models of recent Newfoundland ecosystems. At this low level they are essentially extinct (Heymans and Pitcher 2004, this volume). This technique, however, can create some technical problems as, during simulations, the species may undergo an unexpected modelling resurgence if there is enough food for them to do so. It may be possible to 'hold them down' using a biomass forcing function in *Ecosim* (see Martell 2004, this volume and discussion page 149).

An example of active re-introduction of an extirpated species is the sea otter, *Enhydra lutris,* reintroduced to from Alaska to Vancouver Island in British Columbia in the 1990s (see Lucas 2004, this volume). Sea otters became extinct through hunting in BC before 1900 (Kenyon, 1975), but following reintroduction, today have a established a small but increasing biomass in few areas. Sea otter diet and metabolic parameters are well-known (e.g., Bodkin *et al.* 1998, Reidman and Estes 1998) and it is not difficult to incorporate sea otters in ecosystem models (Ainsworth *et al.* 2oo2). The series of models for northern BC should ideally reflect the series of changes: abundant in the ancient past, absent after they were hunted to local extinction for their furs, and then re-introduced. But it is proving hard to include them explicitly in the models for every time period, and in models of restored BTF 'Lost Valley' ecosystems because, at very low biomass, they have 'plenty of food' and tend to undergo a modelling resurgence.

Problems in Modelling Keystone Species

An additional major problem for the BTF modelling here is that sea otters, however, are keystone species, causing large changes in habitat structure (Pitcher 1998, Simenstad *et al.* 1978). They alter the type of kelp available as cover to a suite of juvenile fishes and invertebrates by foraging on kelp-eating sea urchins that themselves graze selectively (Riedman and Estes 1990). The consequence is that inshore kelp ecosystems with and without sea otters have very different habitat structure and a different fauna of inshore fishes and invertebrates (Steneck *et al.* 2002).

When sea otters were extirpated in the Komandorski islands through hunting, this keystone mechanism may have helped to seal the fate of the sea cow: resurgent kelp-eating urchins would have competed for kelp as food (Anderson 1995).

The open canopy habitat known as 'kelp forest' appears to be dependent on the presence of sea otters (Steneck *et al.* 2002). Before human contact, predation by sea otters on urchins prevented overgrazing on kelp forests (Simenstad *et al.* 1978, Estes *et al.* 1998). In Alaska, Aleuts seem to have depleted sea otters as early as 2500 BP, causing the urchins to grow larger (Simenstad *et al.* 1978). From 1700, fur traders hunted sea otters to the brink of extinction, and kelp forests were then destroyed from over-grazing by urchins released from sea otter predation. Then after 1900 in Alaska, legally-protected sea otter populations increased, and the resultant trophic cascade re-established the kelp forest. Recently, however, kelp forests have disappeared again as sea otter populations have fallen prey to killer whales (Estes *et al.* 1998), that have shifted their diet to otters from pinnipeds after the latter populations declined significantly. The reason for the pinniped declines is still open to debate (Rosen and Trites 2000).

The sea otter's keystone effect is mediated through habitat change that in turn alters feeding opportunities and refuge from predators for inshore fish and invertebrate species (Estes *et al.* 1989). Most of these changes are based on a living biomass acting as complex structured habitat, not on feeding interactions in a food web, and hence a purely trophic web model cannot simulate them. A routine to put 'non-trophic' mediation effects in *Ecosim* has been developed (Christensen and Walters 2003), but it is hard to fit the parameters for the interaction in anything other than a post-hoc fashion. In other words, keystone effects, like the sea otter, may be emulated in *Ecosim*, but not simulated.

The problem here is that spatial complexity and structure of habitats are not modelled explicitly in the EwE dynamic ecosystem system. For aquatic ecosystems this may be acceptable for the majority of cases, except where rooted macrophytes or coral reefs are involved, but it would be entirely unacceptable for most terrestrial ecosystems where plant architecture, both living and dead, provides a template of structured habitat for the vast majority of organisms. Alternative ecosystem modelling techniques, such as 'Atlantis' (Fulton *et al.* 2003), may be more appropriate in representing the effects of 'plant architecture'.

CONCLUSIONS

Extinctions cause problems for dynamic ecosystem modelling. This paper has put forward some suggestions about how these issues may be tackled, but some fresh advances in ecosystem modelling techniques are needed before we can approach species extinctions with confidence. BTF is one of the few fisheries policy analysis systems to explicitly and quantitatively deal with the extinction issue (Pitcher 2002).

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For discussion following oral presentation of this paper, see page 149.

CHALLENGING ECOSYSTEM SIMULATION MODELS WITH CLIMATE CHANGE: THE 'PERFECT STORM'

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ABSTRACT

When ecosystem models of the past are constructed, appropriate climate regimes need to be incorporated. Likewise, the effects of possible future climate changes on ecosystem structure and function must be included in forecasts of sustainable fisheries in reconstructed ecosystem. This paper examines how these issues might prejudice the BTF policy process. We show examples of models driven by inter-annual climate indices or by direct indicators of primary production.

Alterations in ecosystem structure due to climate change represent a major challenge to Back-to-the-Future (BTF) investigations. Climate changes that need to be addressed in BTF ecosystem simulations span time scales ranging from short inter-annual fluctuations to the major long-term shifts that result in ice ages. There are two aspects to the problem and each of them forms the basis of one of the most common criticisms of the BTF approach. First, the reconstruction of past ecosystems to use as future policy goals may be prejudiced if those past ecosystems existed under different climate regimes. Secondly, BTF relies on forecasts made by sustainably fishing restored past ecosystem states in which simulations are projected into the future – the 'fished Lost Valley' scenarios – and so these forecasts may not be viable unless likely climate change is taken into account. The two aspects of the problem differ fundamentally in scientific terms. Past climate changes are inherently knowable, can be estimated from reported observations, and these estimates, if poor, can be improved. Future climate changes, in common with all scientific forecasts such as weather forecasting, are unverifiable until the specified future time is reached, and so the best we can do is to project a series of likely scenarios, some of which may be more likely than others. In its most serious form the 'climate change' criticism goes something like this. Even if the climate of past times is well understood and the ecosystem models of the past adjusted accurately to take account of those changes, past ecosystem states cannot be used for future policy goals. We can expect climate to induce differences among past ecosystems, the present day ecosystem from which we have to commence the reconstruction process, and the projected future. This paper aims to analyse these issues and assess the degree to which the BTF process might, in practice, be prejudiced by them.

Pitcher, T.J. and Forrest, R. (2004) Challenging ecosystem simulation models with climate change: the 'Perfect Storm'. Pages 29–38 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

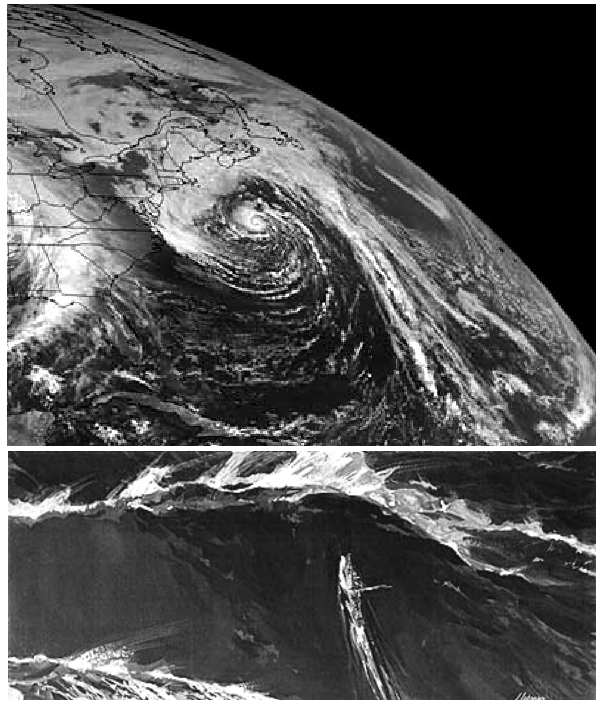

Figure 1. On November 1st 1991, the 'Perfect Storm' in the north-western Atlantic was accurately forecast by meteorologists (*top panel: composite radar picture, NOAA*) and many lives were saved, even though the swordfish vessel, the *Andrea Gail*, sank with all hands (*lower panel: pre-production watercolour from film*) because they ignored the warnings (Junger 1997). The science of weather forecasting is pretty good these days, although, in October 15th 1987 the British meteorological office was blamed for failing to predict the most damaging storm (18 people died) to hit southern Britain since 1703 (26th November, 8000 people died; Sutton 2003). Likewise, it may be both encouraging and hazardous to attempt to forecast the state of marine ecosystems under the influence of inter-annual climate fluctuations, climate-induced regime shifts and one-off catastrophic events.

Types of climate change

Oceanographic influences on the living organisms in marine ecosystems are mediated ultimately through temperature and ocean circulation currents. Proximal factors driven by these changes affect thermocline depth and the upwelling of nutrients from sediments that determine phytoplankton production. Freshwater runoff, driven by rainfall, and ice melt, driven by temperature, can also have a profound influence

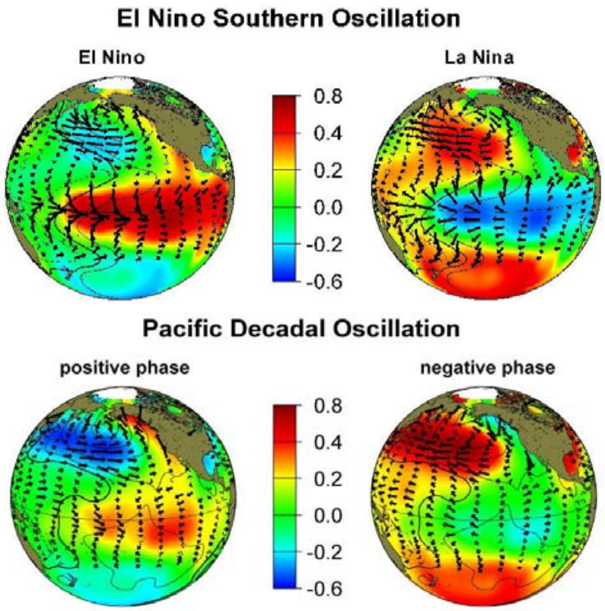

Figure 2. Temperature contour and water flow diagrams showing ENSO and PDO from a North Pacific perspective. Colour-scaled values are degree Celsius deviation from long-term mean (from NOAA).

on inshore marine ecosystems. Changes in ocean currents are important in the physical dispersal of planktonic larval stages of fish and invertebrates. Temperature changes can affect fish physiology directly, but can also determine global wind patterns, that in turn affect ocean currents. Hence, a complex of climatic factors affects the templates of habitat offered by the marine environment to the suites of organisms that compose its ecosystems (Review: Barange 2002).

Time scales of climate change

These climate influences occur over a range of time and spatial scales. Seasonal climate changes are those with which we are most familiar and, especially in polar regions, can have a dramatic effect on the structure and functioning of marine ecosystems. In this paper the ecosystem modelling in which we are interested is based on annual changes in biomass, and so seasonal changes are not considered further here, although they can be incorporated into *Ecosim* modelling (S. Martell, unpublished). Inter-annual changes include more-or-less random fluctuations in temperature and ocean currents from year-to-year, whose variance is characteristic of a particular geographical location. It is this variance that is most likely to increase under the influence of a global warming trend.

Inter-annual changes also include major ocean forcing such as El Niño (male child), named because the main effects occur at 'navidad' (Christmas). Its primary effect is to shift the equatorial current in the tropical Pacific to a greater or lesser degree, with a time span for its effects of 6-18 months. Spring warming of the sea to the north of Indonesia causes the Eastward warm equatorial current to increase. This current then swings poleward off South America to displace and overlay the cold northerly Humboldt current, with origins in the Antarctic ice melt, whose upwelling normally drives exceptional marine production off Peru. Exactly what triggers El Niño to start is not yet known, although the Earth's spin is reduced by the mass of less dense warm water. The opposite effect, La Niña, gave rise to the concept of ENSO (El Niño Southern Oscillation: Figure 2). Although based in the central and southern Pacific, ENSO's influence extends to the North Pacific, Indian and Atlantic oceans. Records up to the 1970s indicated major ENSO events occurring about once every 15 years, but in the past two decades they have become up to three times as frequent.

Medium-term, quasi-cyclic changes occur over larger ocean regions on decadal time scales, for example the Pacific Decadal Oscillation (PDO: Figures 2, 3) with a period of 20-30 years. These are major shifts in currents and temperatures,

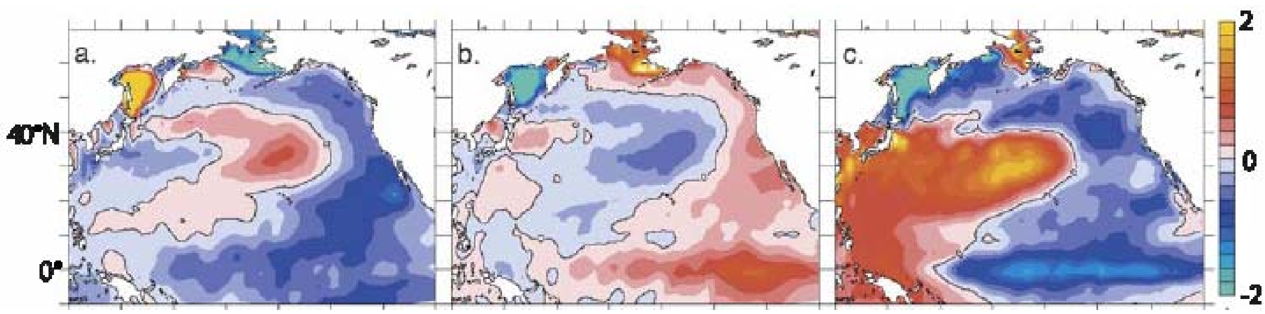

Figure 3. Recent changes in the Pacific Decadal Oscillation (PDO). Clear evidence of decadal regime shift revealed by sea surface temperature anomalies in the North Pacific. (NOTE: coloured figure may not show up well in grey scale). Panels show left-to-right, (a) 1970-1976, cool phase of PDO; (b) 1977-1983, warm phase of PDO; (c) 1999-2003, strong cool phase of PDO. These temperature changes are paralleled by sea level pressure and wind patterns. (Diagram from Peterson and Schwing 2003.)

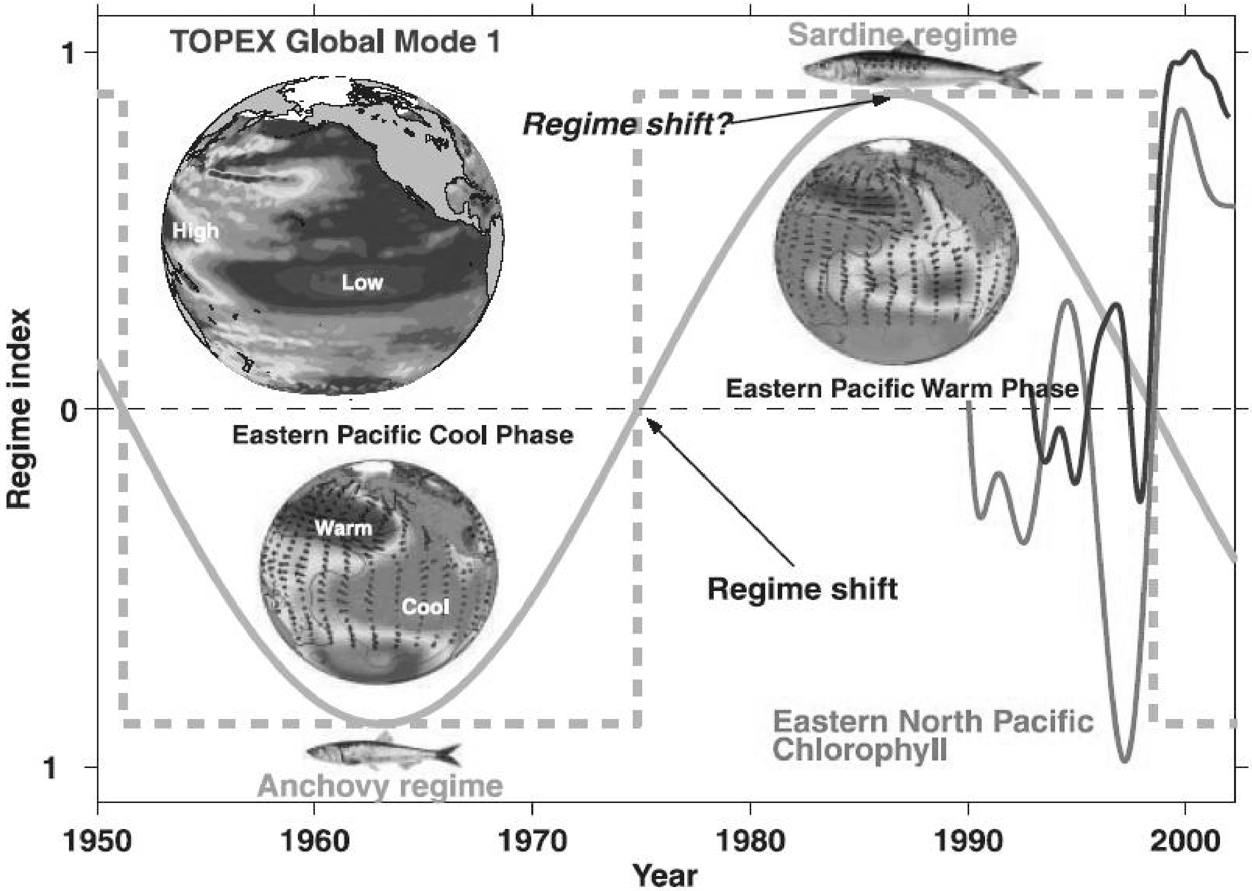

Figure 4. El Viejo/La Vieja marine climate regime analysis for the Pacific. In cooler conditions, anchovies dominate (La Vieja), while in warmer regime (El Viejo) sardines are abundant. Spatial SST and atmospheric circulation anomalies are shown for each regime (globes). Note that the eastern Pacific is out of phase with the central North and South Pacific. Some indices suggest rapid shifts (dashed line), whereas others are gradual (solid line). Low sea surface height (TOPEX) and high chlorophyll (California Current) in the cool anchovy regime mean a shallow thermocline/nutricline. Associated basin-scale current systems support recent stronger California Current and a weaker Kuroshio Current. (Diagram from Chavez *et al.* 2002).

sometimes occurring rapidly between relatively stable periods. A number of longer-term cycles have been suggested (e.g. Klyashtorin 2001), the most compelling of which is an approximately 62-year cycle in the Pacific, termed El Viejo/La Vieja [old man/old woman] (Chavez *et al.* 2003) (Figure 4). Very long-term climate trends can lead to ice ages and consequent sea-level changes. In addition, there is good evidence for a dramatic human-made recent global warming trend (Figure 5).

Four questions are critical to the use of climate influences as a part of the BTF process. (1) Can we drive and/or tune past models using time series of climate or surrogate climate data? (2) Are these models stable? (3) Are the observed biomass dynamics realistic and do they emulate observed regime shifts? (4) Can we determine and 'lock on' to the appropriate state of ecosystem for the model of a past time period?

HOW DO CLIMATE CHANGES AFFECT AQUATIC ECOSYSTEMS?

The vast majority of papers in the 'effects of climate on fisheries' literature describe climate impacts on a single species at single geographical location, and only a few deal with populations of the same species over a wider geographical area. As might be expected, a fair number of well-argued publications supported by solid data cover the impact of climate changes on fisheries recruitment. There are also a small number of synoptic, global-scale analyses of climate-induced changes to groups of fisheries of interest such as the small pelagics. There are very few attempts (e.g., Barange 2002) to deal with the integrated effects of climate on whole ecosystems, and even fewer attempt to compare ecosystem-scale effects over wide areas. This paper therefore includes a review of recent publications that shed light upon the ways in which climate changes alter fish

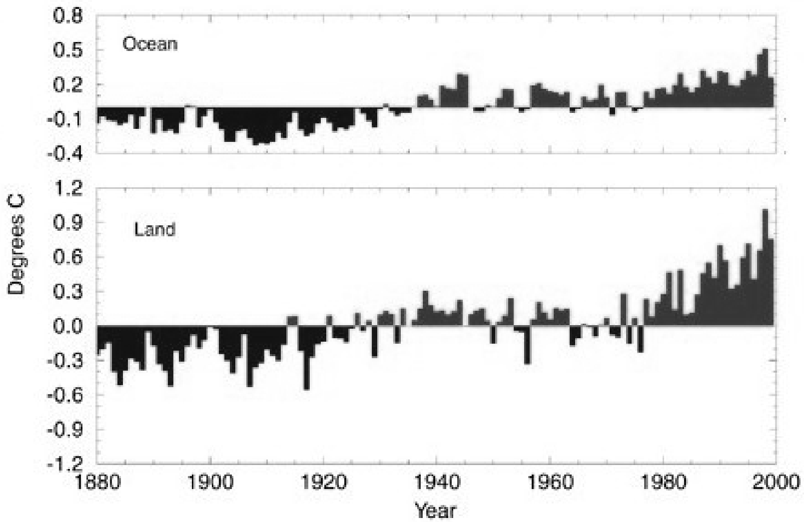

Figure 5. Global warming trend shown in average annual global temperate anomalies, 1880-2000, from land and sea. Source: National Climatic Data Center, NOAA, USA.

populations and fisheries within an ecosystem context.

It seems that shifts in ocean climate regimes can alter ecosystem structure quite quickly, and these may be faster at lower trophic levels (Barange 2002, Hare *et al.* 1999). Changes in wind patterns affect oceanic circulation, salinity, thermocline depth and primary production; changes in the distribution and abundance of predators and prey influence fish, marine mammal and bird populations (Barange 2002). Sometimes changes can affect similar species within a single domain in opposite ways. Surprisingly, some hold that climatic regime shifts can have opposite effects on the same species in different ocean domains (Benson and Trites 2002).

Fish growth is often affected directly if water temperature alters (e.g., halibut; Clark *et al.* 1999), but there is usually little attempt to partition this effect into a direct metabolic influence and indirect effects mediated though the food web. Extreme temperatures can directly affect the physiology of migrating salmon (Hinch *et al.* 2002).

It is well documented that climate shifts can have a serious impact on fisheries (e.g., Japan; Kawasaki and Omori 1995), especially when they coincide with overfishing, as in the classic collapses of the Monterey sardine in the 1950s and the Peruvian anchoveta in 1971 (see accounts in Pitcher and Hart 1981). And, more recently, recruitment of cod in the heavily overfished North Sea appears to be threatened by climate warming trends (O'Brien *et al.* 2000).

Time series of catches and other data often suggest synchronous changes over large ocean basins, suggestive of climatic and oceanographic factors at work in determining abundance. For example, using catch time series several centuries long from the Mediterranean and adjacent Atlantic areas, Ravier *et al.* (2001) demonstrated 7-fold fluctuations in abundance, and synchronised 100-year and 20-year cycles, in the traditional tuna 'tonnara' trap fisheries that formerly caught bluefin tuna on their annual spawning migrations Moreover, coherent patterns observed across large regions of the Pacific demonstrate the strong role of climatic forcing in determining the size fish populations (Hollowed *et al.* 2001). Catch records suggest that warmer years and regimes may lead to higher fisheries production (e.g., sablefish; King *et al.* 2001) in higher latitudes (e.g., Beamish 1993).

Fishery catches, however, may be influenced by a number of factors and so other means have been explored to examine climate-linked changes. For example, nitrogen isotopes in lake sediments demonstrated large changes over 300 years of Alaskan sockeye salmon abundance related to climate (Finney *et al.* 2000). Similar analyses

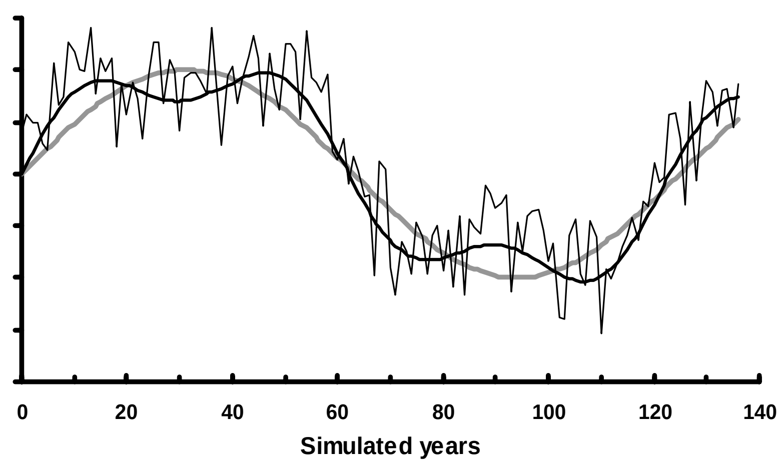

Figure 6. Simulated climate influence time series constructed from 62 and 20-year cycles (sine waves), and ENSO anomaly (triangular probability distribution). Note that coincidence of two cycles can lead to 'rapid shift of regime', and to 'stable plateau' periods. Authors' simulations show that these effects depend on relative wavelengths and starting point.

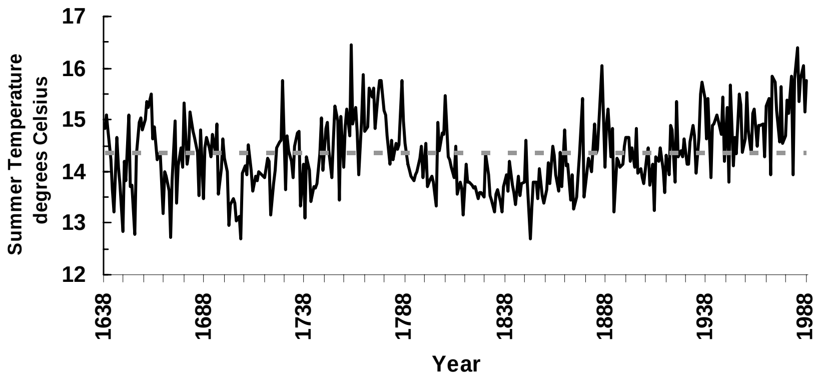

Figure 7. Summer temperatures in northern British Columbia as reconstructed from pine tree rings. Dotted horizontal line shows mean. Note recent warming trend. Data from Szeicz and MacDonald (1995).

spanning 2,200-years reveal very large shifts in abundance resulting from climatic forcing, far exceeding the decadal-scale variability recorded from catches during the past 300 years. For example, salmon declined from 2100—1200 BP, but were more abundant from 800—100 BP (Finney *et al.* 2002). On equally long time scales, the abundances of 1200 years of Pacific sardine and Northern anchovy off the California coast (Baumgartner *et al.* 1992) alternate with the salmon, giving some clues as to the ocean mechanisms at work (Finney *et al.* 2002). The regime of high clupeid abundance (2000–800 BP) is confirmed by archeological studies (Tunnicliffe *et al.* 2001).

Alheit and Hagen (1997) describe an example of long-term climate forcing of European herring and sardine populations. In the Skagerrak, since the 10th century, there were nine boom periods for inshore herring fisheries, each lasting several decades. Otherwise, the herring fishery was very small. Some other European herring fisheries coincide (English Channel and the Bay of Biscay), whereas others (Norwegian herring and sardines) alternate with these periods, apparently driven by negative anomalies in the North Atlantic Oscillation index (more sea-ice in the Arctic, cold European air and water temperatures, fewer westerly winds).

In Norwegian waters, the North Atlantic Oscillation index relates to recruitment of North East Arctic cod (Godø 2003), while sea surface temperature is linked to Barents Sea capelin and Norwegian spring spawning herring stocks, although heat flux, ice cover and heat transport are also important variables (Stiansen *et al.* 2002).

Climate influences on recruitment are often a very important mechanism. In the North Sea, 22 years of data on climate during larval stages explained more than 70% of recruitment variability leading to models that could forecast recruitment in the summer of the spawning year (Svendsen *et al.* 1995). In coho salmon climate factors determine cohort strength; faster growing fish better survive the first winter at sea when upwelling nutrients have led to better plankton feeding conditions in the previous summer and autumn (Beamish and Mahnken 2001). Rodhouse (2001) shows how squid recruitment is correlated with synoptic oceanographic data. For example, in the eastern Pacific coastal upwelling system catches in a squid fishery for *Dosidicus gigas* are linked to the El Niño (ENSO) cycle. Twenty-fold fluctuations in mackerel recruitment in the Gulf of St. Lawrence were related to copepod abundance, which was negatively related to climate expressed as freshwater discharge (Runge *et al.* 1999). Many prawns recruit like this too.

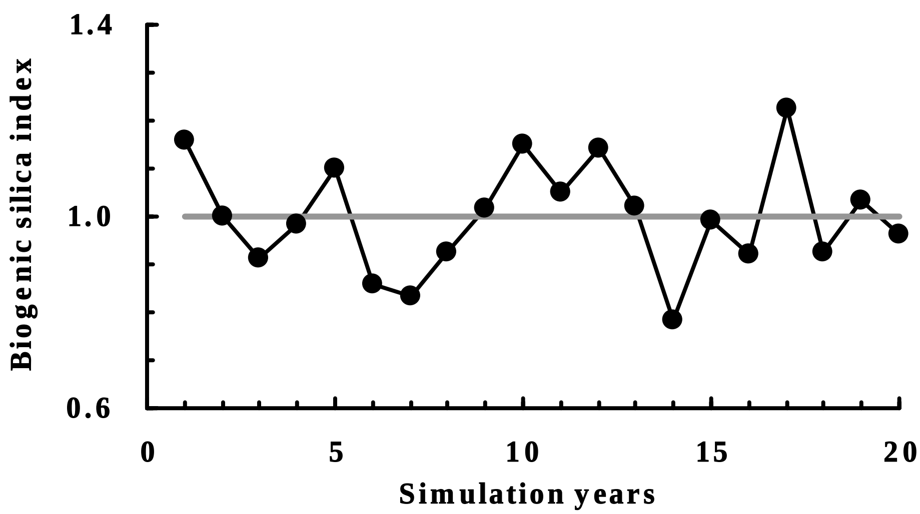

Figure 8. Twenty-year time series of data used to drive primary production in dynamic ecosystem model forecasts of Lake Malawi. Data is based on published time series of biogenenic silica in lake sediments, in randomized order, normalised to unit mean, and the variance adjusted iteratively to fit likely extreme lake biomass values. Data from Johnson *et al.* 2001.

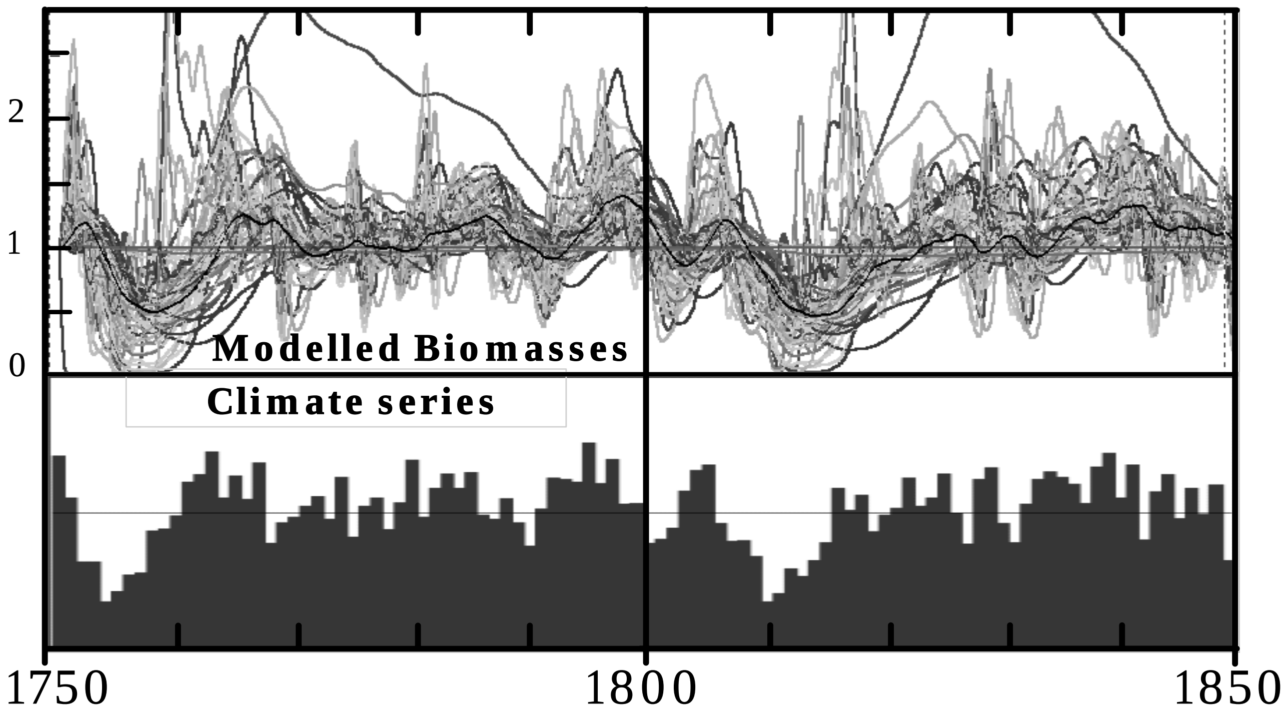

Figure 9. Example of 46-compartment whole ecosystem model driven by 100 years of a marine climate index based on tree ring data. Annual values of climate series shown at bottom panel and were used to drive primary production. Modelled biomass changes relative to starting values shown above and below the unity line in upper panel. Starting model is a reconstruction of Northern British Columbia as it may have been in 1750. Marine climate data from Gedalof and Smith (2001).

The recruitment – climate relationship may be quite complex. For example, the spring phytoplankton bloom can vary by up to 6 weeks in Newfoundland, driven by the amount of colder, fresher water from glacial runoff. First-feeding cod larvae have a precise dietary requirement: the nauplii of a copepod *Calanus finmarchicus* in the spring bloom. 'Match/mismatch' feeding conditions drive cod recruitment success, and global warming may prejudice recovery of depleted cod stock by creating long runs of ‘mismatch’ years (Conover *et al.* 1995). In a similar way, climate-driven fluctuations of sardine, hake and mackerel populations in the northern part of the California current appear to be linked to specific diatoms required by sardine larvae (McFarlane and Beamish 2001).

In the Pacific North-west, the PDO cycle has a strong influence on sockeye, pink, chinook, and chum salmon, herring and halibut, especially juveniles (Clark *et al.* 1999, Beamish and Bouillon 1993, Mantua *et al.* 1997). The El Viejo/La Vieja cycle describes an alternation between warm eastern boundary currents favouring sardine and colder conditions favouring anchovy regimes. Moreover, in this system the transitions between different regimes are relatively abrupt, but may be out of phase in different parts of the Pacific (Figure 4).

Other less obvious ecological effects are sometimes found. For example, a long-term trend for warmer water has stabilized the water column in Lake Tanganyika, reducing mixing, so that primary production is reduced by 20% and fish production by 30% (O’Reilly *et al.* 2003).

Fish species with life spans comparable to or exceeding the duration of adverse conditions may weather out the adverse period of a cycle, but at low population sizes, cascade effects can impede population growth in the good period. Fish with life spans shorter than the duration of adverse conditions can only be managed by linking catches to the environmental conditions, preferable using a delayed response (MacCall 2002).

DRIVING ECOSYSTEM MODELS

Clearly, the effect of climate change has to be accommodated in forecasts using ecosystem simulation models as much as possible. To do this, primary production, and other parameters of ecosystem models, such as stock-recruitment relationships, may be driven in a variety of ways.

Driving models with forcing functions

Although precise forecasts of inter-annual climate changes may never be possible, randomized selections of such data, or functions that emulate past climate changes, can be used to drive forecasts on the basis of likely scenarios. Forcing functions may be based upon empirical inter-annual variation, decadal or longer-period oscillations, or climate proxies such as a local upwelling index. Longer term climate cycles may be included in the forcing function, like the 62-year 'La Vieja/El Viejo' alternation between warm/cold eastern boundary current sardine/anchovy regimes (Chavez *et al.* 2003). All these factors can fairly easily translated into a driving variable for ecosystem modelling (e.g., Figure 6). The algorithm could be modified to take account of large ENSO events that may trigger PDO shifts (Peterson and Schwing 2003).

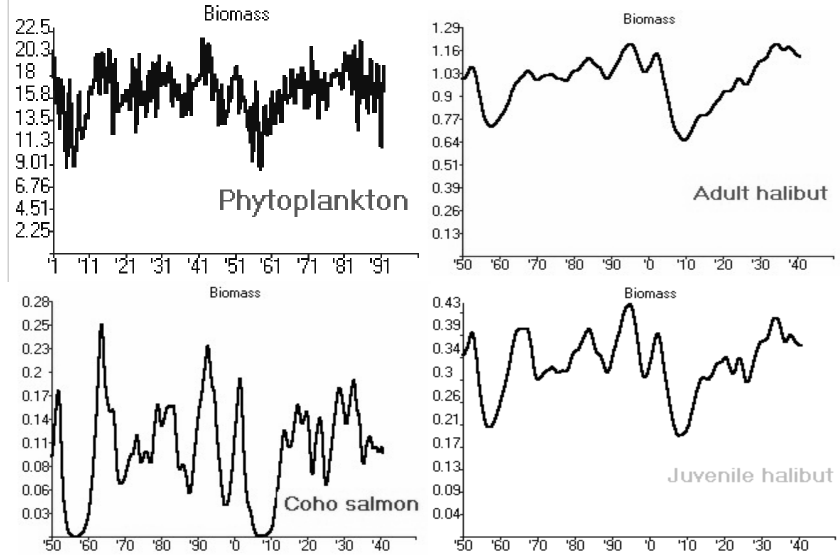

Figure 10. Biomasses of some of the individual groups in the ecosystem model driven by climate time series shown in Figure 9. Top left panel: phytoplankton; Top right panel: adult halibut; lower left panel: coho salmon; lower left panel: juvenile halibut.

Residuals between historically measured biomasses and simulated biomasses can be minimized in *Ecosim* models by comparing fits of a range of climate forcing functions. Climate forcing of modelled phytoplankton production may be sufficient, but in some cases climate forcing of recruitment parameters may also be useful for some fish species.

Driving models with climate data

Rather than use mathematical surrogates, tree rings can supply long historic records of inter-annual temperature changes in a region (e.g., Figure 7, northern British Columbia; Szeicz and MacDonald 1995). In the deep sea, growth rings of bamboo coral have been used in a similar fashion (Koslow and Thresher 1996). Sea surface temperature data has been used to drive a biomass model for Japanese sardine (Noto and Yashuda 2003). Sea temperature anomalies successfully improved biomass fits in an *Ecosim* model of the English Channel (Stanford 2004). In small pelagic fish in upwellings world-wide, production rate rather than biomass seems to be the best correlate for climate regimes (Jacobson *et al.* 2001) and hence the best variable to force in single species models. Multi-species modelling driven by temperature time series suggests that species respond differently to climate depending on their position in the food web (Jurado-Molina and Livingston 2002).

Lehodey (2001) has modelled the spatial effect of warmer and cold waters. In the tropical Pacific, ENSO affects a cold tongue of upwelling water that favours high production adjacent to warm unproductive pools. A spatial production model of skipjack tuna uses spawning area, larval and juvenile transport, adult tuna temperature preferences and forage fish prey driven by primary production. Observed movements of skipjack confirm the model results, which show ENSO driving an out-of-phase pattern between the western Pacific region and the cold tongue.

In some cases, biogenic silica deposits in sediments, which track the abundance of diatoms, may accurately reveal the past annual changes in primary production (e.g., Lake Malawi; Johnson *et al.* 2001), and such data has been used to drive forecasts in ecosystem simulation models (Figure 8).

Figure 9 illustrates an ecosystem model, representing a past time (1750) in Northern British Columbia, with phytoplankton production driven by a 10-year time series of marine climate data (transformed tree ring data; Gedalof and Smith 2001). Figure 10 shows separate plots of some of the groups in the model: large climate-driven changes in coho and juvenile halibut

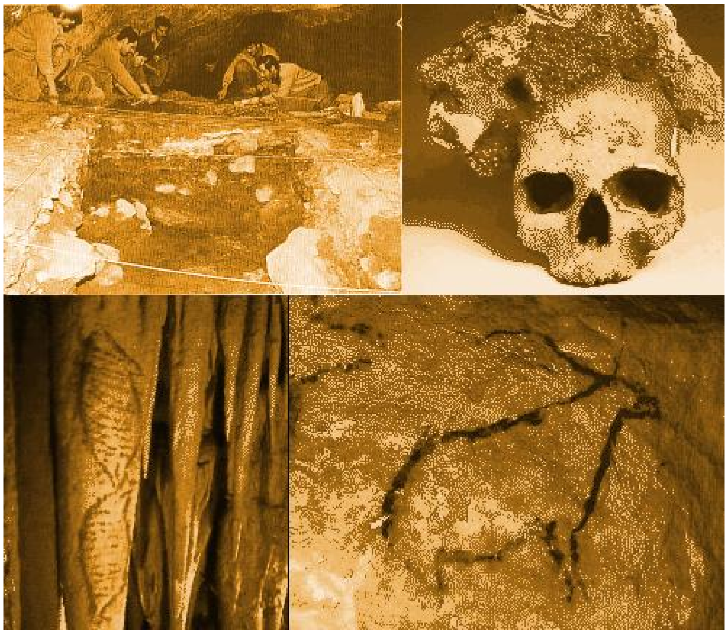

Figure 11. Top left: the first excavations taking place at Nerja, Adalusia, in the 1920s. Top right: human skull from the cave dated at 18,0000BP; Lower left: cave art of food fish, possibly *Pagrus*; Lower right: more cave art food. (From www.cuevadenerja.es).

emulate those expected from the literature (Mantua *et al.* 1997, Clark *et al.* 1999).

Information about specific past times from climate time series might be used to adjust each of a series of BTF ecosystem models to the appropriate contemporary regime conditions. This has not yet been attempted, however, because there is a logical complication. Starting values for the ecosystems of 'sustainably fished Lost Valley' analyses would have to be re-adjusted to a regime appropriate for starting the rebuilding process. Past climate data could at least enable past models to avoid major fluctuations compared to the present. In addition, the problem might be minimised by approximating an average ecosystem state over a period of 10-20 years.

THE 'CAST OF PLAYERS' TECHNIQUE: A SUGGESTION

To emulate changes in species composition in an ecosystem model as climate changes, the modeling system could perhaps be modified to use a 'cast of players', members of which might be brought on-stage and off-stage when conditions are appropriate (Pitcher 2004). In the 'on-stage' condition a species would play its full part in the food web of functioning model, acting as a predator, prey and competitor, and as an actor in any mediation processes, according to its model parameters and diet matrix. When 'off-stage' the species would play no part in the model dynamics. On-stage and off-stage conditions would be set, for example, by the value of an external time series, such as water temperature or a climate index. By bringing on stage members of a food web at different times and temperatures, a large number of intermediate ecosystems might be modelled. The technique could also be used to emulate species re-introductions, or recolonisations, following local extinctions (see Pitcher 2004, this volume).

Some archaeological data sets may provide useful test-beds for the 'cast of players' technique. For example, in the Cueva de Nerja, Andalusia, Spain (Figure 11), human middens reveal the fish that early Mediterranean people were eating over a 9000-year sequence (Morales *et al.* 1994, Rosello-Izquierdo and Morales-Muniz 2001). Early in the sequence, from about 14000 BP, the human diet consisted of a sparid fauna similar to the present, but, during a pluvial period at the end of the last Ice Age between 11000 BP and 9000 BP, humans were eating large cod and haddock, a fauna typical of Norway today. The midden fish bones the show that, by 8000 BP, a typical Mediterranean fauna had returned. The shift from Mediterranean to Nordic and then back to Mediterranean ecosystems might be emulated using the 'cast of players' driven by ancient temperature or climate proxies. Stratigraphic archaeological data could be used to 'tune' the process.

If successful in a trial such as the above, the 'cast of players' technique could also be used to forecast the consequences of global warming in a marine ecosystem by including a set of species from adjacent warmer ocean areas as well as those present today, for example, and then driving the actors on-stage and off-stage with a trend in temperature or climate factors.

CONCLUSIONS

We are now in a position to provide some preliminary answers to the four questions raised in the introduction to this paper. (1) It is certainly possible to make credible attempt to drive and/or tune models of the past using time series of climate or surrogate climate data. (2) Only a few climate-driven whole-ecosystem models have been constructed, all of which have appear to be stable, but far more will have to be done before we are sure of their stability. (3) Whole-ecosystem models have yet to emulate observed regime shifts, and the validity of their biomass dynamics needs more investigation. (4) We do not yet know if we can determine and 'lock on' to the appropriate state of ecosystem for the model of a past time period. Clearly, it is early days for climate-driven whole-ecosystem modelling.

Climate cycles mean that fisheries management aimed at rebuilding stocks may have to use a much longer planning horizon has been typical. MacCall (2002) suggests that, during adverse periods little rebuilding may occur even if fishing is halted, while in favourable periods, depleted populations of large predators allow smaller unfished competitors to thrive, again inhibiting population growth. Consequently, rebuilding of apex predators may require a century or more. Again, for policy work based on whole-ecosystem modelling, these issues need systematic investigation using the new climate-driven simulations.

Climate-change affects species mix and shifts centres of production. Everett (1997) warns that,

> "The positive effects of climate change, such as longer growing seasons, lower natural winter mortality, and faster growth rates in higher latitudes, may be offset by negative factors such as changes in established reproductive patterns, migration routes, and ecosystem relationships. Serious consequences could occur where these factors interact with pervasive over-fishing, diminishing nursery areas, and extensive coastal pollution."

Barange (2002) advises that multi-disciplinary research is required to understand the challenges of climate change. Moreover, as in other areas of fishery management, suitable actions consequent upon accurate forecasts of the effects of climate fluctuations may be hard to implement as policy. All sorts of human constraints may apply, such as lack of understanding, failure to appreciate uncertainties, and unanticipated reactions depending on unequitable benefits (El Niño, Broad *et al.* 2002).

The 'Perfect Storm' in November 1993 was formed when two independent meteorological phenomena occurred together. The storm was accurately forecast and its likely impacts well understood, but when it arrived, those caught up in its fury were both astonished and ill-prepared. It is to be hoped that forecasts of the effects of directional climate change - global warming - on natural ecosystems in the sea will not catch us so unprepared. While recent effort has been rightly focused on the disastrous effects of an era of outrageous and uncontrolled overfishing, it is sobering to realise that climate may bring about equally devastating changes. Finney *et al.* (2002) warns that

> "an unprecedented shift to a very low productivity regime, lasting centuries, can occur even without the influence of fisheries and other anthropogenic impacts".

Today, with both overfishing and climate shift independently caused by human actions, we may have unwittingly set the stage for a 'Perfect Storm' of changes in the ocean ecosystems.

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For discussion following oral presentation of this paper, see page 142.

TUNING ECOSYSTEM MODELS TO PAST DATA

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ABSTRACT

This note sets out how whole ecosystem simulation models may be tuned using past surveys or fisheries assessment outputs.

The question is often asked as to whether these *Ecopath-with-Ecosim* models could actually influence decision-making? Their usefulness for policy is strongly connected to the accuracy of their outputs. Are the predictions that they make reliable and robust? The process of tuning is intended to enable the models to reflect reality.

Ecosystems have enormous complexity and the grim reality for modelers is that capturing this is an impossible task (Oreskes *et al.* 1994). To predict with absolute certainty what the future holds is beyond the capabilities of computer simulations. Conversely, if the models cannot simulate what has already known to have occurred, they are not reliable enough to be used as a predictive tool. Hence, the essence of 'tuning' an *Ecopath* with *Ecosim* model is to run the model through time and compare it's estimates to observed time-series data.

Tuning is an iterative process through which group by group the model moves towards the a better representation of the actual ecosystem. The first stage is to have a balanced base *Ecopath* model that you are confident reflects the time period you have modeled. Simple diagnostic checks on the model, such as setting fishing mortality to zero, or increasing it ten-fold, give an early indication of the validity of the results. Certain groups with a high Ecotrophic Efficiency (EE), whose abundance is controlled primarily by fishing, will rapidly increase if fishing pressure is suddenly reduced. The modeler, being aware of the system, will be able to ascertain whether this increase is reasonable and modify the basic input parameters if necessary.

The aim of my English Channel ecosystem model was to predict into the future using a range of policies. Sufficient data were available to build an accurate contemporary model of the English Channel (Stanford 2002, 2004). In order to have confidence in these predictions it was necessary to build a past model, which would act as an anchor point from which to extrapolate to the present day. A number of the commercially exploited stocks had been assessed since 1973 and this was the year designated for the earlier model. This model was constructed and run from 1973 to 1995 using stock assessment data for fishing mortality. Where this was not available, estimates were provided from experts or similar stocks so that for each exploited functional group there were fishing mortality data.

Where the biomass estimates of the model significantly differed from stock assessment data the English Channel model required modification through one or more of three ways:

1. *The basic input parameters entered into Ecopath could be changed.* Fishing mortality may cause the EE to be close to 1 and an increase in fishing will cause the group to decline. If the 1973-1995 time-series data indicated that the group was more resilient than predicted by the model, increasing the starting biomass or the estimate for production/biomass will dull the impact of fishing.

2. *Vulnerability settings can be altered.* Vulnerabilities are a measure of whether the system is predator or prey controlled (top down or bottom up). Increasing the vulnerability towards 1 means that predators control the system and that prey are constantly available for capture. A group that consumes prey with a high vulnerability is likely to increase rapidly if its predation or fishing mortality is reduced. Conversely the increase will be moderated by lower vulnerabilities. There are three stages to modeling vulnerabilities. The first is to accept the default value of 0.3 for all groups. Secondly, vulnerabilities can be set according to the trophic level of the prey and finally the best method is to assign vulnerabilities on a group-by-group basis that enable the model to closely replicate time-series data (see Ainsworth 2004, this volume).

3. *Forcing functions can be used. Ecopath* with *Ecosim* has the capability of including effects not generated by trophic interactions or fishing. These were particularly significant in the English Channel model because the English Channel is located at the boundary of two bio-geographical regions (Southward and Boalch 1988). Variations in temperature will allow different species to be successful (see Pitcher and Forrest 2004, this

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volume). Hence, a warmer climate will have positive impacts on sole (*Solea solea)* stocks (Henderson 1994) and negative effects on cod (*Gadus morhua*) (O'Brien *et al.* 2001); (Planque and Fox 1998). Although sole fishing mortality increased between 1973 and 1995 their biomass simultaneously increased as warmer temperatures had a positive effect on recruitment. Forcing functions do not fix the biomass so a rapid increase in fishing or predation pressure will still reduce sole biomass.

One of the major problems with tuning the model is knowing what to change. Regarding sole, there is significant evidence that there is a correlation between temperature and recruitment, although the exact mechanism of this depends on the region (Rijnsdorp *et al.* 1992, Philippart *et al.* 1996, Henderson 1994). Hence it was justifiable to include this in the model. For other groups that had not been studied so extensively it was difficult to know which data to trust. Using Virtual Population Analysis will mean that past data becomes more accurate with each new assessment. Conversely, past estimates for a group may be based only on an expert's guesstimate or current techniques such as acoustic surveys may mean that the contemporary estimates are better. Consequently, although time-series data may suggest a change is necessary, high confidence in your contemporary model may mean that it is not changed.

It is at this stage of tuning that the pedigree screen in *Ecopath* is valuable. This gives an indication of what data can be trusted and provides a basis for tuning. For example, in the English Channel it is known that the abundance of sharks (blue sharks *Prionace glauca*, porbeagle *Lamna nasus* and tope *Galeorhinus galeus*) has decreased. This is attributable to both a reduction in prey species and increasing fishing mortality. The pedigree screen in *Ecopath* indicated that there was little confidence for most of the data for this group. Hence I could legitimately modify biomass, P/B and the vulnerability until the model predicted the decline in abundance that the literature seemed to indicate.

Tuning cannot overcome all of the inadequacies in a model. It can identify where functional groups may need to be sub-divided, particularly if temperature influences recruitment. Comparing the model's output to stock assessment data is a valuable exercise that can bring confidence to both the modeler and the policy maker that the results are realistic. In response to the original question in the Prince Rupert workshop concerning their value to decision-making (see Pitcher *et al.* 2002), we would affirm that yes these models are valuable when tuned to data and that enhancing the time-series data can only increase their predictive power.

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For discussion after the oral presentation of this paper, see page 150.

DEALING WITH MIGRATORY SPECIES IN ECOSYSTEM MODELS

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ABSTRACT

This paper sets out the logic for dealing with migratory species in the *Ecopath*-with-*Ecosim* whole ecosystem simulation modelling framework. Examples are provided from salmon and hake populations.

As a technical convenience, *Ecopath* models are bounded by arbitrary borders that allow the user to 'define' the system. This 'box' should be large enough so that interactions *within* the system add up to a larger flow than the interactions *between* the system and the ecosystems outside the box. In almost all cases, it is not possible to define such an area that includes the entire life history of all groups in the model. Furthermore, some groups only use a portion of the box, and never interact with other groups in the model (e.g., A in Figure 1), whereas another group's distribution may overlap with the defined ecosystem model (e.g., B in Figure 1). Neither example poses a significant problem when building an *Ecopath* model. In case A, simple accounting of trophic interactions determines which prey is consumed and which predators consume the group that has a limited distribution. In case B, the fraction of the stock that resides within the model area is used as the biomass input. But what potential problems arise as we move from static pictures of the ecosystem to dynamic changes over time?

Biomass dynamics can have profound effects on the distributions of species, *Ecosim* is a biomass dynamics model that uses the *Ecopath* inputs to calculate initial states. If the ellipse in example A, figure 1, represents the entire distribution of the species in question, then there are no real or potential problems in calculating biomass within the system over time. In example B, it is possible to assume that the fraction of the total stock remains constant over time, and there is little or no exchange across the boundary. At first this assumption may sound crazy, but consider species such as abalone that have limited mobility and small dispersal distances. A more realistic, and worrisome, case is represented in example C, where the distribution of a species changes over time. Here the area over which the stock is distributed is a function of stock size. When stock is reduced in abundance, though fishing activities, or perhaps increased predation, the range collapses to a smaller area of more favorable habitat. This phenomenon has been observed in many fish

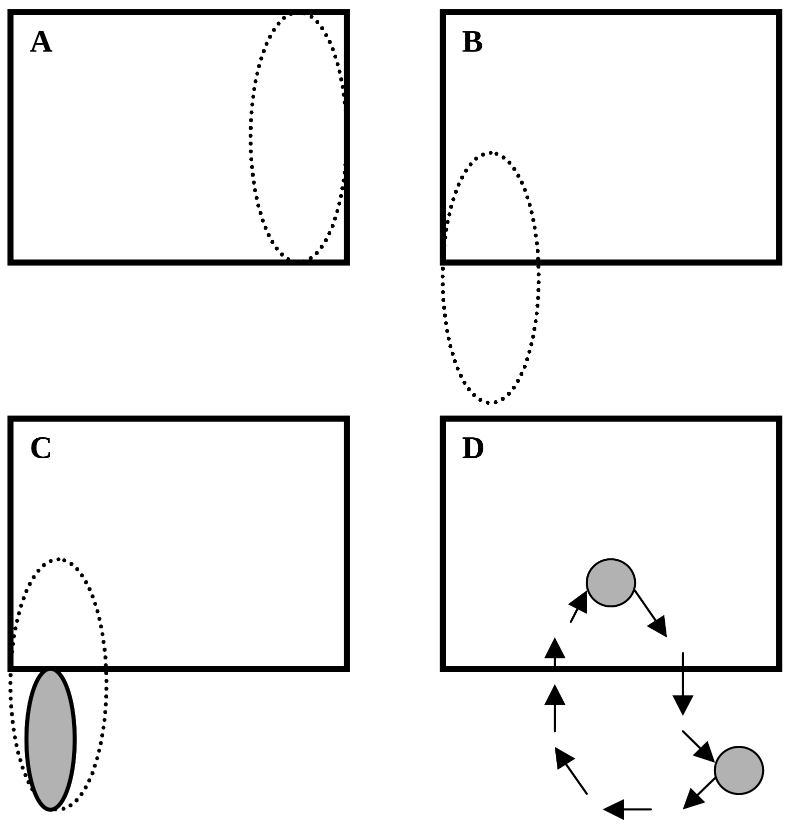

Figure 1. Four examples of ecosystem models, where model boundaries are represented by rectangles, and ovals represent distribution of a group in the model. A) Here the group is only partially distributed in the entire ecosystem, B) the distribution overlaps with ecosystem boundaries, C) distribution overlaps, but may collapse outside boundaries as stock is reduced, and D), arrows represent a complicated life history trajectory, where the gray circles might represent an area of importance such as spawning grounds, or where the fishery takes place.

Martell, S. (2004) Dealing with Migratory Species in Ecosystem Models. Pages 41–44 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

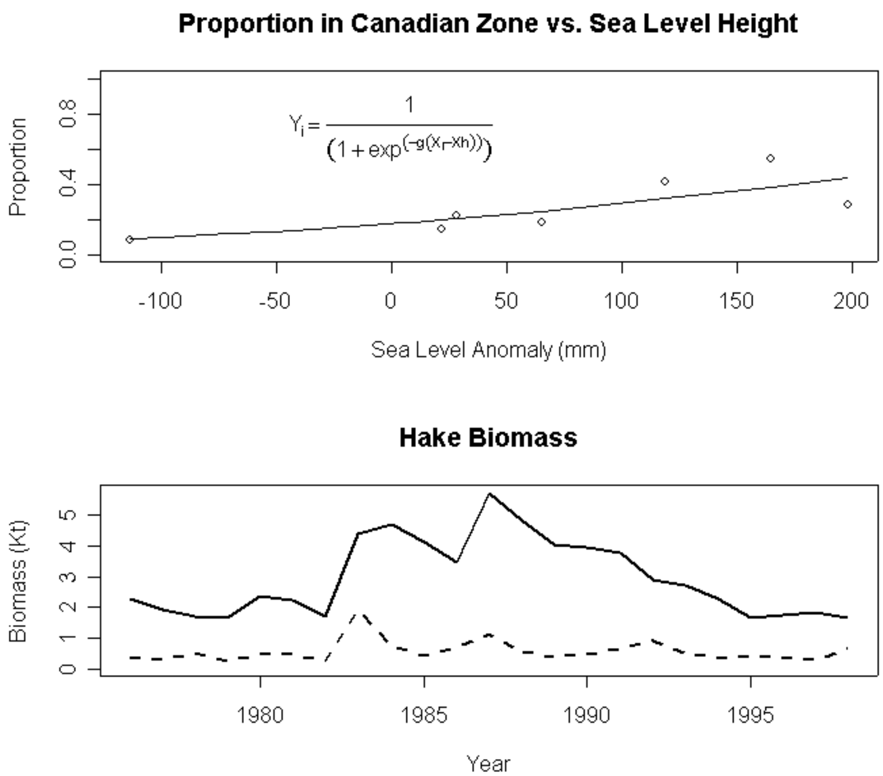

Figure 2. An example of estimating the fraction of a large migratory hake stock that enters the Canadian zone each year. The fraction of hake that enters Canadian waters is a function of sea level height, and we can use sea-level height to predict the fraction of the total stock (solid line) to generate a time series of biomass (dashed line) that enters the defined ecosystem.

stocks around the world (e.g., Atlantic cod off the east coast of Canada, Rose 1999). Such range collapses might involve the species leaving the defined ecosystem.

Example D in Figure 1 represents one of the more difficult issues to be represented in *Ecosim*. In this example, only a portion of the life history trajectory is within the defined ecosystem, and important events such as spawning or targeted fisheries occur both in and outside the define ecosystem. Pacific salmon are probably the best example of a species with a highly migratory life history, where fisheries occur in the oceanic, coastal and freshwater environments. Furthermore, there is another ecosystem that salmon play a functional role in, such as food for bears and eagles, and providing nitrogen through decaying bodies (Watkinson, 2001). Juvenile salmon spend one or more years rearing in freshwater and are subject to variable mortality rates due to competition with other stream inhabitants or anthropogenic impacts such as logging or urban development. Modellers of salmon using *Ecosim* need therefore to deal with this issue (Stanford 2002). Users of *Ecosim* should be aware that the stock recruitment relationship represented by split pool dynamics, assumes that everything that happens outside the box remains constant over time. There are however, some built in tools that can be used to represent variation in stock-recruitment production, or the effect of hatcheries. More on this later.

There are two phases to the ‘Back to the Future’ (BTF) approach. First is to reconstruct several ecosystem models, usually representing the present day, some time period in the past that might represent an unfished state, and one or more ‘intermediate’ states between pristine and present. The second phase is to simulate how one should optimally utilize the resources of an unfished ecosystem and compare results of such simulations to present day states. The reconstruction phase might include fitting *Ecosim* models to time series data to help parameterize the model. The second phase simply makes forward projections to explore alternative management policies. Each phase challenges the modeler with different problems for dealing with migratory species or populations that are only partially represented in the ecosystem model. In the reconstruction phase, time series information is required about changes in abundance within the model area. For example, if the distribution is changing over time, then what fraction of the total stock, or total catch, at each year were within the defined system? Often the data lack the spatial resolution that would allow total catch, or biomass to be partitioned among spatial areas. This should be taken into consideration when defining the boundaries of the system.

Species with complicated life history trajectories, where only part of the life history is represented in the model, are even more problematic. For example, dramatic changes in abundance may be a result of mortality that occurred outside the defined ecosystem, yet we search for mortality agents within the ecosystem to explain the observed declines. These problems carry forward into the simulation phase of BTF in addition to deciding how to represent life-history trajectories that occur outside the defined ecosystem. We cannot assume the freshwater phase of salmonid production remains constant over time! *Ecosim*, at its present stage of development, is not capable of explicitly modeling dynamic changes that might occur outside the system. Despite this limitation, there are alternative solutions for dealing with migratory species, or populations that share boundaries between neighboring ecosystem.

One of the most obvious options is to simply do nothing. That is, just assume that what happens outside the ecosystem remains constant over time, and assume that stocks that overlap the defined system are disconnected. Such assumptions may be valid for reasons such as limited dispersal, or because the biomass pool is simply too small to be of importance to modeling questions. An alternative option is to increase the scale of the model such that the entire distribution, or life history trajectory is included in the model (e.g. turn cases B and C in Figure 1 into case A). Exercising this option may be tricky for groups that have long distance migrations, as expanding to such large scales may introduce more problems with data. Having to add additional groups that live outside the previously defined ecosystem, may also require increased participation and substantial increase in the scale of the project.

There are a couple of alternative options for dealing with migratory species in reconstructed dynamic models using *Ecosim*. One such option is to impose a time series of biomasses on the ecosystem, where this time series is estimated independently of *Ecosim*. For example, biomass for a particular group could be estimated using single species models (incidentally, this should be done anyway to generate a fishing rate time series to drive fishing mortality in *Ecosim*), then read into *Ecosim*[1]. Also, the time series should be corrected for the fraction of the total stock that is within the defined ecosystem. As an example, Pacific hake populations off the west coast of Vancouver Island are part of a large migratory stock that winters in southern California and some fraction of the total stock migrates into Canadian waters in late spring-early summer. The stock is assessed every three years using information from fishery independent surveys, and the proportion present in the Canadian zone is a function of sea level height which is correlated with water temperature (Dorn 1995). Here the southern boundary of the ecosystem model is the Canada-US border, and the objective is to correct the assessment predictions to reflect hake biomass inside Canadian waters. Figure 2 presents a logistic relationship between sea level height and proportion in the Canadian zone. This logistic equation can be applied to the total stock to estimate a time series of hake biomass present inside the defined ecosystem (dashed line in bottom panel), this time series can then be read in as a forced biomass pool.

'Egg forcing' is an option for forcing split pool dynamics frequently used to represent enhancement programs such as salmon hatcheries. Salmon hatcheries, in some cases, have more than doubled smolt output into the marine environment, and in *Ecosim* this is just represented by a doubling of egg production in the forcing function. A time series of hatchery releases scaled to wild salmon production is read into *Ecosim* using the standard *.csv file and specified shape number. The shape number is then applied to egg production for the salmon group. A similar option could also be used to represent other disturbances that might have occurred in the freshwater phase of salmonids (e.g., set egg production to near zero to represent the catastrophic impacts of the Fraser canyon slide that nearly destroyed Fraser River sockeye stocks). This could apply to entrainment of fish larvae in cooling towers for nuclear power plants. The options are endless, but just require some time series data and a known scale of the effect of juvenile production. These time series effects on fish production could also be implemented in forward projections, where alternative hypotheses about the magnitude of the effect can be explored. For example how might the removal of hydroelectric dams affect eulachon populations in the Columbia River?

Another interesting simulation issue related to salmonids, anadromous fishes, and groups that move between two distinctly different ecosystems is how to connect the two systems. As an example, consider the life history of Pacific salmon, where the marine phase involves complicated migrations, consumption, predation, and variability in annual survival rates. These exact same processes also occur in the freshwater phase, where adult salmon are food resources for scavengers/predators such as bears and eagles (Watkinson 2001 and references therein). The remaining adults that survive the predator gauntlet are also responsible for egg production

[1] Note that this time series should be scaled to *Ecopath* units (e.g. tonnes/km^{-2}), and use the '–1' option for the data type code in the *.csv file.

and recruitment, while juveniles remain in the freshwater environment for up to a year or more and face other challenges. If the ecosystem model only represents the marine phase of the salmonid life history, we might simply proceed with policy exploration using new high-tech gear that reduces by-catch and conclude it is safe to proceed with such developments. The new policy works great in the model and in practice, but grizzly bears are starving and going extinct in many watersheds. Oops! Clearly we should consider how our policy affects neighboring ecosystems, and the question is how do we do this?

For neighboring ecosystem models that share a couple of groups (consider a near-shore versus off-shore ecosystem, where one group forages and spawns near-shore during the summer months) it is a simple matter to combine two *Ecopath* models. In nature, species interactions can be direct (i.e. predation), or indirect (i.e. competition). In *Ecopath*, direct interactions are specified by setting a non-zero value in the diet matrix for predator j on prey i, and indirect interactions are specified when two groups share the same resource. It is possible to carry out the same mass balance exercise for two independent *Ecopath* models that are loaded into the same file. In other words, you can have two independent models of 10 groups each, or one model with 20 groups. When you balance these models, parameter estimates are the same if the two diet matrices are independent of each other. To connect the two ecosystems, to represent a group that moves between the two systems, simply recalculate the diet composition for that group, where some proportion P comes from one model, and 1-P comes from the adjacent model. Such an exercise has already been shown to work quite well for the Prince William Sound model (Okey and Pauly 1998), where the ecosystem was sub-divided into nearshore and offshore components. Since predator-prey interactions are specified in the *Ecopath* diet matrix, there is no problem moving into *Ecosim* and representing a group moving between the two systems. With a little programming experience, it is also possible to integrate *Ecosim* with other models that represent the dynamics of neighboring ecosystems.

For example, suppose we had a terrestrial model for salmon recruitment in the freshwater environment that includes predation and population dynamics of bears and eagles (Watkinson 2001). The input to this model is the number of adult salmon entering the river. Within each annual time step, we can pass predicted adult abundance of salmon from *Ecosim* to the terrestrial model, where bear and eagle dynamics are updated partly based on how much salmon was available. The terrestrial model then returns the number of juvenile salmon to *Ecosim* 1-2 years later, where *Ecosim* graduates the juveniles into adults and the process repeats for N years. Such a framework would provide insights about the affects of harvesting salmon in the marine environment on bears and eagles in the terrestrial environment.

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ESTIMATING THE EFFECTS OF PREDATOR-PREY VULNERABILITY SETTINGS ON ECOSIM'S DYNAMIC FUNCTION

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ABSTRACT

In the context of foraging arena theory, prey vulnerabilities are proportional to the flux of prey from safe refuges to feeding areas, where they are subject to predation. In the absence of empirical data, *Ecosim* modelers may use an approximation method to estimate prey vulnerabilities. Four such methods are evaluated in this report in their ability to permit *Ecosim* to generate predictions of abundance that resemble stock assessment time-series. The first method is to scale prey vulnerabilities proportionately to the trophic level of their predators ('predator control' hypothesis). The second is to scale vulnerabilities proportionately to the trophic level of the prey ('prey control'). The third is to apply a flat vulnerability to all groups. The fourth method customizes group vulnerabilities according to logical rules. Four *Ecosim* models are used to compare the assumptions. The results fall marginally in the favour of prey control. Three out of four models show improved dynamic functioning under this assumption and biomass trends are improved in 18 out of 32 functional groups (compared to 12 groups for predator control). Prey control was therefore adopted for all Back-to-the-Future applications. Ideally, each predator-prey combination should receive its own independent score. This will be addressed in later revisions of 'Lost Valley' policy search methodology.

Central to the dynamic function of *Ecosim* are the input prey vulnerabilities to predators. Vulnerability, a concept rooted in foraging arena theory, describes the flux of prey from safe refuges to feeding areas, where they are subject to predation (Walters *et al.*, 1997). The vulnerability parameter (v) is assumed by *Ecosim* to be proportional to the relative time spent feeding and hiding. Figure 1 shows a schematic representation of *Ecosim* vulnerabilities.

The vulnerability parameter is defined in *Ecosim* on a logarithmic scale from 0.01 to 1.0. Low prey vulnerability indicates bottom-up control; high vulnerability indicates top-down (Lotka-Volterra) control. Christensen *et al.* (2000) warn that strict bottom-up control in *Ecosim* tends to produce unrealistically smooth changes in prey and predator biomass that fail to propagate through the food web, while strict top-down control may cause rapid oscillations in biomass and unpredictable simulation behaviour (see also Mackinson 2002).

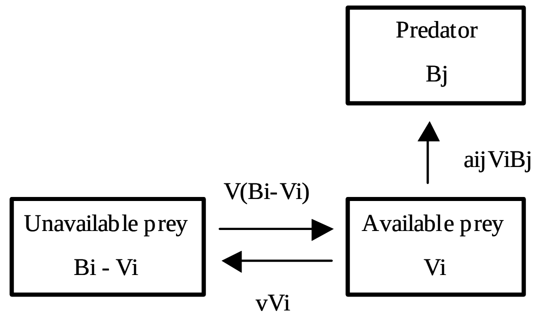

Figure 1. *Ecosim* vulnerabilities in the context of foraging arena theory. Vulnerability (v) describes the exchange rate between vulnerable prey biomass pool (Vi) and invulnerable pool (Bi-Vi). (a) describes predator (i) search rate for prey (j). Bj is predator biomass pool. Source: Walters *et al.* 1997.

Further, Cheung *et al.* (2002) suggest that using the blanket assumption (applied to all groups) of top-down control (>0.5 vulnerabilities) will generate a complex response surface with many optima; they found it difficult to find a global maximum when searching for optimal fisheries. Moreover, Martell *et al.* (2002) found that low blanket vulnerabilities impart on the system a high degree of resiliency to fishing effects. Models based on this assumption, they suggest, will return unreliably optimistic policy recommendations. The default setting in *Ecosim* describes a mixed condition (on the low end of the vulnerability spectrum as established by convention), where all prey vulnerabilities are set to 0.3. Cheung *et al.* (2002) report that a consensus emerged at the FAO/Fisheries Centre *Ecopath* workshop that scaling vulnerabilities in proportion to trophic level (TL) was more realistic than the blanket assumption. Here we test these methods as well as a more customized approach, which involves assigning group vulnerabilities according to logical rules.

Walters (*pers. comm.*) suggests that each predator-prey combination should ideally receive its own unique vulnerability since anti-predator defenses (e.g. behavioural, structural) may provide differential protection against various modes of predator attack. In lieu of vulnerability estimates derived from data, modelers may employ a shortcut - scaling vulnerabilities proportionately to either predator or prey trophic

Ainsworth, C. (2004) Estimating the Effects of Prey-predator Vulnerability Settings on *Ecosim*'s Dynamic Function. Pages 45–47 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

level (TL). While Cheung *et al.* (2002) were the first to try the latter method (repeated by Mackinson *et al.* (2002), Martell *et al.* (2002) and others), the former is tried here for the first time. These two techniques make different assumptions about trophic interactions. The former 'predator control' assumption contends that a prey species will be more vulnerable to high TL predators than low TL predators. The alternate hypothesis, 'prey control', implies that low TL prey is more vulnerable to predators than high TL prey.

This paper examines whether prey or predator control hypotheses enable *Ecosim* to predict a biomass trend that more closely resembles a time-series of biomass from stock assessment, and whether either technique improves on the default (all vs =0.3) assumption. Finally, we test the ability of a more customized vulnerability regime to recreate known biomass trends.

To test these issues, I have used four *Ecopath* models of past times from various authors along with time-series abundance estimates of their (commercial) functional groups: 1970 Bay of Biscay (Ainsworth *et al.*, 2001), 1950 Strait of Georgia (Dalsgaard *et al.*, 1998), 1973 English Channel (Stanford 2002) and 1950 northern British Columbia (Ainsworth *et al.*, 2002).

METHODS

Using default *Ecosim* settings for all four models, I first set the vulnerability of prey groups in proportion to their predators' trophic level (predator control), and then in proportion to their own (prey control). In the *Ecosim* interface (under the 'flow control' tab), vulnerabilities are entered vertically for predator control and horizontally for prey control. For both trials, the range of vulnerabilities was set from 0.8 for high TL groups to 0.2 for low TL groups.

A simulation was run for each model, under each hypothesis. The biomass trend, obtained from *Ecosim*'s output CSV file, was compared to stock assessment records with a non-parametric Spearman's correlation test.

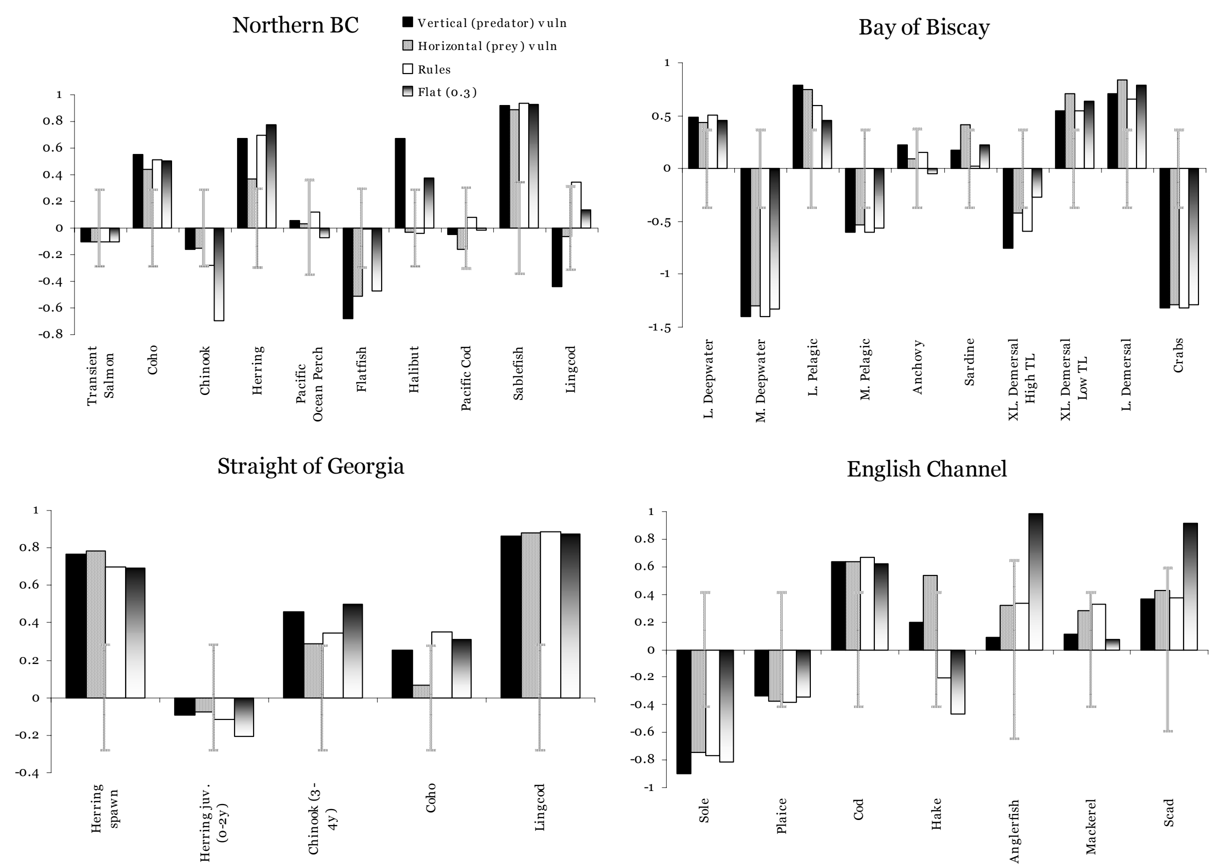

Figure 2. Correlation of biomass outputs from four *Ecosim* models with time-series stock assessment under four assumptions of prey vulnerability. Dark bars show predator control; stippled bars show prey control; white bars show logical rules; shaded bars show all vs = 0.3. Crossbars show correlation needed for significance at >= 0.05.

RESULTS

Figure 2 shows the correlation of stock assessment information with the biomass trend predicted by *Ecosim*. Dark bars show the correlation under predator control, light bars show correlation under prey control. Significance level at a=0.05 is indicated by crossbars for each functional group.

Prey control vulnerabilities allow *Ecosim* to generate a biomass trend that more closely resembles stock assessment information in 18 out of 32 functional groups studied; predator control vulnerabilities perform better for 12 groups and the two methods perform equally well for 2 groups. Prey control generates a closer overall correlation in all models except northern BC, where only 3 functional groups correlate better under prey control and 6 groups correlate better under predator control.

CONCLUSION

In most cases, prey control vulnerabilities allow *Ecosim* to predict an index of relative abundance that more closely conforms to stock assessment than the alternate hypothesis, predator control. Unfortunately, the BC model (which is the subject of CUS BTF applications) does not perform better under this assumption. However, we judge predator control to be less supportable, since it requires that prey know which predator is attacking them. Although evolution has probably equipped them with this ability to some extent, in the absence of supportive data it is safer to assume that a prey has adjusted its transfer rate to protect itself equally from all likely predators encountered.

Ideally, we would examine each predator-prey combination individually; this is the next step to improve the dynamic function of the BC model. Avdin and Friday (2001) found that vulnerabilities in the lower order prey groups were most critical to the simulation; this is where fine-tuning should begin.

Consequently, vulnerabilities for all *Ecosim* models used in the Lost Valley policy search (Ainsworth *et al.* 2004, this volume, Ainsworth, 2004a and 2004b) were set to prey control (vulnerabilities proportional to prey TL in the range 0.2-0.8 by convention).

ACKNOWLEDGEMENTS

I would like to thank Dr Carl Walters and Dr Villy Christensen for their input and discussion.

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POLICY SEARCH METHODS FOR BACK-TO-THE-FUTURE

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ABSTRACT

Using the policy search routine in *Ecosim* we identify the pattern of exploitation that would allow us to gain the most benefit from restored '*Lost Valley*' ecosystems of northern BC and Newfoundland. The policy search determines the fishing mortalities for each gear type that will maximize its objective function over a 50 year-simulation. Five objective functions are considered: ecological, economic and social, as well as a mixed objective and a conservative 'portfolio log utility function' that resists altering the ecosystem far from its baseline. The ecological function increases the abundance of slow-growing groups, the economic function maximizes rent from the system, and the social function maximizes fishery employment. A mixed objective function combines economic, social and ecological priorities. The portfolio log-utility function combines these priorities as well, but includes a risk aversion algorithm. Using the mandated rebuilding routine, constraints were included in ecological and mixed objective runs for northern BC models to prevent extinctions. Four time periods are evaluated as starting points for the optimization in each ecosystem (1750, 1900, 1950 and 2000 for northern BC and 1450, 1900, 1985 and 1995 for Newfoundland); the most valuable of these represents possible restoration goals. Three fleets are considered in their ability to harvest the restored system. The '*lost valley*' fleet includes twelve and sixteen fisheries in northern BC and Newfoundland, respectively. These allow a minimal level of bycatch and discards. The '*no recreational*' fleet omits the sport fishery and the '*no trawlers*' fleet omits groundfish trawl and shrimp trawl. We confirm that the search routine has identified the optimal policy by conducting additional trials using random fishing mortalities a starting point rather than *Ecopath* baseline values. The restored systems are subjected to 100 years of simulated fishing including a 50-year (dynamic) fishery development phase and a 50-year (steady-state) equilibrium phase. Seven valuation techniques examine the resulting harvest profile and ecosystem condition to measure the success of each restoration period, fleet and harvest objective. Economic valuation considers the conventional and intergenerational net present value of the harvest profile. Ecological valuation measures biodiversity of the restored system based on the Q90 statistic, the change in ascendancy throughout the system, and the occurrence of local extinctions. Social valuation determines the total number of jobs generated by each restoration/harvest scheme, and the employment diversity across fishing sectors.

Ainsworth, C., Heymans, J.J. and Pitcher, T.J. (2004) Policy Search Methods for Back to the Future. Pages 48–63 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

INTRODUCTION

Harvesting the Lost Valley

The methods presented here describe an attempt to determine the combination of gear types and fishing mortalities will allow us to optimally exploit the restored *Lost Valley* ecosystems of northern BC and Newfoundland under a variety of policy objectives. The general principles and methodology of the *Lost Valley* approach is described in Pitcher (2004b, this volume) and in Pitcher *et al.* (2004).

Briefly, we have constructed *Ecopath* with *Ecosim* (EwE) ecosystem models of northern British Columbia and Newfoundland to represent the marine environment as it appeared in the distant past, the recent past and the present. These periods are here referred to as *Lost Valley* ecosystems. In order to evaluate these as possible restoration goals for the future, we determine the optimal pattern of fishing mortality per gear sector (using the policy search routine in *Ecosim*) that will generate the greatest benefit in a specified harvest objective. Five objectives are tested that, together, span the spectrum of human use versus conservation. In order to explore which combination of gear types (see Ainsworth 2002) should be used to harvest the restored system, we conceptualize an idealized *lost valley* fleet, which includes only responsible fisheries (Pitcher 2004b this volume, Pitcher 2004a, Pitcher *et al.* 2004). We also test two abbreviated versions: one that includes *no recreational* sector and one that includes *no trawlers*.

We apply the optimal fishing patterns to the restored system, simulating 100 years of harvest (including a 50-year dynamic period and a 50-year steady-state equilibrium). The resulting harvest profiles are then valued in economic, ecological and social terms.

By quantifying the benefits that each historic period has to offer as a restoration goal, we can judge what costs are justified in achieving restoration. Future work (Ainsworth, *in prep*) will look at strategies for achieving restoration in northern British Columbia, and determine how far into the past we should restore to maintain cost-effectiveness.

Period (BC/NFLD)	Fleet	Harvest objective
1750/1450	LV fleet	Ecological
1900/1900	LV no rec.	Economic
1950/1985	LV no trawl	Social
2000/1995		Mixed
		Port. Log.

Figure 1. Policy searches. The optimal fishing policy is determined for each period, under each fleet and harvest objective. Sixty runs were conducted for each ecosystem. Re-trials with random F starting points validate the optima.

METHODS

The 1750, 1900, 1950 and 2000 *Ecopath* base models of northern BC used here are based on Ainsworth *et al.* (2002); the 1450, 1900, 1985 and 1995 models of Newfoundland are based on Pitcher *et al.* (2002). For both the west and east coasts, this exercise will test the ability of our three proposed responsible fleets to harvest each of our restoration goals (based on four historical periods), in order to maximize five harvest objectives (Figure 1). A total of sixty runs were conducted for each ecosystem.

For the northern BC models, we verify that the policy search has found the optimal combination of fishing mortalities under its objective by conducting additional searches using random fishing mortalities (F) as the starting point for the optimization procedure, rather than *Ecopath* base values. Ideally, the search algorithm will locate the global maximum on the response surface curve regardless of the starting values of F.

Ecosim parameterization

Most *Ecosim* parameters were left as default. Appendix A Tables A1, A2 and A3a and b detail parameters used to initialize *Ecosim* including specific run information, group information and juvenile/adult linking parameters. The juvenile/ adult linking parameters for cod and American plaice in Newfoundland were different for 1985 and 1995; the values for 1985 were used for the 1900 and 1450 models.

Prey vulnerabilities to predators (Table A4a and b) were set in proportion to prey trophic level, where the lowest trophic level prey receives a vulnerability of 0.2 to its predators and the highest trophic level prey receives a vulnerability of 0.8. The prey vulnerabilities were varied for the different Newfoundland time period models (Table A4b). Scaling vulnerabilities proportional to prey trophic level rather than predator trophic level was chosen for reasons discussed in Ainsworth (2003).

Initializing the Policy Search

Fleets

The *Lost Valley* fleet chosen for the west coast includes groundfish trawl, shrimp trawl, shrimp trap, herring seine, halibut longline, salmon freezer troll, salmon wheel, live rockfish, crab trap, clam dredge, aboriginal and recreational fisheries. The *Lost Valley* fleet chosen for the east coast includes bottom and shrimp trawls, recreational and First nations fisheries, cod traps, capelin seine, longline, midwater trawl for redfish, traps for lumpfish, snow crab, inshore crabs and lobster, salmon wheels, pole and line, clam dredges and urchin diving. Retained bycatch on the west coast occurs in all fleets except salmon wheel, live rockfish, clam dredge and aboriginal fisheries, while cod longline, cod traps and redfish midwater trawls retain bycatch on the east coast. Discards were assumed to be minimal, only groundfish/shrimp trawls and clam dredge produce discards on both coasts.

Percentages listed in Appendix B Tables B1a and b (catch) and B2a and B2b (discards) refer to the proportion of total group biomass caught in the first year of the optimal policy exploration; these values will change throughout the simulation. Group biomass for each time period is listed in Ainsworth *et al.* (2002) for the west Canadian coast and in Pitcher *et al.* (2002) for the east coast.

Generally, the fisheries were set to initially catch 2.5% of the total biomass of their target groups annually, and 0.5% or 0.25% of retained bycatch groups. In northern BC, major discards were set at 1.25% of group biomass, while minor discards were set to 0.25% or 0.025% of group biomass. In Newfoundland discards were all set at 2.5% of group biomass for fish and 0.1% for birds. Catches and discards vary between time periods in proportion to system biomass. As the policy exploration progresses these values are free to change.

The baseline values of fishing mortality should have no impact on the final policy. However, we had to use initial Fs small enough to avoid having to rebalance the model for each of our trial fisheries (thereby affecting the search results), and large enough so that the routine's outputs (which are multipliers of the base F) remain small for convenience. Since the policy search routine was designed to accommodate much larger initial fishing mortalities (as would be seen when evaluating any real-world fishery for example), the output multipliers deliver an uninformative “>60” string, when optimal Fs are greater than sixty times the baseline value[1]. Careful choice of baseline fishing mortalities can circumvent this software limitation.

For both coasts there are three fleets tested in the present analysis. First, the *Lost Valley* fleet, secondly the *Lost Valley* fleet minus recreational gear and finally the *Lost Valley* fleet minus trawlers (shrimp trawl and groundfish trawl on both coasts). The aboriginal fishery was held constant, omitted from the policy search for all fleets and objectives. In ‘no recreational fishery’ trials, the recreational fishery was removed from the base model and omitted from the policy search. Similarly, shrimp trawl and groundfish trawl were removed from the model and omitted from the policy search for the ‘no trawl’ trials.

Policy objectives

Five *Lost Valley* policy objectives were considered: ecological, economic, social, mixed and portfolio log utility optimization. These are discussed in the following sections. Since the search routine does not normally attempt to preserve species biodiversity, we entered into the ecological and mixed objective runs of the northern BC ecosystem a constraint (using mandated rebuilding) that there should be no extinctions. The portfolio log utility optimization, in only a few cases, would recommend harvest policies that included extinction of vulnerable groups. A constraint was added to prevent this (see below). For the economic and social optimization runs, no such constraints were included – extinctions were allowed under these objectives. The optimization procedure was not constrained for any of the Newfoundland models.

Mandated rebuilding

The mandated rebuilding routine was designed to allow users to identify fishing policies that would facilitate the rebuilding of a depleted stock. In this exercise we do not try to increase stock size, but use the routine (in the BC models) to prevent extinctions by setting the biomass goal to one times the *Ecopath* base level. This novel procedure works well to maintain a steady abundance in protected groups. Although in ecological and mixed objective runs many functional groups tended towards extinction, it was possible in all cases to identify a key group, which when protected, allowed the run to proceed without any extinctions. The smallest mandated rebuilding weight that would stop extinctions was used, so as not to disturb the optimum policy any more than necessary.

Initially, with the BC trials, we tried to prevent extinctions ecological and mixed runs by increasing the biomass/production (B/P) ratio of key groups. As explained below, the ecological objective (present in the mixed objective run as well) increases the biomass of functional groups with high B/P ratios. Groups prone to extinction would then have an inflated importance in the policy search. However, this technique was rejected for mandated rebuilding since there was no single set of B/P values found that would stave off extinctions when commonly applied to all models.

Software difficulties

To prevent the policy search program from becoming unstable, it was sometimes also necessary to use mandated rebuilding to prevent groups from exploding or going extinct. The economic optimization runs were particularly prone to instability, 8 out of 12 economic runs in northern BC required restraint on problem functional groups to allow the program to operate. Two out of 12 social runs required manipulation. We gave mandated rebuilding a low priority in the policy search: enough to allow the search routine to function, but not enough to stop extinctions (since we did not wish to perturb the outcome any more than was necessary). In northern BC, the migratory group, *transient salmon*, in particular was prone to exploding in abundance under most policy objectives causing a computer crash. It was often necessary to restrict its growth to a factor of about eight times the baseline in order to avoid crashes. The problem in modeling migratory species has to do with the diet matrix. When groups feed primarily out of the study area, their food source is not subject to systemic fluctuations in productivity. In times of low system productivity, biomass of the migratory group is inappropriately bounded only by top-down control. For a complete discussion on the problems of migratory species in *Ecosim* modeling refer to Martell (2004, this volume). Less often than transient salmon, it was also

[1] In preliminary work, the EwE code was modified to return numerical multipliers beyond sixty times. However, this version of the code was abandoned when a more fundamental bug was discovered in the policy search routine that limited the number of fleets that could be examined. Unfortunately, the next version of EwE, which corrected the more severe bug, did not include the maximum-multiplier fix.

necessary to manage skates and juvenile/adult turbot to allow the policy search to complete itself.

Mandated rebuilding was not used in the Newfoundland policy exploration; unstable runs are indicated in Appendix B Table B4b. Social runs proved the most problematic for the Newfoundland trials, with all the social runs in 1450 and 1985 becoming unstable. Unstable runs resulted in either huge oscillations of biomass, a collapse in biomass (especially salmon, shortfin squid and large and small crabs), or an explosion of biomass (adult Greenland halibut in the 1450 model).

Policy objectives

Ecosystem

Under the ecosystem policy objective, the search seeks to maximize the occurrence of long-lived species. Pristine and unfished ecosystems have been characterized as having many large slow-growing animals (Odum 1969). Therefore, using a high biomass/production (B/P) ratio across functional groups as a surrogate to describe this condition, the ecosystem policy objective suggests an exploitation profile that will increase the abundance of slow-growing functional groups. Cheung *et al.* (2002) were the first authors to use this technique. The B/P ratios used in the present exercise are listed in Appendix A Table A5a and b. However, the ecological objective does not necessarily preserve species diversity; it will sacrifice high turnover groups (e.g. predators, competitors) in favour of the long-lived animals. Therefore, (in the BC models) we used mandated rebuilding to protect against extinction of any functional group under this policy objective.

Economic

The economic objective seeks to maximize total rent from the system. Under this objective, high value fisheries will be favoured at the expense of low value fisheries, even to the extent of causing extinctions among detrimental groups (e.g. predators, competitors). We do not expect this run to preserve biodiversity. Economic valuation methodology is presented in Ainsworth and Sumaila (2004a).

Social

The social optimization will increase the number of jobs by eliminating fisheries with a low number of jobs per catch value in favour of more labor-intensive gears. Appendix B Table B3a and b give the jobs per catch value used for initialization. At 15 jobs per catch value unit (an estimate), the recreational fishery of northern BC employs three times as many people as the next highest fishery. Relative values were estimated by expert opinion (Pitcher, *pers. comm.*).

Mixed

The mixed objective combines ecological, economic and social elements. The search routine attempts to maximize the total objective function (the weighted sum of all components). Mackinson (2002) tried a similar mixed objective function on a model of the North Sea. He found that the relative improvement in ecosystem criteria consistently failed to match the relative improvement of social and economic criteria and it did not improve markedly as a higher relative weight was given. However, that author used much smaller relative weightings for ecology than the present paper (i.e. the largest relative weighting he applied was 10, 1 and 1 for ecological, social and economy). Zeller and Freire (2002) likewise found that the relative improvement over baseline of ecology was quite invariant to the weighting given to the ecological objective. Buchary *et al.* (2002) also found that a 1,1,1 mixed search for ecology, economics and social benefit results in an optimal policy that is very similar to their social optimization. These authors used a low relative weighting, with the ecological function receiving the same weight in the policy search as economy and social (i.e. 1, 1 and 1 for ecology, economy and social functions).

However, it is evident that entering equal weightings in the *EwE* software panel does not result in an equal improvement in criteria over *Ecopath* baseline. Since there is no intrinsic comparability between the three objective functions, then the relative weightings used to parameterize the search are meaningless and so a 1:1:1 ratio between the three objective functions does not imply that the policy search will increase all objectives evenly. Rather, only the relative improvement in each field over baseline is significant. We therefore adjust the weightings iteratively, based on the overall figure given by the completed search, so that each factor influences changes in the overall figure by an equal (or the desired) amount. This technique has been used in the LV work reported in Pitcher *et al.* (2004).

From the baseline condition, we find that in general, a much higher relative weighting must be given to ecology in order to achieve an equal improvement among mixed factors (see Pitcher

2004b, this volume). In this paper, the relative weighting of the three fields were determined in such a way as to minimize variance between the overall improvement values of the three functions. It turned out that a relative weighting of 1, 1 and 100 for economic, social and ecological priorities was found to consistently produce the most equal increase as measured from the final line of multipliers in the policy search. This ratio was therefore adopted for all BC runs. Variance of the relative ecological, economic and social improvements for BC runs are presented in Table B4a.

The Newfoundland models required a relative weighting of 0.1, 0.1 and 100 for economic, social and ecological weightings to obtain an equal increase in each priority. Thus, the ecological priorities had to be three orders of magnitude higher than the social and economic priorities to get similar outcomes for these three functions (as opposed to the two orders of magnitude required by the BC models). The only Newfoundland model that did not conform to the 0.1:0.1:100 ratio was 1450 (see Appendix B Table B4b).

The very high value required for ecological improvement in both ecosystems suggests that it is more difficult to manage an increase in the B/P surrogate than it is to increase rent, for example (i.e., *Ecosim* must structure virtually the entire strategy towards ecological gain in order to produce a minimal increase in average B/P of the system). Although the relative weightings required to levy an equal improvement across criteria will be model-specific. The relative insensitivity of the ecological function is also noted by Mackinson (2002), Zeller and Freire (2002), Buchary *et al.* (2002) and Pitcher *et al.* 2004.

Portfolio Log Utility

The recently devised portfolio log utility function attempts to account for the inherent uncertainty in changing the system far from its base state. Christensen *et al.* (2000) and Christensen and Walters (2004) provide a more detailed description of this *Ecosim* subroutine. Policies that promise the greatest benefit tend to carry with them the greatest risk, since the extreme combination of fisheries required to manipulate the ecosystem into a hyper-productive state will change the system far from its present condition. Such a policy may, for instance, involve destroying competitors and predators of the most valuable species, as is done in agriculture.

In portfolio log utility the user enters three parameters. Prediction variance describes the amount of uncertainty associated with changing the ecosystem far from its baseline. A high value will increase the discounting rate (reducing the net present value of future benefits), and make large returns unappealing when they require drastic manipulation of the ecosystem. Existence value defines the worth one assigns to the continued existence of functional groups: assigning a high value to this parameter will maintain a diverse biological 'portfolio' in economics terms. Finally, users enter a coefficient that modifies the net present value from the system (the sum of profits from all functional groups, discounted over time). A high value of this can make risky policies worthwhile.

For some runs with the BC models there was a precarious balance between receiving a policy recommendation that included extinctions, and receiving a flat line (zero change from base state). To fine-tune these runs we added a very small prediction variance, from 0.02 to 0.003. This fix helps prevent extinctions by devaluing daring portfolio choices. Only the lowest existence value that would still prevent extinctions was used. With the Newfoundland models this was not a problem. We only used existence values without having to use prediction variance. The existence values used for the Newfoundland models ranged from 0.01 to 0.1 (Appendix B Table B4b).

The portfolio log utility trials are very stable. Runs change slowly from the base state, and are not subject to the same wild fluctuations in biomass often seen when using the other policy objectives. This is the most conservative method. We do not expect high returns from the system compared to ecological, economic, social or mixed runs.

Verification of optimal policy

For the northern BC models, we next repeated each optimization 25 additional times, using random fishing mortalities as the starting point for the optimization, rather than *Ecopath* base values. Ideally, each replication should result in the same optimum fishing pattern (i.e., locate the global maximum on the response surface). However, prior investigations revealed that random F starting points do not necessarily allow the search routine to converge on the same maximum. Rather, the resultant 'optimal' fishing mortalities seem to cluster around common peaks, indicating that the search can stall on local maxima of the response surface.

In the CUS BTF results report for BC models

(Ainsworth *et al.* 2004), a two-way analysis of variance tests whether the 25 treatments have generated a statistically similar pattern of fishing mortalities. Results from the second factor, gear type, are discarded since we expect fishing mortality to vary between gear types. If the random F runs are shown to be dissimilar, this may indicate that the policy search routine has identified two or more local maxima for a given scenario, or alternatively, that the search routine has identified a single, broad peak (i.e. a plateau) where major variation in the harvest pattern yields an equivalent improvement over baseline.

Multidimensional scaling (MDS) offers a method to differentiate between these possibilities. Using SPSS v.10.0 statistical software, MDS is performed on a subset of runs (chosen to demonstrate the potential of this analysis in describing the shape of the response surface). MDS reduces all factors affecting scenario performance (i.e. fishing mortalities per gear type) to two dimensions, allowing us to sketch the shape of the optimal peak and/or detect the presence of local maxima. Such an approach may be used to judge the robustness of a harvest recommendation for management; however, more random F runs would be required to fully explore the shape of the response surface.

If a recommended harvest policy resides on a narrow peak, than any variation from the specified optimal fishing pattern may result in sub-optimal harvests. If however, the identified maximum resides on a broad peak, than deviations in fleet-effort structure may still result in a near-optimal manipulation of the ecosystem. The latter situation may represent a more robust goal for management than the former.

Valuation indices

Having determined the optimal combination of fishing mortalities per gear type that will maximize our five objective functions for each restored period, we then simulated a 100-year harvest regime (50 years dynamic and 50 years equilibrium) under each of our 3 idealized fleet structures. The resulting harvest profile was evaluated using two economic measures: conventional and intergenerational net present value (Sumaila and Walters 2003, 2004; Sumaila 2001, Sumaila and Bawumia, 2000). Economic valuation methodology is discussed in Ainsworth and Sumaila (2004, this volume).

The ecological success of the restoration/harvest scheme was determined using three valuation measures: the Q-90 statistic, system resilience and presence of local extinctions. Based on Kempton's Q index (Kempton and Taylor 1976), the Q-90 statistic is a measure of biodiversity that concerns species evenness. It looks at the slope of the cumulative species abundance curve between the 10 and 90 percentiles (see Ainsworth and Pitcher 2004, this volume, for methods). A second index involves measuring the resiliency of the system to fishing using ecosystem redundancy from network analysis (see Heymans 2004, this volume, for methodology and theory). The third measures the risk of local extinctions in composite functional groups (see Cheung and Pitcher 2004, this volume).

Social valuation measures include relative number of jobs created and employment diversity. Relative number of jobs created by an optimal plan is calculated as the product of total catch value (i.e. all simulation years summed) and the gear-specific jobs per unit catch value (Tables B3a and b). Employment diversity across fishing sectors is calculated after Atteran (1986). Ainsworth and Sumaila (2003b) describe how this index was applied to BTF methodology.

Using Kendall's coefficient of concordance (W; Kendall 1962), we finally determine the ability of each restoration period, fleet structure and harvest objective to maximize these economic, ecological and social valuation measures. Specific expectations are discussed below.

All valuation results will be presented in Ainsworth *et al.* (2004) for British Columbia and Heymans *et al.* (2004) for Newfoundland.

DISCUSSION

Ecosystem value will depend mainly on what period is restored. The pre-contact systems have in them the greatest biomass of valuable commercial groups; we therefore expect this period to permit the most valuable fisheries – scoring high in the economic analyses. On both coasts, models of the recent past represent a more depleted state than do models of the distant past; these will not be able to generate as much economic benefit.

Since the conventional model of discounting places most value on the immediate future, we expect also that the pre-contact and 1900 runs will do especially well under this valuation scheme. These simulations start at a high level of biomass and *Ecosim* can fish down the natural capital, generating immediate revenue and leaving the system in a depleted (but more productive) state. Intergenerational discounting, however, will not favour the immediate profit as strongly; it will be content to leave more natural capital in the sea and maintain high harvests farther into the future. Therefore, although the pristine states (pre-contact and 1900) should always produce greater revenues than the more depleted systems (1950 and 2000 in BC; 1985 and 1995 in Newfoundland), the difference will be more apparent under conventional discounting than under intergenerational discounting because of the relative shape of harvest profiles. The more recent time periods will require rebuilding in order to generate maximum monetary returns. Their harvest profiles will slope upwards (or slope downwards less sharply than distant past periods); therefore, they will score proportionately better under intergenerational discounting.

Of the three fleets tested (*Lost Valley*, *no recreational*, *no trawl*), we expect the *Lost Valley* fleet to generate the most valuable harvest of the restored system for two reasons. First, the additional gear types allow the search routine to probe for the best policy with improved dexterity. Since the policy search is at liberty to minimize any of its fleets, allowing more gear types can only enhance the search routine's ability to manipulate the ecosystem into its most commercially valuable condition. Secondly, the CUS BTF models (at this stage) do not consider the problems of trawl damage, ghost fishing, or any other deleterious gear effect. In the simulation, there is no ecological or economic benefit associated with preserving habitat, and nothing is to be gained by restricting damaging fisheries (except perhaps a coincidental reduction in discards). Similarly, ecologically responsible fleets that omit damaging gear types will not be credited with their full ecological benefit. Future efforts to model the system spatially will allow us to include these considerations.

We expect the mixed objective function to yield exploitation profiles similar to the ecological runs. Our preliminary efforts have confirmed the findings of other researchers that the ecological objective is the most difficult to maximize – the policy search must virtually disregard the other objective functions in order to increase the ecological criteria. For example, a typical ecological run will rarely exceed a 10% improvement in the B/P surrogate over 50 years, under even the most vigorous attempts to do so. Rent and jobs, on the other hand, regularly exceed a seven times improvement on the economic and social objective functions. Where improving the ecology involves a slow restructuring of the ecosystem (and a sacrifice in catch), the economic and social functions need only to redistribute fishing effort to increase rent or jobs. This is especially true since the economic and social functions were not constrained by the requirement to avoid extinctions. Further, the search routine will be hard pressed to improve the B/P ratio of the already under-exploited pre-contact and 1900 models. As an objective, it is easier to disassemble the ecosystem, particularly one that is under-exploited, than it is to build it.

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For discussion after the oral presentation of this paper, see page 153.

APPENDIX A
ECOSIM PARAMETERS

Table A1. Run Information for both ecosystems.

Duration of simulation (years)	50
Integration steps (per year)	100
Relaxation parameter [0,1]	0.5
Discount rate (% per year)	5
Equilibrium step size	0.003
Equilibrium max. fishing rate (relative)	3
Number of time steps for averaging results	5

Table A2. Group Information for both ecosystems

Maximum relative feeding time	2
Feeding time adjustment rate	0.5
Fraction of 'other' mortality sensitive to changes in feeding time	1
Predator effect on feeding time	0
Density dependant catchability	1
QBmax/Qbo	1000

Table A3a. Stage (Juvenile/adult linking parameters) for northern BC.

	Herring	Piscivorous rockfish	Turbot	Flatfish	Halibut	Sablefish	Lingcod	Pollock	Pacific Ocean Perch	Pacific Cod
Min. time as juv. (rel. to orig. setting)	1	1	1	1	1	1	1	1	1	1
Max. time as juv. (rel. to orig. setting)	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001
Recruitment power parameter	1	1	1	1	1	1	1	1	1	1
Weight (g) at transition to adult group	1	1	1	1	1	1	1	1	1	1
Age (year) at transition to adult group (tk)	2.1	16	4.5	4.5	10	4.5	4	2.3	16	2.3
Wavg / Wk (Av. adult weight / weight at transition)	2	2.7	2	2	1.357	1.88	3.684	3.597	2.7	1.725
K of the VBGF (/year)	0.47	0.05	0.243	0.243	0.08	0.3	0.263	0.373	0.88	0.27
Base fraction of food intake used for reproduction	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Fraction of increase in food intake used for growth	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Table A3b. Stage (Juvenile/adult linking parameters) for Newfoundland

	Cod		American plaice		Greenland halibut
	1985	**1995**	**1985**	**1995**	
Min. time as juv. (rel. to orig. setting)	1	1	1	1	1
Max. time as juv. (rel. to orig. setting)	1.0001	1.0001	1.0001	1.0001	1.0001
Recruitment power parameter	1	1	1	1	1
Weight (g) at transition to adult group	1	1	1	1	1
Age (year) at transition to adult group (tk)	7	7	5	5	9
Wavg / Wk (Av. adult weight / weight at transition)	1.247	1.051	3.427	2.299	2.000
K of the VBGF (/year)	0.07	0.07	0.099	0.099	0.025
Base fraction of food intake used for reproduction	0.3	0.3	0.3	0.3	0.3
Fraction of increase in food intake used for growth	0.8	0.8	0.8	0.8	0.8
Weight at transition	1.927	2.353	0.104	0.095	
Adult weight	2.403	2.474	0.358	0.218	

Table A4a. Flow control in northern BC.

Functional Group	1750	1900	1950	2000
Seals, sea lions	0.80	0.80	0.80	0.80
Transient salmon	0.50	0.50	0.50	0.50
Coho salmon	0.76	0.76	0.76	0.76
Chinook salmon	0.71	0.71	0.71	0.71
Small squid	0.57	0.57	0.57	0.57
Squid	0.71	0.71	0.71	0.71
Ratfish	0.57	0.57	0.57	0.57
Dogfish	0.64	0.64	0.64	0.64
Juvenile pollock	0.53	0.53	0.53	0.53
Pollock	0.60	0.60	0.60	0.60
Forage fish	0.46	0.46	0.46	0.46
Eulachon	0.48	0.48	0.48	0.48
Juvenile herring	0.47	0.47	0.47	0.47
Adult herring	0.51	0.51	0.51	0.51
Juvenile POP	0.48	0.48	0.48	0.48
Adult POP	0.52	0.52	0.52	0.52
Inshore rockfish	0.72	0.72	0.72	0.72
Juvenile picivorous rockfish	0.53	0.53	0.53	0.53
Adult picivorous rockfish	0.59	0.59	0.59	0.59
Juvenile planktivorous rockfish	0.49	0.49	0.49	0.49
Adult planktivorous rockfish	0.62	0.62	0.62	0.62
Juvenile turbot	0.73	0.73	0.73	0.73
Adult turbot	0.77	0.77	0.77	0.77
Juvenile flatfish	0.51	0.51	0.51	0.51
Adult flatfish	0.53	0.53	0.53	0.53
Juvenile halibut	0.70	0.70	0.70	0.70
Juvenile Pacific cod	0.44	0.44	0.44	0.44
Adult Pacific cod	0.79	0.79	0.79	0.79
Juvenile sablefish	0.54	0.54	0.54	0.54
Adult sablefish	0.66	0.66	0.66	0.66
Juvenile lingcod	0.70	0.70	0.70	0.70
Adult lingcod	0.77	0.77	-	-
Shallowwater benthic fish	0.62	0.62	0.62	0.62
Skates	0.65	0.65	0.65	0.65
Large crabs	0.45	0.45	0.45	0.45
Small crabs	0.47	0.47	0.47	0.47
Commercial shrimp	0.35	0.35	0.35	0.35
Epifaunal invertebrates	0.20	0.20	0.20	0.20
Infaunal carnivorous invertebrates	0.23	0.23	0.23	0.23
Infaunal invertebrate detritivores	0.20	0.20	0.20	0.20
Carnivorous jellyfish	0.23	0.23	0.23	0.23
Euphausiids	0.25	0.25	0.25	0.25
Copepods	0.20	0.20	0.20	0.20
Macrophytes	0.20	0.25	0.25	0.25
Phytoplankton	0.20	0.23	0.23	0.23

Table A4b. Flow control in Newfoundland.

Functional Group	1500	1900	1985	1995
Walrus	0.53	0.53	0.48	0.53
Cetaceans	0.71	0.72	0.66	0.67
Grey seals	0.79	0.80	0.73	0.79
Harp Seals	0.73	0.73	0.68	0.74
Hooded Seals	0.80	0.80	0.80	0.80
Ducks	0.45	0.45	0.42	0.45
Piscivorous Birds	0.78	0.76	0.69	0.75
Planktivorous Birds	0.58	0.58	0.53	0.53
Cod (> 40 cm)	0.68	0.68	0.67	0.71
Cod (≤ 40 cm)	0.60	0.60	0.60	0.63
American plaice (> 35 cm)	0.56	0.56	0.56	0.55
American plaice (≤ 35 cm)	0.54	0.54	0.56	0.59
Greenland Halibut (> 65 cm)	0.79	0.79	0.75	0.77
Greenland Halibut (≤ 65 cm)	0.75	0.75	0.68	0.73
Yellowtail Flounders	0.48	0.48	0.44	0.48
Witch flounder	0.45	0.45	0.42	0.46
Winter flounder	0.47	0.47	0.43	0.45
Skates	0.75	0.75	0.68	0.73
Dogfish	0.70	0.70	0.63	0.67
Redfish	0.62	0.62	0.56	0.58
Transient Mackerel	0.66	0.66	0.60	0.64
Dem. BP Pisc. (>40 cm)	0.77	0.77	0.71	0.75
Dem. BP Pisc. (≤ 40 cm)	0.67	0.68	0.63	0.61
Demersal Feeders (> 30 cm)	0.54	0.54	0.49	0.51
Demersal Feeders (≤ 30 cm)	0.52	0.52	0.48	0.48
Small Demersals	0.47	0.47	0.44	0.47
Lumpfish	0.59	0.59	0.54	0.55
Greenland cod	0.67	0.71	0.64	0.69
Salmon	0.76	0.76	0.69	0.74
Capelin	0.51	0.51	0.47	0.49
Sandlance	0.50	0.50	0.46	0.48
Arctic cod	0.54	0.54	0.50	0.51
Herring	0.52	0.52	0.48	0.49
Transient Pelagics	0.70	0.71	0.65	0.68
Small Pelagics	0.55	0.55	0.51	0.50
Small Mesopelagics	0.54	0.54	0.50	0.50
Shortfin squid	0.69	0.69	0.64	0.69
Arctic Squid	0.52	0.52	0.48	0.48
Large Crabs (> 95 cm)	0.43	0.43	0.40	0.43
Small Crabs (≤ 95 cm)	0.47	0.47	0.43	0.46
Lobster	0.43	0.43	0.40	0.43
Shrimp	0.31	0.31	0.30	0.31
Echinoderms	0.20	0.20	0.20	0.20
Polychaetes	0.20	0.20	0.20	0.20
Bivalves	0.20	0.20	0.20	0.20
Other Benthic Invertebrates	0.20	0.20	0.20	0.20
Large Zooplankton	0.34	0.34	0.32	0.28
Small Zooplankton	0.20	0.20	0.20	0.20
Phytoplankton	0.30	0.30	0.30	0.30

Table A5a. Biomass/production ratios for BC *.

	2000	1950	1900	1750
Sea Otters	7.69	7.69	7.69	7.69
Mysticetae	50.00	50.00	50.00	50.00
Odontocetae	25.00	50.00	25.00	25.00
Seals, sea lions	16.67	16.67	16.67	16.67
Seabirds	10.00	10.00	10.00	10.00
Transient salmon	0.40	0.40	1.61	1.93
Coho salmon	0.36	0.36	0.94	0.86
Chinook salmon	0.46	0.46	2.75	2.73
Small squid	0.17	0.17	0.17	0.17
Squid	0.17	0.17	0.17	0.17
Ratfish	10.10	10.10	5.03	5.03
Dogfish	10.10	10.10	7.14	9.09
Juvenile pollock	0.94	0.94	4.35	4.35
Pollock	3.80	3.80	6.49	6.54
Forage fish	0.70	0.70	1.70	1.68
Eulachon	0.70	0.70	1.67	1.67
Juvenile herring	0.46	0.46	0.85	0.85
Adult herring	1.46	1.46	1.25	1.26
Juvenile POP	1.49	1.49	2.96	2.96
Adult POP	6.94	6.94	4.41	4.41
Inshore rockfish	5.26	5.26	5.49	5.49
Juvenile picivorous rockfish	3.83	3.83	3.83	3.83
Adult picivorous rockfish	27.03	27.03	27.03	27.03
Juvenile planktivorous rockfish	3.83	3.83	3.83	3.83
Adult planktivorous rockfish	14.71	14.71	14.71	14.71
Juvenile turbot	3.03	3.03	3.03	3.03
Adult turbot	4.55	4.55	4.55	4.55
Juvenile flatfish	0.52	0.52	2.62	2.62
Adult flatfish	1.05	1.05	3.89	3.89
Juvenile halibut	1.67	1.67	8.62	10.10
Adult halibut	2.50	2.50	11.90	14.93
Juvenile Pacific cod	0.51	0.51	3.88	3.88
Adult Pacific cod	0.76	0.76	5.75	5.75
Juvenile sablefish	1.67	1.67	3.66	3.66
Adult sablefish	3.62	3.62	5.43	5.46
Juvenile lingcod	0.83	0.83	2.57	2.57
Adult lingcod	1.25	1.25	3.33	3.82
Shallowwater benthic fish	0.67	0.67	3.76	3.76
Skates	3.23	3.23	6.67	6.67
Large crabs	0.67	0.67	0.67	0.67
Small crabs	0.29	0.29	0.29	0.29
Commercial shrimp	0.09	0.09	0.18	0.18
Epifaunal invertebrates	0.69	0.69	0.69	0.69
Infaunal carnivorous invertebrates	0.50	0.50	0.50	0.50
Infaunal invertebrate detritivores	0.74	0.74	0.77	0.77
Carnivorous jellyfish	0.06	0.06	0.06	0.06
Euphausiids	0.16	0.17	0.17	0.17
Copepods	0.04	0.04	0.04	0.04
Corals and sponges	100.00	100.00	100.00	100.00
Macrophytes	0.19	0.19	0.19	0.19
Phytoplankton	0.01	0.01	0.01	0.01

**Ecological objective maximizes B/P surrogate*

Table A5b. Biomass/production ratios for NFLD.

	1450	1900	1985	1995
Walrus	16.6	16.6	16.6	16.6
Cetaceans	20	10	10	10
Grey seals	16.6	16.6	16.6	16.6
Harp Seals	9.8	9.8	9.8	9.8
Hooded Seals	9.2	9.2	9.2	9.2
Ducks	4	4	4	4
Piscivorous Birds	4	4	4	4
Planktivorous Birds	4	4	4	4
Cod (> 40 cm)	4.6	10.4	2.4	3.4
Cod (≤ 40 cm)	4.8	4.2	0.6	0.6
American plaice (> 35 cm)	12	12	4.4	11.4
American plaice (≤ 35 cm)	8	8	1.6	2.4
Greenland Halibut (> 65 cm)	17	29.8	3.4	10.2
Greenland Halibut (≤ 65 cm)	13.2	39.8	1.2	2.6
Yellowtail Flounders	3.2	3.2	1.8	3.2
Witch flounder	4.2	4.2	1.8	2.8
Winter flounder	3.8	3.8	3.8	3.8
Skates	4.2	9	2.8	3.2
Dogfish	6.2	6.2	5.2	5.2
Redfish	8.8	8.8	2	6.8
Transient Mackerel	1.8	1.8	3.4	3.4
Demersal BP Piscivores (>40 cm)	10.2	10.2	1.6	4.8
Demersal BP Piscivores (≤ 40 cm)	6.8	6.8	6.8	6.8
Demersal Feeders (> 30 cm)	6.4	6.4	3.6	4.4
Demersal Feeders (≤ 30 cm)	4.4	4.4	4.4	4.4
Small Demersals	1.8	1.8	1.8	1.8
Lumpfish	8.8	8.8	8.8	8.6
Greenland cod	9.8	9.8	6	1.6
Salmon	3.6	3.6	1.6	1.6
Capelin	1.4	2	0.8	0.8
Sandlance	1	1	0.8	0.8
Arctic cod	1.8	1.8	2.4	1.8
Herring	2	2	1.8	1.8
Transient Pelagics	5.4	5.4	2.4	2.4
Small Pelagics	1.6	1.6	1.6	1.6
Small Mesopelagics	0.8	0.8	0.8	0.8
Shortfin squid	1.6	1.6	1.6	1.6
Arctic Squid	2	2	2	2
Large Crabs (> 95 cm)	2.6	2.6	2.6	2.6
Small Crabs (≤ 95 cm)	2.6	2.6	2.6	1.6
Lobster	2.6	5.2	2.6	2.6
Shrimp	0.6	0.6	0.6	0.6
Echinoderms	1.6	1.6	1.6	1.6
Polychaetes	0.4	0.4	0.4	0.4
Bivalves	1.8	1.8	1.8	1.8
Other Benthic Invertebrates	0.4	0.4	0.4	0.4
Large Zooplankton	0.2	0.2	0.2	0.2
Small Zooplankton	0.2	0.2	0.2	0.2

APPENDIX B
POLICY SEARCH PARAMETERS

Table B1a. Lost Valley catch for BC *

	Groundfish Trawl	Shrimp Trawl	Shrimp Trap	Herring Seine	Halibut Longline	Salmon Freezer Troll	Salmon Wheel	Rockfish Live	Crab Trap	Clam Dredge	Aboriginal	Recreational
Transient salmon						2.5	2.5				2.5	
Coho salmon						2.5					2.5	2.5
Chinook salmon						2.5					2.5	2.5
Ratfish	0.25	0.25										
Dogfish	0.25	0.25				0.25						
Pollock	0.25											
Eulachon		2.5									2.5	
Juvenile herring				2.5								
Adult herring				2.5								
Adult POP	2.5											
Inshore rockfish	2.5				0.25	0.25		2.5				0.25
Adult picivorous rockfish	2.5					0.25						0.25
Adult planktivorous rockfish	2.5					0.25						
Juvenile turbot					0.25							
Adult turbot	0.25	0.25			2.5							
Juvenile flatfish					0.25							
Adult flatfish	2.5	0.5			0.25							
Juvenile halibut					2.5							0.25
Adult halibut					2.5						2.5	0.25
Adult Pacific cod	2.5				0.25							
Adult sablefish	0.25				0.25							
Adult lingcod	0.25				0.25			2.5				2.5
Shallow water benthic fish		0.25	0.25	0.25								
Skates	0.25	0.25			2.5							
Large crabs	0.25								2.5			
Small crabs									0.25			
Commercial shrimp		2.5	2.5									
Epifaunal invertebrates										2.5		

*Percentages indicate the fraction of the total group biomass caught in the first year of the policy exploration. The *Ecopath* description is available in Ainsworth *et al.* (2002). 2.5% of total biomass is caught for target species, 0.25% or 0.5% of total biomass is caught in retained bycatch.

Table B1b. Newfoundland Lost Valley Catch as a percentage of the biomass of each group *

Group Name	Bottom trawl	Shrimp trawl	Recreational	First Nations	Cod trap	Capelin	Longline	Redfish	Lumpfish trap	Snow crab traps	Inshore crab traps	Lobster traps	Salmon	Pole and line	Bivalves	Urchins
Walrus				0.25												
Cetaceans				0.01												
Grey Seals				0.25												
Harp Seals				0.25												
Hooded Seals				0.25												
Cod > 35cm	2.5		0.25		2.5		2.5	0.25								
Cod < 35 cm	0.25	2.5			0.25			0.25								
American plaice > 35cm	2.5						2.5	0.25								
American plaice < 35cm	0.25	2.5														
Greenland halibut > 40cm	2.5						2.5	0.25								
Greenland halibut < 40cm	0.25	2.5					0.25									
Yellowtail Flounder	2.5						2.5	0.25								
Witch flounder	2.5						2.5	0.25								
Skates	2.5	0.25					2.5									
Dogfish	2.5	0.25					2.5									
Redfish	2.5							2.5								
Transient mackerel			0.25													
L. D. Bentho-pelagic Pisc.	2.5						2.5	0.25								
S. D. Bentho-pelagic Pisc.	0.25	0.25					0.25									
L.Dem.Feeders	2.5						2.5									
S.Dem.Feeders	0.25	0.25					0.25									
O.S.Demersals	0.25	0.25														
Lumpfish	0.25	0.25							2.5							
Greenland cod					2.5											
Salmon			2.5										2.5			
Capelin						2.5										
Herring	0.25															
Transient Pelagics														2.5		
Small Pelagics	0.25	0.25	0.25													
Shortfin squid	0.25															
Large Crabs										2.5						
Small Crabs											2.5					
Lobster												2.5				
Shrimp	0.25	2.5														
Echinoderms																0.25
Bivalves															2.5	

*Percentages indicate the fraction of the total group biomass caught in the first year of the policy exploration. *Ecopath* description is available in Pitcher *et al.* (2002). 2.5% of total biomass is caught for target species, 0.25% or 0.25% of total biomass is caught in retained bycatch.

Table B2a. West coast discards. Percentages indicate the fraction of total biomass caught in the first year of the policy exploration. Major sources of bycatch are set at 1.25% of group biomass, minor bycatch is 0.25% or 0.025%.

Group Name	Groundfish Trawl	Shrimp Trawl	Salmon Freezer Troll	Clam Dredge
Seabirds			0.025	
Small crabs	1.25	1.25		0.25
Epifaunal invertebrates	1.25	1.25		0.25
Infaunal carnivorous invertebrates	1.25	1.25		0.25
Infaunal invertebrate detritivores	1.25	1.25		0.25
Corals and sponges	1.25	1.25		0.25

Table B3a. Jobs per catch value for northern BC.

Fleet	Jobs/catch value
Groundfish Trawl	0.4
Shrimp Trawl	0.6
Shrimp Trap	5
Herring Seine	4
Halibut Longline	1.3
Salmon Freezer Troll	2
Salmon Wheel	0.2
Rockfish Live	5
Crab Trap	5
Clam Dredge	5
Aboriginal*	-
Recreational	15

*Policy search did not include aboriginal fleet.

Table B2b. East coast discards. Percentages indicate the fraction of total biomass caught in the first year of the policy exploration. Major sources of bycatch are set at 1.25% of group biomass, minor bycatch is 0.25% or 0.025%.

Group Name	Bottom trawl	Shrimp trawl	Bivalves
Echinoderms	2.5	2.5	2.5
Polychaetes	2.5	2.5	2.5
Bivalves	2.5	2.5	
Other Benthic Invertebrates	2.5	2.5	2.5

Table B3b. Jobs per catch value for Newfoundland.

Gear	Jobs/catch value
Bottom trawl	0.4
Shrimp trawl	0.6
Recreational	15
First Nations	0.1
Cod trap	2
Capelin	0.4
Cod long-line	1.3
Redfish	0.6
Lumpfish trap	5
Offshore crab traps	1
Inshore crab traps	5
Lobster traps	5
Salmon	0.2
Pole and line	1
Bivalves (clams etc.)	10
Sea urchins	10

Table B4a. Value weight settings for fleets, years and policy objectives in northern BC. *Bold values indicate that mandated rebuilding was required to prevent computer crashes. ** Numbers in parentheses indicate the biomass goal of the policy search relative to the *Ecopath* baseline.

Fleet	Period	#	Objective	Policy Search Parameters					
				Ecological	Economic	Social	Mandated Rebuilding*	Variance (□^{2}) of mixed	MR protected groups**
Lost Valley	1750	1	Ecological	1	0	0	0		
		2	Economic	0	1	0	0		
		3	Social	0	0	1	0		
		4	Mixed objective	100	1	1	0.1	0.309	Juv/ad turbot (1)
		5	Portfolio Log Utility	Existence value = 0.1					
	1900	6	Ecological	1	0	0	5		Juv/ad turbot (1)
		7	Economic	0	1	0	0		
		8	Social	0	0	1	0		
		9	Mixed objective	100	1	1	5	0.192	Juv/ad turbot (1)
		10	Portfolio Log Utility	Existence value = 0.1					
	1950	11	Ecological	1	0	0	10		Skates (1)
		12	Economic	0	1	0	5		Juv/ad turbot (1)
		13	Social	0	0	1	0		
		14	Mixed objective	100	1	1	10	0.316	Skates (1)
		15	Portfolio Log Utility	Existence value = 1			Prediction variance = 0.005		
	2000	16	Ecological	1	0	0	7		
		17	Economic	0	1	0	5		Transient Salmon (1)
		18	Social	0	0	1	0		
		19	Mixed objective	100	1	1	10	0.679	Transient Salmon (1)
		20	Portfolio Log Utility	Existence value = 10			Prediction variance = 0.02		
No Recreat.	1750	21	Ecological	1	0	0	0		
		22	Economic	0	1	0	10		Transient Salmon (0.5)
		23	Social	0	0	1	0		
		24	Mixed objective	100	1	1	0.1	0.194	Juv/ad turbot (1)
		25	Portfolio Log Utility	Existence value = 1					
	1900	26	Ecological	1	0	0	5		Juv/ad turbot (1)
		27	Economic	0	1	0	10		Transient Salmon (0.5)
		28	Social	0	0	1	0		
		29	Mixed objective	100	1	1	50	0.304	Juv/ad turbot (1), Skates (1.5)
		30	Portfolio Log Utility	Existence value = 1					
	1950	31	Ecological	1	0	0	0		
		32	Economic	0	1	0	10		Juv/ad turbot (1)
		33	Social	0	1	0	10		Skates (1)
		34	Mixed objective	100	1	1	5	0.268	Skates (1)
		35	Portfolio Log Utility	Existence value = 1					
	2000	36	Ecological	1	0	0	2		Skates (1)
		37	Economic	0	1	0	10		Transient Salmon (1)
		38	Social	0	0	1	1		Skates (1)
		39	Mixed objective	100	1	1	20	0.247	Skates (1)
		40	Portfolio Log Utility	Existence value = 1			Prediction variance = 0.003		
No Trawlers	1750	41	Ecological	1	0	0	0		
		42	Economic	0	1	0	5		Transient Salmon (1)
		43	Social	0	0	1	0		
		44	Mixed objective	100	1	1	0	0.218	
		45	Portfolio Log Utility	Existence value = 0.1					
	1900	46	Ecological	1	0	0	1		Transient Salmon (1)
		47	Economic	0	1	0	5		Skates (1)
		48	Social	0	0	1	0		
		49	Mixed objective	100	1	1	2	0.097	Juv/ad turbot (1)
		50	Portfolio Log Utility	Existence value = 0.1					
	1950	51	Ecological	1	0	0	0		
		52	Economic	0	1	0	0		
		53	Social	0	0	1	0		
		54	Mixed objective	100	1	1	10	0.258	
		55	Portfolio Log Utility	Existence value = 0.1					
	2000	56	Ecological	1	0	0	0		
		57	Economic	0	1	0	0		
		58	Social	0	0	1	0		
		59	Mixed objective	100	1	1	0	0.278	
		60	Portfolio Log Utility	Existence value = 0.1					

Table B4b. Value weight settings for fleets, years and policy objectives in Newfoundland. *Mandated rebuilding was not used with the Newfoundland models; some species went extinct. **Group biomass increased or decreased more than twice. Increased indicated by + and decreased indicated by - ***Unstable indicates that ecosystem never stabilized over the 50 year time span.

Fleet	Period	#	Objective	Policy Search Parameters					
				Ecological	Economic	Social	Mandated Rebuilding*	Variance (σ^2) of mixed	Large change in group biomass**
Lost Valley	1450	1	Ecological	1	0	0	0		Salmon (-) G. halibut (+)
		2	Economic	0	1	0	0		Many (+), many (-)
		3	Social	0	0	1	0		Unstable***
		4	Mixed objective	100	1	0.5	0	0.646	Skate, sf squid (-) halibut (+)
		5	Portfolio Log Utility	Existence value = 0.05					
	1900	6	Ecological	1	0	0	0		Salmon (+) short fin squid (-)
		7	Economic	0	1	0	0		Large and small crabs (-)
		8	Social	0	0	1	0		Crabs, transient pelagics (-)
		9	Mixed objective	100	0.1	0.1	0	0.195	Salmon (+) short fin squid (-)
		10	Portfolio Log Utility	Existence value = 0.05					
	1986	11	Ecological	1	0	0	0		
		12	Economic	0	1	0	0		Salmon (-) short fin squid (+)
		13	Social	0	0	1	0		Unstable***
		14	Mixed objective	100	0.1	0.1	0	0.181	
		15	Portfolio Log Utility	Existence value = 0.1					
	1996	16	Ecological	1	0	0	0		
		17	Economic	0	1	0	0		Salmon (-)
		18	Social	0	0	1	0		Salmon (-)
		19	Mixed objective	100	0.1	0.1	0	0.304	
		20	Portfolio Log Utility	Existence value = 0.1					
No Recreational	1450	21	Ecological	1	0	0	0		Skate, sf squid (-) halibut (+)
		22	Economic	0	1	0	0		Many (+), many (-)
		23	Social	0	0	1	0		Unstable***
		24	Mixed objective	100	1	0.1	0	0.095	Skate, sf squid (-) halibut (+)
		25	Portfolio Log Utility	Existence value = 0.1					
	1900	26	Ecological	1	0	0	0		Salmon (+) short fin squid (-)
		27	Economic	0	1	0	0		Large and small crabs (-)
		28	Social	0	0	1	0		Large and small crabs (-)
		29	Mixed objective	100	0.1	0.1	0	0.196	Salmon (+) short fin squid (-)
		30	Portfolio Log Utility	Existence value = 0.01					
	1986	31	Ecological	1	0	0	0		
		32	Economic	0	1	0	0		Short fin squid (+), many (-)
		33	Social	0	1	0	0		Unstable***
		34	Mixed objective	100	0.1	0.1	0	0.177	
		35	Portfolio Log Utility	Existence value = 0.05					
	1996	36	Ecological	1	0	0	0		Salmon (-)
		37	Economic	0	1	0	0		Many (+), many (-)
		38	Social	0	0	1	0		Many (+), many (-)
		39	Mixed objective	100	0.1	0.1	0	0.191	Salmon (-)
		40	Portfolio Log Utility	Existence value = 0.05					
No Trawlers	1450	41	Ecological	1	0	0	0		Salmon (-) G. halibut (+)
		42	Economic	0	1	0	0		Many (+), many (-)
		43	Social	0	0	1	0		Unstable***
		44	Mixed objective	100	1	0.1	0	0.335	Salmon (-), G. halibut (+)
		45	Portfolio Log Utility	Existence value = 0.1					
	1900	46	Ecological	1	0	0	0		Salmon (+) short fin squid (-)
		47	Economic	0	1	0	0		Large and small crabs (-)
		48	Social	0	0	1	0		Large and small crabs (-)
		49	Mixed objective	100	0.1	0.1	0	0.145	Salmon (+) short fin squid (-)
		50	Portfolio Log Utility	Existence value = 0.05					
	1986	51	Ecological	1	0	0	0		
		52	Economic	0	1	0	0		Short fin squid (+), many (-)
		53	Social	0	0	1	0		Unstable***
		54	Mixed objective	100	0.1	0.1	0	0.039	
		55	Portfolio Log Utility	Existence value = 0.1					
	1996	56	Ecological	1	0	0	0		
		57	Economic	0	1	0	0		Many (+), many (-)
		58	Social	0	0	1	0		Salmon (-)
		59	Mixed objective	100	0.1	0.1	0	0.251	
		60	Portfolio Log Utility	Existence value = 0.1					

ENVIRONMENTAL ARCHAEOLOGY: PRINCIPLES AND CASE STUDIES

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ABSTRACT

Archaeological data are most commonly applied towards understanding past human activities. However, these data can include environmental information such as animal and plant remains which offer insight into past environmental history. This paper outlines general introductory principles of environmental applications in archaeology, including the character of archaeological data, the preservation of environmental remains, and problems of interpretation arising from the "cultural filter" through which these remains necessarily have passed. We conclude by noting problems and prospects in environmental archaeology, leading to two case studies which demonstrate the value and potential of archaeological analyses to the reconstruction of past ecosystems. The first case study explores the period of European contact in Gwaii Haanas (Queen Charlotte Islands, British Columbia), a time characterized by rapid and substantial environmental changes. In particular, archaeological evidence is described that relates to the extirpation of the sea otter during the maritime fur trade and the resulting impact on ecologically related species such as abalone, sea urchin, and kelp-dependent fish. The second case study examines prehistoric fish use in the Aleutian Islands. Specifically, size reconstruction of Pacific cod specimens recovered from Aleut archaeological sites shows the harvesting of fish that exceed the size of those commonly encountered by modern commercial fisheries. Together, these case studies demonstrate that archaeological analysis can provide a picture of the past environment that is not readily available through other sources of data.

INTRODUCTION TO ENVIRONMENTAL ARCHAEOLOGY

Archaeological faunal remains provide a useful, if imperfect, record of the past environment. The majority of archaeological faunal remains enter a site's deposits through direct human action, though a portion of such remains may result from the activities of scavengers and other animals, or may enter a site as a secondary by-product of the targeted resources (Erlandson and Moss 2001, Lyman 2002, Moss and Erlandson 2002, Orchard 2001b). As humans tend to harvest resources from a wide variety of niches, these deposits often provide a broad view of the environments available to a site's inhabitants. The anthropogenic nature of archaeological deposits, however, means that faunal remains from archaeological sites can be seen as a culturally filtered sample of the environment from which the site residents obtained their resources. Despite this bias, however, the abundance, accessibility, visibility and broad scope of archaeological faunal deposits make them a particularly useful environmental record, especially when compared to typically rare and limited natural faunal deposits. This is particularly true for marine mammals and fish, which have vanishingly small probabilities of ending up in accessible paleontological deposits. The value of archaeological sites as sources of environmental history has been recognized in a number of recent projects and texts (Amorosi *et al.* 1997; Cannon 1995; Grayson 1984, 2001; Orchard 2001b; Reitz *et al.* 1996; Reitz and Wing 1999; Sandweiss 1996). Of particular interest and relevance to the case studies outlined below, are papers that discuss and exemplify the role that zooarchaeological analysis can play in wildlife management (Amorosi *et al.* 1996; Lyman 1996). The following are some simple analytical techniques or domains which have promise for answering questions about paleo-ecology.

Addressing bio-diversity is most straightforward through the creation of a species list from identified remains. Such lists from shell-bearing archaeological sites – which typically offer the best preservation of bone – can run into hundreds of taxa. From such lists, local ecological niches can be identified and past biodiversity compared to the present. Of particular interest are indicator or keystone species with very narrow niches or specific environmental tolerances, or whose presence or absence is a strong predictor of other species. Sea Otter probably fills such a role in near-coastal marine ecologies, as discussed below (and see Pitcher 2004, this volume).

Another area of inquiry includes changes in faunal 'demographics'. Some species will have undergone historic change in population structure or growth and development as a result of changing human or animal predation patterns or intensity. For example, species which are under heavy predation may exhibit a flattened population structure, with fewer mature individuals and more immature individuals than

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might be expected. Potentially, population information can be derived from:

- Shellfish, especially bivalves, through the study of annual growth rings, size, and growth rates. Such studies have been commonly undertaken in archaeology, sometimes showing a decline in average size with apparent increased predation (Ham and Irvine 1975; Wessen 1988, Claassen 1998). Shellfish incorporate seasonal and annual growth rings, and relatively complete shells, especially bivalve shells, can be thin-sectioned and these rings examined. This has the potential to illuminate both the cultural and natural history of an area by tracking changing predation pressures, water temperatures, and so forth.

- Fish, through the study of size and age structure of the population. The main sources of data would be *otoliths* (ear bones) whose rings track age and growth rates, and *scales*, which can preserve surprisingly well in archaeological sites. Rockfish otoliths are the largest and most robust amongst likely fish remains to be found (Wigen pers. comm.). Fish vertebrae can also be aged using x-ray densitometry. Key indicator fish skeletal elements can be correlated via regression equations to length and body mass. For example, rockfish size can be accurately estimated using the diameter of the atlas (Wigen pers. comm.); Pacific cod using dimensions of the quadrate and other mouth elements (see below).

- Mammals and birds: as they have different reproductive strategies than the above, may be predated upon differently, and as their remains may be rarer in absolute terms, it is more difficult to be confident in one's ability to draw conclusions. An interesting exemplary species is the sea otter, whose population is known to have declined to extirpation by ca. 1830. Knowing the temporal parameters and outcome of this increased predation it would be of use to see if this was archaeological visible through changing age structure of recovered remains (see below). Also, juvenile mammal remains can be aged, teeth can reveal information about dietary stress, and stable-isotope analysis can show changes in long-term diet. For example, preliminary, unpublished results from Haida Gwaii suggest that prior to ca. 10,000 years ago, black bears consumed little or no marine protein, in stark contrast to their present day habits.

Archaeological data can provide a very alluring source of Palaeonvironmental data for other historical sciences, but the use of these data should be well-informed. The following discusses some interpretive constraints in environmental archaeology, with emphasis on BC coastal processes.

Cultural choice: the faunal record at an archaeological site is a product of culturally-mediated choice. It is not a microcosm of the natural ecology, but a reflection of the human niche in that ecology. In spite of this, it is important to remember that not all the taxa were taken directly by humans: some came in as incidentals, stomach contents, etc. Furthermore, humans can only select from what is actually available, although trade and exchange can widen their catchments considerably. This "cultural filter" must always be accounted for. Hence, for example, a finding that 70% of the fish bones in a particular site are from herring tells us more about human taste in food than the absolute or relative abundance of herring in the environment.

Differential preservation of environmental remains: some classes of evidence, such as large land mammal bones and shells preserve relatively well, while other remains, such as delicate fish elements, crustaceans, small land mammal and bird bones preserve less well. Some environmental information, such as terrestrial plants, marine plants, and fungi only preserve in special situations. Further, preservation may be spatially heterogeneous across the site (Stein 1996). Therefore, the diversity and proportions of environmental remains in the present do not necessarily bear a 1:1 correspondence with the material when deposited. Furthermore, most of these taphonomic processes unfold over time, meaning that the actual remains found in an archaeological site is a complex function of time, inherent durability, soil chemistry, and site sampling strategies. All of these factors need to be accounted for when attempting interpretation of environmental remains, whether for cultural or natural historical ends.

A major interpretive consideration is the amount of material that must be excavated to produce a reliable sample size and representative taxonomic diversity. At Crescent Beach, a shell midden near Vancouver, the relationship between diversity of fish taxa and size of sample (expressed as number of identified skeletal elements, NISP) is clear. After ca. 750 to 1,000 elements of all fish taxa are recovered, there is virtually no increase in taxonomic diversity (Driver 1993: 93). Achieving these sample sizes of archaeological fish remains is fairly common. However, fish tend to be among the more numerous faunal categories, and if similar numerical relationships hold for birds and mammals, then it may become an issue whether taxonomic diversity is fully represented at any given site.

The case studies outlined below exemplify some of the methods which can be applied to the gathering and analysis of environmental data from archaeological sites, as well as the types of results that may be obtained. There are many more methods that could be, or have been, applied to these cases (see, for example, Dincauze 2000), and the results presented are in some cases preliminary. Together, the case studies demonstrate some of the problems and prospects of an archaeological contribution to marine environmental reconstruction and management.

CASE STUDY 1: GWAII HAANAS

The period of European Contact in Gwaii Haanas National Park Reserve/Haida Heritage Site, Haida Gwaii (Queen Charlotte Islands, British Columbia), was one of rapid and dramatic change for the Haida (Acheson 1998; Duff and Kew 1958). Similarly, the current ecology and environment of Gwaii Haanas has been profoundly influenced by historic-period environmental changes, beginning with the first European contact in 1774 (Blackman 1990). In particular, activities related to the maritime fur trade such as the rapid extirpation of sea otter populations, had a dramatic impact on the local environment. The removal of sea otters, for example, is known to have allowed the spread of sea urchins, which in turn limits the growth of kelp forests and their associated ecosystems (Bodkin 1988; Breen *et al.* 1982; Duggins 1981; Estes and Palmisano 1974; Pace 1981). Similar changes are known to have resulted from the introduction of non-indigenous species, such as deer (Vourc'h *et al.* 2001), rats (Bertram and Nagorsen 1995; Drever 1997; Taylor *et al.* 2000), and raccoons (Hartman and Eastman 1999); and from modern industrial harvesting of timber and other resources (Forest 2001; Grzybowski and Slocombe 1988). Furthermore, European contact introduced diseases and changed settlement patterns which lead to mass human depopulation of Gwaii Haanas and the sequential amalgamation of small villages of 2 to 3 houses into larger villages (Acheson 1998). By 1890, all the surviving Haida had settled in the villages of Skidegate and Masset on Graham Island to the north of Gwaii Haanas (Blackman 1990), and thus the Gwaii Haanas human ecology had also been greatly altered.

Despite the importance of this period in Haida culture history, relatively little work has attempted to document or address these issues. Rather, most archaeological work in Gwaii Haanas has focussed on early Holocene occupations or on general site inventory (Fedje *et al.* 1996a,b, 2001; Fedje and Christensen 1999; Hobler 1978), with contact-period archaeology limited to excavations at only a very few sites (Abbott and Keen 1993; Acheson 1998; Duff and Kew 1958; MacDonald and Cybulski 1973). Of greatest relevance to the current case study is a project carried out by Acheson (1998), which revealed the wealth of environmental data available from sites dating to the last 2,000 years, recovering remains of 165 separate faunal taxa, representing a wide range ecological niches, from small scale excavation at 18 archaeological sites. Acheson's work, however, was not intended to address issues of environmental reconstruction, and only three of his excavated sites included historic period deposits (Acheson 1998). Although scholars in other disciplines have examined the Gwaii Haanas ecology from a current perspective while acknowledging historic changes (eg. Forest 2001; Grzybowski and Slocombe 1988), no one has specifically used archaeological data to examine the pre-contact to early contact period environment of the region.

Thus, though it is possible to speculate about many of the factors that are likely to have caused environmental changes in Gwaii Haanas since the time of first European contact, the pre-contact environment itself is largely unknown. Examination of environmental data from archaeological sites dating to the late pre-contact/early contact periods provides a unique window into this period of environmental change. Aside from providing a better understanding of the context in which the Haida people lived prior to European contact, knowledge of the "natural" pre-contact environment is a useful tool for the management of the relatively recently established Gwaii Haanas National Park Reserve/Haida Heritage Site. Although Parks Canada's mandate includes the environmental management of the region, the question remains as to which environment to manage, the pre-contact environment prior to the impact of European activities, the current environment, or that of some intervening period. Greater knowledge of a pre-contact environmental via archaeological environmental data would contribute to such management issues. In addition, demonstrating the inherent role of Haida food harvesting in the long-term ecological structure of the Gwaii Haanas region may provide evidence for aboriginal use-rights within the park reserve.

In order to investigate the potential for environmental archaeological work, a pilot project was conducted in June of 2000. As

Table 1. Number of Taxa Recovered Per Site (from Mackie *et al.* 2001). Totals are for all three sites, therefore columns do not add up.

Site	Vertebrate Taxa	Invertebrate taxa	Total[1]
1134T (Protected)	14	21	35
923T (Semi-Protected)	10	10	20
740T (Exposed)	23	24	47
Totals[1]	31	36	67

indicated above, much of the recent archaeological work in Gwaii Haanas has consisted of an extensive program of site survey, the results of which have been compiled in a Parks Canada database. This database contains information on the locations of all the known sites in Gwaii Haanas, the types of deposits found at each site, the dates of the sites when known, and the artifacts found or recovered at each site, providing a basis for the identification of sites with high potential for containing the information that we wished to recover. Specifically, we were interested in examining sites that: were occupied during the late pre-contact to early contact transition, and thus had dates or artifacts that indicated this period; contained shell midden deposits and thus had a high potential for the preservation of environmental remains; each represented a different set of environmental conditions in the form of exposed, protected and intermediate locations. Thus, the study sites (Figure 1) were selected from the database prior to the beginning of our field season.

Prior to excavation, each site was examined and tested via surface exposures, deposits in windfalls, cutbanks and other natural exposures, and through probe and auger testing. Such testing served primarily to verify the presence of preserved environmental remains in the form of shell midden deposits. Based on this testing one site, 1221T on the East coast of Lyell Island, was eliminated from our sample due to inadequate shell midden deposits. This site was replaced with site 740T on East Copper Island, another exposed site. Soil probes and augers were also used to aid in the placement of excavation units. Such subsurface sampling techniques have been shown to provide a reasonably good picture of the distribution of subsurface deposits (Stein 1986; Casteel 1970). Auger samples were also collected in some cases, and may be used as a supplemental source of environmental data (see Cannon 2000; Casteel 1970). Excavation units were placed judgmentally based on the results of soil probing and augering, with 1m by 1m units excavated in 10 cm arbitrary levels. To facilitate the recovery of environmental data, all material was water-screened through 1/8 inch mesh, with all bone, a representative sample of shell, and any other environmental remains, such as floral remains and fish scales, collected. In addition, column samples were collected from one wall of each unit following excavation, as column samples have been shown to provide a representative sample of environmental remains from an excavation unit (Casteel 1970, 1976a). All artifactual material was also collected, as were carbon samples for dating purposes when available, and each site was mapped with a total station.

The final analysis of materials from this pilot project is incomplete, and will form part of the ongoing Gwaii Haanas Environmental Archaeological Project being conducted as a component of the doctoral research program of the senior author. Nevertheless, preliminary results suggest that faunal remains from small-scale investigations can provide a picture of the past environmental characteristics of a site's local region, and can map regional environmental differences between sites in different ecological niches (see Table 1) (Mackie *et al.* 2001). This is

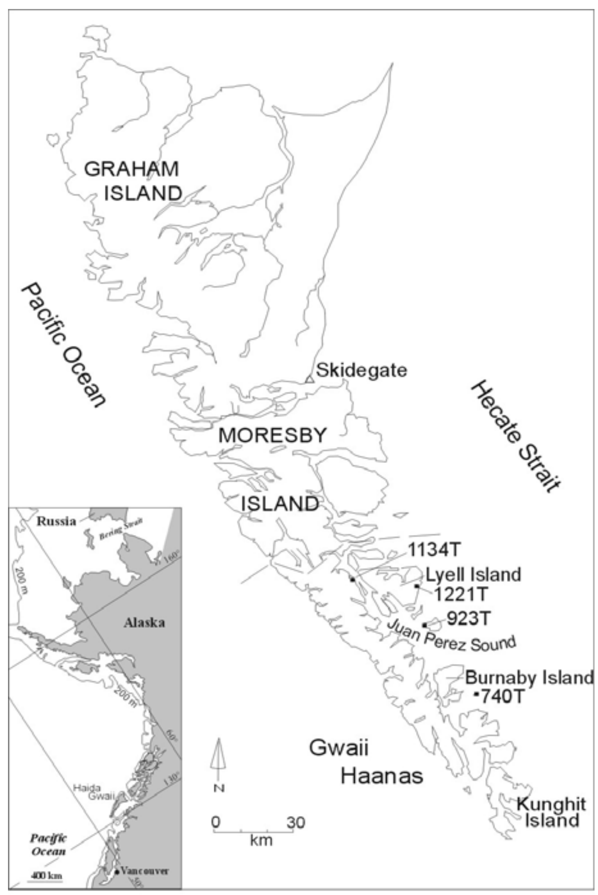

Figure 1. Map of Haida Gwaii showing location of study sites (Adapted from Fedje et al. 1996a).

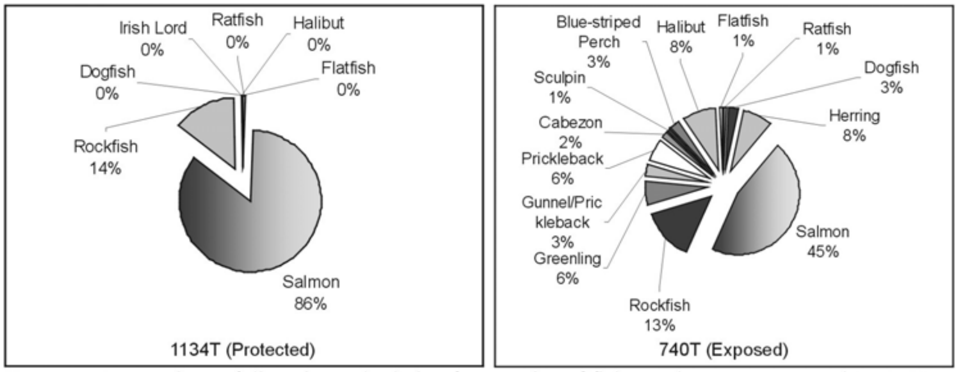

Figure 2. Comparison of diversity and relative frequencies of fish taxa between protected (1134T) and exposed (740T) locations.

particularly evident in the differences in the diversity of fish taxa between the protected site (1134T) and the exposed site (740T) as illustrated in Figure 2. Unsurprisingly, the protected site is dominated by salmon remains, contains the majority of the terrestrial-based avifauna, and was the only site to contain terrestrial mammal (Black bear). In contrast, the exposed site contained the greatest diversity of taxa, including a wide variety of fish (13 taxa), numerous remains of marine birds, and the greatest quantity of sea otter remains. Similarly, California mussel comprises the majority of invertebrate remains from the exposed and semi-exposed sites, whereas the protected site contains primarily Butter clam, Littleneck clam and small mussel (probably edible Mussel: *Mytilus trossulus*) (Mackie *et al.* 2001). Also of considerable interest is the small but intriguing correlation between the presence of sea otter in the assemblages and the presence of related taxa such as sea urchins, abalone, and kelp-dependent fish. As seen in Table 2, a strong presence of sea otter remains is loosely correlated with a near absence of abalone and sea urchin and an abundance of kelp dependent fish at the exposed (740T) and semi-exposed (923T) sites, while the opposite pattern is evident at the protected site (1134T). The well documented relationship between kelp and sea urchin grazing (Duggins 1981; Pace 1981) provides an ecological link between sea otter predation on sea urchins and the presence of nearshore, kelp dependent communities of fish. It is important to note, as well, that the low density and resulting low weight of sea urchin shell yields low proportions for sea urchin when compared to other invertebrate remains from each assemblage. However, the difference in proportion between 1134T (0.82) and the other two sites, 740T (0.03) and 923T (0.01), is relatively quite significant. Slightly differing dates at these sites (Mackie *et al.* 2001; Orchard 2001a) suggests that this pattern may map the shift from a pre-fur trade to a post-fur trade environment.

In addition to these interesting faunal results, radiocarbon dates from the sites and the recovery of contact-period artifacts (Mackie *et al.* 2001; Orchard 2001a) supports the occupation of the selected sites during the targeted time period, thus providing support for the utilized methodology. This is further evidenced by the absence, in the recovered faunal assemblages, of any introduced species, confirming that the recovered assemblages date prior to the major environmental changes discussed above. Though patterns in the data are clearly present, the small sample size and the potentially conflicting effects of varying exposure and varying temporal period may bias these results. An increased sample size resulting from ongoing work should clarify this issue. Generally, then, the pilot project demonstrated the potential of small-scale archaeological excavation to contribute to

Table 2. Sea Otter, Sea Urchin, and Ecologically Related Taxa (Derived from Mackie *et al.* 2001).

Taxon	740T (Exposed) 490±40 to 390±50[1]	923T (Semi-Protected) 150±50	1134T (Protected) 430±70 to 60±60
Sea Otter (% mammal by NISP)	57.1	57.1	0
Sea Urchin[2] (% invert. by weight)	0.03	0.01	0.82
Abalone[3] (% invert. by weight)	0	0.59	0
Nearshore/Kelp Forest Fish[4] (% fish by NISP)	21.2	35.7	14.1
Nearshore/Kelp Forest Fish (# identified taxa)	3	1	1

[1]Radiocarbon age ranges include marine reservoir corrected shell dates.

[2]Sea urchin is one of the primary food sources of sea otters (Estes and Palmisano 1974; Estes *et al.* 1978; Breen *et al.* 1982).

[3]Abalone density has also been inversely correlated with sea otters (Cooper *et al.* 1977).

4A variety of fish taxa are dependent upon or ecologically related to kelp forests, and are thus tied into the sea otter ecological web. In the Gwaii Haanas assemblages such fish include greenling (Estes and Palmisano 1974), rockfish (Bodkin 1988), and cabezon (Bodkin 1988).

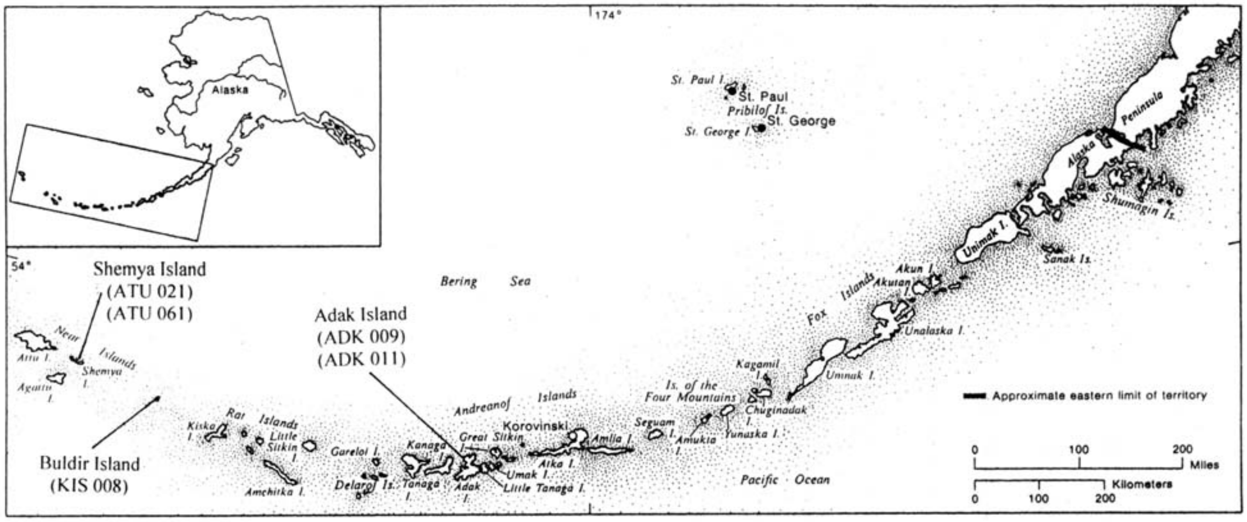

Figure 3. Map of Aleutian Islands study area with site locations (modified from Lantis 1984).

environmental reconstruction during the targeted late pre-contact to early contact time period. The "cultural filter" through which these data have passed is important, but the underlying ecological relationships show through. This confirms the availability of a wealth of environmental data in sites that are known, through the presence of early European trade goods, ethnohistoric records, and radiocarbon dates, to have been occupied through the early contact period (Mackie *et al.* 2001; Orchard 2001a).

CASE STUDY 2: ALEUTIAN ISLANDS PACIFIC COD

The reconstruction of the live size of animals represented by archaeological remains can provide useful information for both culture historical and environmental reconstructions. Our second case study examines the potential of such an approach in the context of environmental reconstruction through the synthesis of a project which was aimed at examining fish size in prehistoric Aleut sites as related to Aleut subsistence and to ecological change (Orchard 2001b). The Aleutian islands of southwest Alaska form a particularly interesting illustration of the potential of environmental archaeology, as they represent a relatively unique environmental context. It is this unique setting and the isolation of the archipelago that makes it particularly useful as a "cultural laboratory" (McCartney 1975: 288; cf. Black 1981; Corbett *et al.* 1997a; McCartney and Veltre 1999; Yesner and Aigner 1976). The project outlined here, completed as the M.A. thesis of the senior author (Orchard 2001b), involved the analysis of faunal assemblages from 5 sites in the central and western Aleutian archipelago (see Figure 3). This includes two sites on Shemya Island (ATU-021 and ATU-061), one site on Buldir Island (KIS-008), and two sites on Adak Island (ADK-009 and ADK-011). For the most part, the results of the excavations at these sites, all conducted by members of the Western Aleutian Archaeological and Paleobiological Project, remain unpublished. The exception is site KIS-008 on Buldir Island, which has generated several publications (Corbett *et al.* 1997b; Lefèvre *et al.* 1997; Bouchet *et al.* 1999), as well as a single publication from site ADK-011 on Adak Island (Bouchet *et al.* 2001).

Regression analysis provides a technique for the statistical comparison of the live size of fish, either length or weight, to the size of skeletal elements. This technique has been widely applied to fish taxa and has demonstrated the strong correlation that exists between fish size and skeletal element size (Casteel 1974, 1976b; Crockford 1997; Desse and Desse-Berset 1996; Enghoff 1983; Leach *et al.* 1996; Owen and Merrick 1994; Rojo 1986; Smith 1995). The case study involved the use of regression analysis to estimate the size (length and weight) of fish specimens from six of the most prevalent taxa encountered in the archaeological samples under consideration. The analysed taxa included Atka mackerel (*Pleurogrammus monopterygius*), greenling (*Hexagrammos* sp.), Irish Lord (*Hemilepidotus* sp.), Pacific cod (*Gadus macrocephalus*), rockfish (*Sebastes* sp.), and walleye pollock (*Theragra chalcogramma*). For each taxon comparative specimens of known live length and weight were used to generate regression formulae that compare these size measurements to measurements of a selection of skeletal elements (Orchard 2001b). These formulae, which produced strong correlations

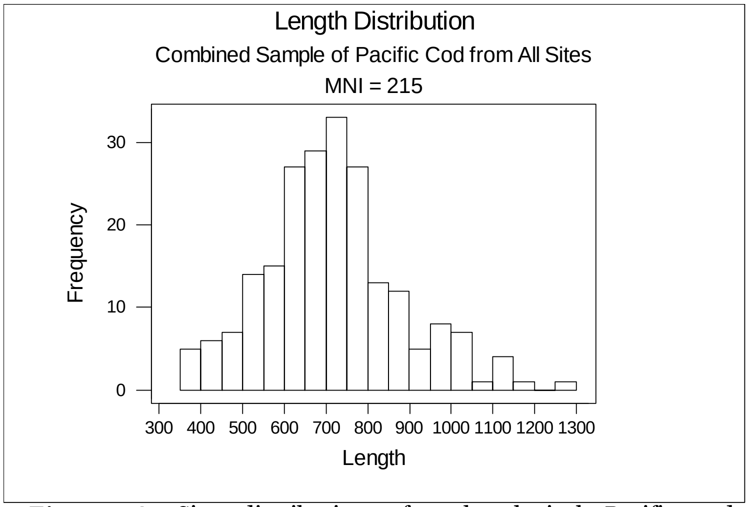

Figure 4. Size distribution of archaeological Pacific cod individuals from all five sites in the Aleutian Islands study area.

with r^2 values generally greater than 0.90 (Orchard 2001b), were then used to generate size estimates from the same measurements of archaeological skeletal specimens.

The estimated sizes of Pacific cod are particularly noteworthy in the context of discussions of environmental reconstruction and fisheries management. Archaeological Pacific cod specimens ranged up to and beyond the size ranges commonly encountered by modern commercial fisheries (see Figure 4). Of the total MNI[1] of 215 Pacific cod, 27 exceed 90 cm in length and 14 exceed 100cm in length. In comparison, published maximum sizes of Pacific cod range from 1 meter (Hart 1973) to 118 centimeters (Vinnikov 1996). Reported size ranges of commercial catches include 7 to 110 cm from the eastern Bering sea (Bakkala 1984), and 27 to 97 cm from Canadian catches (Foucher 1987). It is also telling that the largest specimen in the University of Victoria comparative collection, which was derived largely from modern commercial fisheries specimens, is only 88cm in length. In addition to the general size of Pacific cod specimens, there is some indication from the archaeological remains of a decrease in the size of Pacific cod over time (Table 3). Though the mean lengths show no consistent temporal trend across assemblages, the maximum lengths show a fairly consistent decrease over time (also see Orchard 1998). However, when the mean lengths and the proportion of individuals larger than 100cm in length are considered, site KIS 008 appears to stand out from the general trend (Table 3). Both the generally large size of Pacific cod from Aleutian sites and the apparent temporal trend provide insight into the structure of past populations of Pacific cod in the region. Generally, archaeological fish size profiles, such as those for Pacific cod presented in figures 4 and 5, may provide insight into ancient fish population structures, and when combined with established dates for the archaeological deposits, can reveal long term trends and variation in commercially important stocks. In a consideration of similar archaeological data for Atlantic cod, Amorosi and colleagues suggest that "zooarchaeology . . . would appear to have an important role in lengthening the observational series of environmental managers, perhaps warning of critical threshold discontinuities before the resource crash (rather than after, as in the case of the Atlantic cod)" (1996: 151). Thus, the cod length data presented here may have some utility in the management of the Pacific cod fishery. This is further evidenced by the utilisation of aspects of this methodology in the assessment of Steller sea lion prey consumption as it relates to North Pacific commercial fisheries (Zeppelin *et al.* 2001).

[1] Note that MNI values were determined using a combination of the traditional MNI approach (White 1953) and the additional data available from regression-estimated lengths (see Orchard n.d.).

CONCLUSIONS

The two case studies presented above are unified in their use of archaeological faunal assemblages to help answer questions about past environmental conditions and changes. The first case study demonstrates that small-scale regional archaeological testing can provide faunal samples that reflect local ecological variation, and thus can be helpful in the reconstruction of local environmental histories. In addition, this case demonstrates that predicted changes in local ecology as a result of sea otter extirpation are visible in archaeological faunal samples. The

Table 3. Temporal patterns in Aleutian Islands Pacific cod (from Orchard 2001b).

Site	Radiocarbon Dates	Mean Length (mm)	Max. Length (mm)	Proportion > 100cm (%)
ATU 061	2570 ± 140 to 3096 ± 155	687	1250	10.00
ATU 021	1700 ± 70 to 1980 ± 60	746	1198	9.38
ADK 009	1040 ± 70 to 1240 ± 90	726	1122	4.62
ADK 011	180 ± 60 to 440 ± 40 (<2490 ± 50)	704	1048	1.96
KIS 008	220 ± 60 to 390 ± 80	807	1073	14.29

second case study demonstrates that the detailed reconstruction of fish size from archaeological faunal assemblages can provide data relevant to reconstructing the history of commercially important fish species, data which may play a role in current management plans for those species. Generally, these case studies exemplify the ability of archaeological data to make a useful contribution to the reconstruction of past environments and to the documentation of environmental changes.

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For discussion after the oral presentation of this paper, see page 138.

How Traditional Knowledge can Contribute to Environmental Research and Resource Management

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Over the last three years I, along with my colleague Dr James Kari, have worked with First Nations in Alaska documenting their traditional knowledge of salmon. The objectives of this research are to provide fisheries biologists with information that could be useful in resource management and improve communications between First Nations and biologists. One of the problems is that within the scientific and management communities there is considerable uncertainty as to how traditional knowledge can contribute to scientific research. In this paper I outline four ways that traditional knowledge can contribute to environmental research and resource management. These are: 1) Traditional knowledge has a chronological depth which far surpasses written historical sources; 2) Traditional knowledge includes observations of the environment that are usually far more detailed than those collected by scientists; 3) Traditional management systems are community based; and 4) Traditional knowledge stems from a belief system that is ecological in nature.

Traditional knowledge can be divided into three analytical components: knowledge, practice and belief (Berkes 1998:13-14). The knowledge base includes such basic information as species identification, taxonomies, species behavior and distribution, and life histories. This knowledge has two significant attributes: it has considerable time depth and it is often very detailed. Collected over generations, traditional knowledge provides information that is not available anywhere else. The earliest written records relating to western Canada and Alaska go back to the 18th century and are often limited in time and space. As a result scientists today have short chronologies on which to build predictions or management plans. In contrast, the historical narratives and oral traditions of First Nations extend well past the earliest arrival of Europeans and often contain precise information about the environment and environmental change. For example, oral traditions often contain information about catastrophic environmental events such as floods, earthquakes, volcanic eruptions, and unusual weather, as well as descriptions of extinct flora and fauna (cf. Cruikshank 1981).

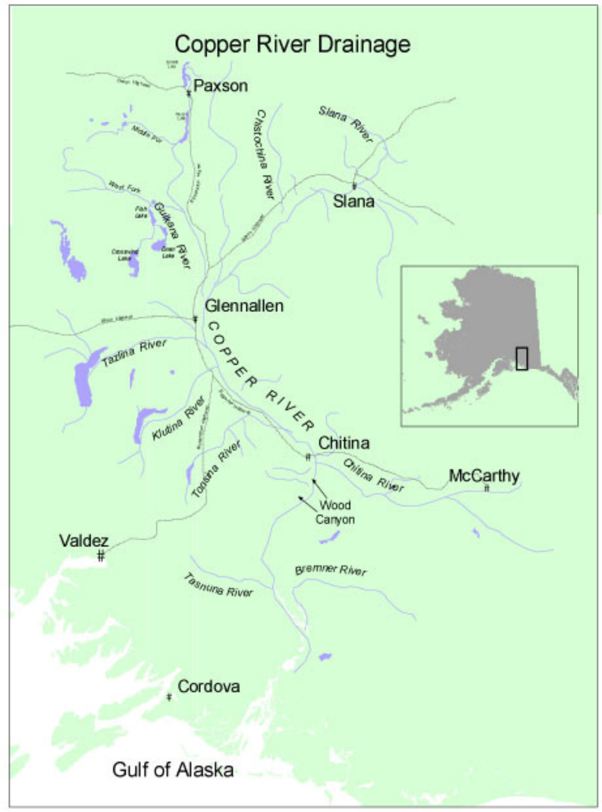

Figure 1. Map of the Copper River area, Alaska, USA.

Traditional knowledge includes considerable detail. Hunters and fishers acquire extensive knowledge of the environment because of the variety of activities they undertake in all seasons of the year. Their dependence on animals and plants for food, clothing, and tools requires a detailed knowledge of when and where resources are available and the environmental processes that affect their availability. This breadth of knowledge is reflected in traditional classification systems that are often much more extensive than those provided by science. Learning how First Nations classify natural systems provides us with a more detailed and nuanced view of the environment.

Ahtna Athabaskans, a First Nation living in Alaska, have developed an accurate and complete taxonomy of all fish species found in the Copper River Basin and gained knowledge of salmon distribution, salmon life histories, and behaviour.

Simeone, W. (2004) How traditional knowledge can contribute to environmental research and resource management. Pages 74–77 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

Figure 2. Andy Tyone of Gulkana pulling a chinook salmon out of his fish wheel on the Copper River, Alaska. Fish wheels were introduced to the Ahtna at the beginning of the 20th century and are now the preferred method for catching salmon on the Copper River. Each fishwheel is registered and receives a number from the Alaska Department of Fish and Game. All fish wheels are home made, usually out of logs and lumber. The Ahtna have a tradition that no metal is to be used in the construction of a fish wheel because the salmon are believed not to like metal.

The Ahtna lexical inventory for fish is a good example of local people's ability to accurately describe local fauna. In the Ahtna language there are terms for 19 species of fish, including all 14 species found in the Copper River Basin, and inventoried by the Alaska Department of Fish and Game (ADF&G). The additional five species exist outside the basin and are known to Ahtna through trade. The Ahtna taxonomy for fish is divided into two empirical categories, ***tsabay***, which are fish other than salmon, and the more general term used for the class *Pisces*, and ***łuk'ae***, a term referring both to salmon in general and sockeye in particular.

For the term ***łuk'ae*** there is considerable lexical embellishment revealing extensive and specific knowledge of salmon ecology. For example, the Ahtna language includes terms covering almost every phase in the life cycle of salmon. Salmon alevin, are ***łuk'ae yiige*** (salmon's spirit); salmon fingerling are referred to as ***łuk'ae ggaay*** (little salmon); little salmon fry headed down stream are called ***'ul'uli*** (those that are swimming past); spawning fish are ***tazdlaexi*** (those that are swimming in water), and dead salmon are called ***tułtaeni*** (the one that is dead in water). Female salmon are referred to as ***K'unn'i*** (the roe one), and male fish are ***tl'ets'i*** (the milt one). Seasonal variations of fish are also noted. Full sized, prime early

Figure 3. Processing salmon on the Copper River. Today some Ahtna keep fish camps but others bring their fish home to process them. On the left side of the photograph is a smoke house made from logs and chicken wire. ***Ba'*** or drying salmon can be seen hanging. Using the traditional method, the salmon are first covered with dust and placed in pits for one or two days and then soaked in the river. This removes some of the grease and makes them easy to handle. The heads are then removed and left to soak while the carcass is split and the backbone removed from the meat. The fish are hung for a week or more until they are dried and then bundled up and stored in a cache.

running sockeye are called ***nulaeggi*** (island swimmer), and late running sockeye are named ***dak'aay*** (that which is ridged, humped). Late running sockeye in Tonsina Lake, located in the lower Copper River drainage, are called ***tsiis luugge'*** (ocher salmon), and whitefish caught in late fall at freeze up are ***nen'ten luugge'*** (frozen ground fish). The comprehensiveness of these terms indicate that Ahtna have long been aware of the various phases in the life cycle of the salmon.

Figure 4. A processed sockeye salmon ready for hanging in the smoke house. A stick is used to hold the meat open so that is will not curl up and leave a raw space where flies can lay their eggs. The meat and backbone are left attached until they are completely dried, then the backbone is removed and stored separately.

Ahtna have recognized and named 21 distinct salmon populations that emanate from particular home streams. The best known of these, recognized by biologists and Ahtna alike, are ***natael luugu'*** 'roasted salmon fish,' the large sockeye bound for Tanada Lake, located in the Wrangell Mountains at the head of the Copper River. These populations are similar to the salmon stocks identified by biologists of the Alaska Department of Fish and Game, but whereas biologists differentiate between stocks that spawn at different locations within the same system, Ahtna do not. Biologists, for example, consider sockeye bound for Tanada Lake as two separate stocks, one that spawns at the outlet of the lake and one that spawns in the lake, but Ahtna classify all sockeye from Tanada Lake as ***nataeł luugu'.***

First Nations have put their knowledge of the environment into practice by developing successful management strategies. Traditional management systems are community based. Management is in the hands of the resource users who adhere to the rules in response to social pressure, cultural mores, and/or ideological conviction rather than government or administrative authority (Feit 1988: 74). The advantage of such systems is that they are designed around a common set of values that everyone understands and accepts. Decisions are not made at a distance or from the top down but locally. One key to implementing successful management strategies is to have the users understand and accept the goals and objectives of the resource managers. For this to happen the users have to have a stake in management.

The 'self management' systems developed by First Nations involve both an understanding of ecological processes and a code of ethics that govern human-environmental relationships. These ethical standards stem from a belief system, or worldview, that is ecological in nature. From this perspective everything in the environment is linked, there is no separation of society from nature. The individual is considered part of a complex web of relationships that includes both human society and the natural environment. Behaviour in all relationships, whether with humans or animals, is guided by a set of principles that stress cooperation, restraint, and balance. Animals are considered powerful actors who freely give themselves to humans, if humans treat them appropriately. Proper treatment involves the sustainable use of animals, maintaining a clean habitat, and taking only what you need without waste.

To avoid waste Ahtna carefully gauge their harvest against the capacity to process the fish. Once this capacity is reached the harvest is suspended, so that fish are not unnecessarily caught and spawning fish can escape. Ahtna are also concerned with catching the right kinds of salmon. To make ***ba'*** or dried fish**,** Ahtna select salmon based on their sex and reproductive condition, preferring male salmon to females because the former are larger and fatter. As one Ahtna elder remarked:

> *That what he used to do, he [we] keep more males...just throw em back in river. Sometime he [we] take em all, sometime he let the female go. That's why he used to have a lot of fish long time ago.* ***Kata'ile'i****, (spawning salmon) they let them go.*

In the past when female salmon were caught in a dip net or trap they were released, but modern fishing technology has altered this practice. Fishwheels run during the night when no one is around, so people are obliged to keep all of the fish they catch. As Ahtna elders note, old fishing practices were in place to "save everything," that is to ensure a sustained yield.

In summary, traditional knowledge can contribute to basic scientific research and to resource management. First Nations have detailed knowledge of their environment and an understanding of long-term ecological processes. Their knowledge provides a time depth that is unsurpassed in the North in its continuity and can help explain ambiguities found in other kinds of evidence that can be incorporated into research. While traditional management systems are rooted in an understanding of the human-nature relationship different from science they can provide us with insights that could spark alternative explanations about the natural world.

To gain understanding means sharing information, which requires creating venues where all parties can feel comfortable sharing information (cf. Pinkerton 1990: 335). Effective communication requires acknowledging that local people do have valuable information or insights, and that scientists and managers have legitimate views and concerns. The objective is to build relationships with local people so that managers and locals can develop common goals.

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For discussion after the oral presentation of this paper, see page 144.

WHY WE HAVE TO 'OPEN THE LOST VALLEY': CRITERIA AND SIMULATIONS FOR SUSTAINABLE FISHERIES

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ABSTRACT

This paper examines why and how sustainable fisheries might be opened in a restored marine ecosystem in the 'Back to the Future' (BTF) approach, termed 'Opening the Lost Valley' (LV). A sequential list of nine criteria for designing LV fisheries includes historical gear types, conservation, community and cultural values. Sustainability is estimated by maximizing ecological, social and economic objective functions, moderated by a set of rules ensuring both sustainability and social acceptance. Pyramids of trophic flows, a surrogate diversity index and biomass profile diagrams provide comparison with present day ecosystems.

An example LV analysis is presented for the North Sea restored to its 1880 condition. Optimizing an equal balance of economic, social and ecosystem objectives results in larger fisheries than adopting ecosystem objectives alone, and larger catches entail trade-offs of conservation with depletions of some ecosystem components. Model uncertainty resides principally in 'top-down' or 'bottom-up' trophic control parameters that govern predator-prey interactions. Process uncertainty mainly lies in responses to climate change.

Imagine a restored ecosystem. All the grief and pain of fisheries being closed to get there. Then the goal is achieved and the fisheries are opened again. In the fishing ports, laid-up fishing vessels are de-rusted, repaired, gear refurbished and the fleets sets off for the first open season in many years. Naturally, huge catches are made. But this situation does not last long, and the depletions of the past are soon repeated because of the huge overcapacity of the fishing fleet (Figure 1). In an ecosystem restored to some state resembling the past under the BTF process, it is clear that we cannot use today's fleet. This paper examines a way to design sustainable fisheries to use in a restored future.

A marine ecosystem restored to some semblance of its past state might be thought of as a 'Lost Valley'[1], an ecosystem, like Arthur Conan Doyle's Lost World (Figure 2, Doyle 1912), discovered complete with all of its former diversity and abundance of creatures. This paper describes how we might achieve sustainable fishing in a restored

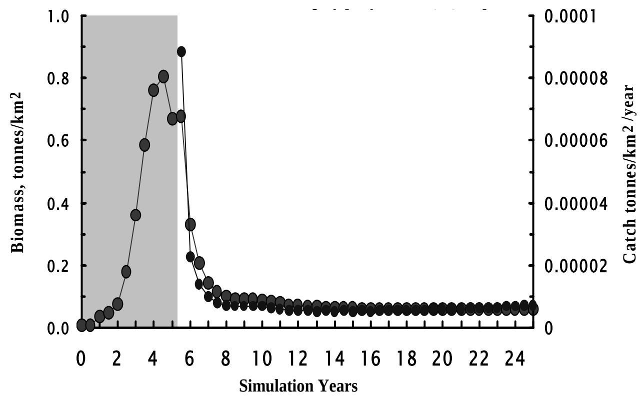

Figure 1. Biomass of one group (large reef fish; left axis) from an ecosystem simulation model of Hong Kong. Biomass recovers during a 5-year no-take period (shaded), only to be rapidly depleted when fisheries are re-opened (catch: right axis) with the former fishing fleets.

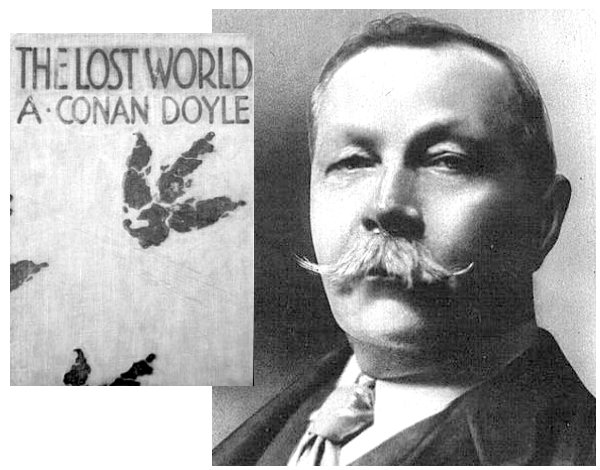

Figure 2. Cover (left) of the first 1912 edition of 'The Lost World' by Sir Arthur Conan Doyle (1859-1930, right), creator of the detective Sherlock Holmes. This book, in which explorers discover an intact ecosystem of dinosaurs from the Jurassic, was one of a series of stories about Professors Summerlee and Challenger, whose characters were based on real life Professors William Rutherford and Sir Robert Christison from Edinburgh University. Another character in the stories, Lord John Roxton, was based on Roger Casement, a British diplomat executed for treason in 1916 because he persuaded the Germans in the First World War to allow Irish nationalists to fight on their side. The 'Lost Valley' term used in BTF combines the 'Lost World' term with the title of an earlier Conan Doyle novel 'The Valley of Fear' (1911).

Pitcher, T.J. (2004) Why we have to open the lost valley: criteria and simulations for sustainable fisheries. Pages 78–86 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

[1] We are grateful to Dr Daniel Pauly for suggesting this term in 2001. Although I think the Conan Doyle reference is the most appropriate, 'Lost Valley' is also the title of a Max Brand cowboy novel from the 1950s, and is now the name of several remote ski and dude ranch resorts in USA.

'Lost Valley' by applying a set of objective criteria to design an 'ideal fishery' for a particular location and then using ecosystem simulations to find the relative fishing mortalities that should be used by each fishery to achieve sustainable catches over a long time period, usually 100 years. This is termed 'Opening the Lost Valley' and forms stage 2 of the BTF procedure (see Pitcher 2004, this volume). The BTF process aims to describe a series of such fished 'Lost Valleys'. In addition, we may seek to challenge these results with climate changes that might realistically be expected for the locality in question, and in the face of uncertainty in the simulation modelling as described in Pitcher and Forrest (2004, this volume). Basic whole-ecosystem modelling techniques employed in the BTF process are not described further here. A complete account of the 'Opening the Lost Valley' procedure appears in Pitcher *et al.* (2004) and an example applied to models used in the CUS project in Pitcher (2002a) in Ainsworth *et al.* (2004).

Choosing a portfolio of responsible and sustainable fisheries is a three-stage process. Fisheries are chosen according to a rational list of criteria. Secondly, the species (and hence model groups) caught by each fishing gear are chosen. Finally, once fisheries and their target species and likely by-catch are chosen, their relative intensity can be determined using the policy search optimization interface in *Ecosim* (Christensen and Walters 2004, Walters *et al.* 2002).

CHOOSING SUSTAINABLE FISHERIES

It is not realistic to expect the fishing gear and methods of former times, including those of ancient aboriginal fisheries, to be re-employed. Of course, some former fisheries might have attractively low by-catch, operating costs or ease of construction and use, so it is evident that some rational criteria for the selection and operation of sustainable fisheries need to be devised.

Criteria devised in the BTF project for designing sustainable fisheries in a restored 'Lost Valley' are listed in Table 1. Many of the items are similar to those set out in the FAO Code of Conduct (FAO 1995), but the overall list is much shorter than that document as a result of combining many issues and avoiding repetition. These criteria are meant to be applied sequentially and with the participation of stakeholders. Ideally, the new fisheries are intended to be newly-designed and the gear and vessels equipped with the latest selectively and efficiency devices. Since this ideal may be costly or unacceptable to the fishers, in practice, older vessels and gear may be re-commissioned or brought in from elsewhere. Hence, the list of criteria will have to have to be interpreted and adapted in a particular case provided that the overall aim of creating new fisheries that are genuinely sustainable is not lost sight of.

1. Minimal by-catch discards. Over the past ten years, trawl, trap and purse seine fisheries have demonstrated large improvements through the use of separators and gates (Kennelly and Broadhurst 2002) or through altering fishing practices (e.g. dolphins released in tuna purse seine fisheries, Hall 1988). It is therefore reasonable to assume that technological advances may be successful in greatly reducing unintended catches of non-target species. Moreover, in some jurisdictions such as Norway and Iceland, discards have become illegal.

2. No damage to habitat. Bottom trawls and dredges have long been suspected of doing great harm to sessile benthic invertebrates (e.g., sponges, cold water corals, gorgonids) that act as refuges for the juveniles of many commercial fish species (Hall 1999). We assume here that, in Lost Valley fisheries, technological improvements will minimise damage by trawls – for example by only permitting trawls that fish above the bottom. Where some collateral damage to benthos is inevitable, such as in prawn trawls, we have assumed 10-fold reductions in damage are

Table 1. List of nine criteria for sustainable and responsible fisheries to be opened in a restored ecosystem. For a full discussion see text (From Pitcher 2004, and modified from Pitcher *et al.* 2004).

#	Criteria for sustainable fisheries	Notes
1	Minimal by-catch discards	Technological modifications to gear
2	No damage to habitat by gear	Technological modifications to gear
3	Include Aboriginal fisheries	Customary rights recognized
4	Include traditional target species	Except where #1 and #2 would bar
5	Minimise risk to charismatic species	Except as under #3 and #7
6	Exclude fisheries on juveniles	Except where minimal impact is proven
7	Participatory vetting of fisheries	By management agency, local community and public
8	Simulations show fishery sustainable	100-year simulations are satisfactory
9	Adaptive management plan in place	Adaptive changes to the unexpected (e.g., climate change)

possible.

3. *Include aboriginal fisheries*. Some fisheries by indigenous or aboriginal peoples were sustainable over thousands of years (e.g., salmon and halibut in the Pacific Northwest). In terms of equity we believe they should be included in the Lost Valley fisheries portfolio, provided the take is sustainable, and where such customary rights are recognised.

4. Include traditional target species. Provided criteria 1 and 2 above are satisfied, this category is included because there will be an understandable demand for traditional desirable fish species in local fishing communities. For example, even if the historic Atlantic halibut fishery has not proven sustainable, the species would be in demand as a target in a restored ecosystem.

5. Minimise risk to charismatic species. Whilst it is evident from the recorded history of seabirds, whales, seals and sirenians that many 'charismatic' species are sensitive to exploitation by humans (e.g., Roman and Palumbi 2003), this criterion may well be in conflict with #3 and #4 above, since coastal peoples traditionally exploited seals, sea lions, whales, dugongs, turtles, ducks, gulls, petrels, auks and other seabirds. (e.g., Australia: Williams and Baines 1993, British Columbia: Brown *et al.* 1997). Where customary rights are recognised, an aboriginal take of these species would be allowed under criterion 3, with appropriate consent under criterion 7 below. On the other hand, many marine mammal, bird and shark species have recently become 'charismatic' to the conservation movement, and legal bans on killing them reflect public revulsion at their use for human food. But these views are volatile and local, so in the last resort, the choice of whether to exploit these types of animals will be locally or nationally determined. The only rational criterion is avoidance of excessive depletion and minimal risk of extirpation.

6. Exclude fishing on juvenile groups. Generally, heavy fishing on juveniles leads to recruitment failure, so such fisheries would not normally be allowed in opening a 'Lost Valley'. In some cases traditional fisheries (criterion 4) include eggs, fry and juveniles of highly fecund species such as herring, anchovy, sardines, milkfish or hake, so such fisheries would be permissible where impacts can be proven to be minimal.

7. Participatory vetting of fisheries. To retain support, the local fishing community has to vet and approve the list of fisheries. In addition, the management agency must be convinced that management and monitoring (criterion 9) are feasible for the chosen fisheries, and that the scientific basis of the 'Lost Valley' forecasting (criterion 8) represents best practice.

8. Simulations show fisheries are sustainable. Assessments must show that, given constant environmental conditions, the biomass of the main ecosystem groups, biodiversity, and the fishery catches themselves are sustainable and do not fluctuate more than a predetermined and agreed amount over a 100-year period. A tougher criterion would be that they are robust against climate fluctuations and uncertainty on that time scale to a specified level of risk (see Pitcher and Forrest 2004, this volume).

9. Adaptive monitoring plan is in place. Because environmental changes (climate, pollution) and our ignorance of fundamental ecology always lead to the unexpected in natural ecosystems, it would be prudent for the restored 'Lost Valley' and its fisheries to be subject to regular monitoring of the indices from criterion 8. This would allow passive adaptive shifts in fishing according to circumstances, much as the way catch quotas and fishing locations are regulated today.

The complete portfolio of fisheries designed for a specific LV ecosystem will depend to a large extent on markets and local tradition. Before a final choice is made, modelling could consider a range of target species of fish and shellfish. And the scope of the new sustainable fisheries would certainly the subject of much debate in the local fishing community. As yet there have been no rigorous comparisons of the effect on ecosystems and sustainability among different fishery portfolio strategies. At one extreme, typical perhaps of aboriginal communities, a broad spectrum of harvested seafood is consumed locally, while at the other extreme, a small number of targeted fish species produce large catches suitable for processing and export.

Compliance of candidate LV fisheries with the listed criteria can be evaluated using a rapid appraisal technique such as *Rapfish*, which has already been applied to compliance with the FAO Code of Conduct (Pitcher 1999).

Even after a fishery design based on the listed criteria is adopted, management mistakes in the form of unacceptable depletions and species losses may well still occur. Two items in the list can help recovery after this unfortunate situation. Criterion 8, simulation modeling, may pick up many potential problems. Criterion 9, passive adaptive management, should eventually identify problems not captured by the modelling. In practice, neither of these fall-backs are perfect, and #9 may not operate fast enough to deal with pollution events or rapid climate shifts for example. Nevertheless, they are included as intended 'fail-safe' mechanisms in the BTF management procedure.

Species caught in opened 'Lost Valley' fisheries

For each fishery in the portfolio, designed according to the criteria above, the species targeted by the gear are determined and related to the ecosystem model groups. In addition, probable by-catch that cannot be avoided by improvements in gear technology (#1) is identified by species and likely percentage amount in relation to catches of the target species.

Initial catches, transformed to tonnes per km2, are entered into the fishery parameter input tables in *Ecopath*. Starting values of 1% and 2.5% of unfished biomass have been used for the optimality simulations in *Ecosim*, but both of these values is a little low for the way that the software is presently written. No systematic analysis of the effect of varying this starting value has yet been performed. Any discarded by-catches, along with ex-vessel prices by species and gear, and operating costs by gear, are also entered in the tables in proportion to the target species.

At this point, the basic parameters of the underlying *Ecopath* model have to be readjusted slightly to achieve mass-balance. For replicability, this was performed with an automated search procedure (adjustments to mortality rates and diet, Kavanagh *et al.* 2004).

SEARCHES FOR OPTIMAL 'LOST VALLEY' FISHERIES

After an 'ideal' set of fisheries and its catches have been selected according to the procedure discussed above, simulations are used to forecast fishing and its effect over a long time period, typically 50 or 100 years (criterion 8). Relative fishing mortalities over the set of fisheries are adjusted from small starting values (see above) until catches are sustainable and impacts on the ecosystem meet specified criteria. In *Ecosim*, the adjustments are carried out automatically using an automated search routine that seeks to maximize a specified objective function using a multi-dimensional Davidon-Fletcher-Powell search algorithm (Christensen and Walters 2004, Walters *et al.* 2002). The search iteratively varies the fishing mortality per gear type to maximize an objective function over the simulated time horizon, usually 50 or 100 years.

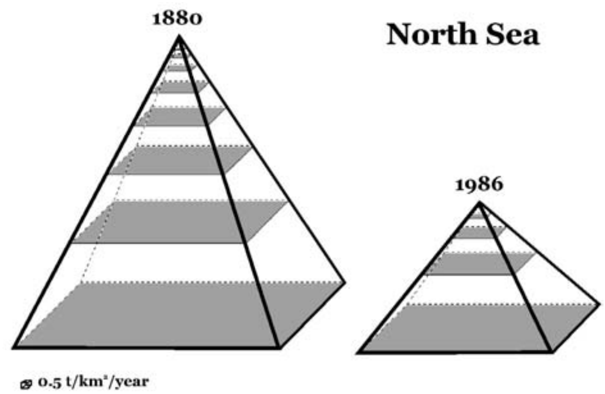

Figure 3. Flow pyramid for the North Sea in Mackinson's 1880 *Ecopath* model, and for a model representing 1981 (Christensen 1995). Horizontal 'floors' represent adjacent trophic levels and distance between floors the relative flow between them. Height of pyramid represents relative length of food chains. Pyramids approximately to same scale, redrawn from *Ecopath* outputs. Note the much smaller flow pyramid and considerably fewer trophic levels (horizontal slices) in the recent model.

Alternative fishery objectives may be selected, including economic value, numbers of jobs, the biomass of long lived species, a log portfolio utility function (Cochrane 2002). Combinations of these policy goals may also be attempted A range of policy options can be used: maximising ecological objectives alone; maximising ecological objectives roughly balanced with employment; and maximising ecology, employment and economics roughly equally balanced. In practice, many searches have to be performed to reduce the chances of finding a local optimum.

The results of the search provide forecast fishery catches, biomass, economic values, numbers of jobs, and biomass changes in all other groups in the fished 'Lost Valley' ecosystem. Results are examined and any scenarios that cause extirpation, or severe depletion of species, are eliminated. In fact, the biomass of designated species may be protected from large changes in biomass as part of the policy search objective function (Cochrane 2002). Adjustments to the weightings in the objective function enable (after some iteration) policies that attempt to balance economic with ecological or social values. This search procedure is repeated for a wide range of policy objectives and for each candidate restored ecosystem, producing a number of forecast scenarios that may be compared.

Table 2. Fisheries selected for North Sea '1880 fished Lost Valley' marine ecosystem simulations. Fisheries were assumed 'clean' of discards due to improved technology. Initial values for the policy search modelling were set at 2.5% of the 'Lost Valley' biomass. Jobs per unit of effort, modified from Mackinson (2002), are required for job optimizations. P = species groups protected from extirpation using the 'mandated rebuilding' option.

Fishery	Landed Species	Relative jobs per unit of catch
Herring	herring	7
Small mixed fish	hake, angler, conger, tusk, ling, redfish, gurnards P, John Dory, blue whiting	7
Salmon	Atlantic salmon, sea trout	5.75
Crabs & lobsters	edible crab P, lobster P	1.5
Tuna	bluefin tuna P	7
Gadoids	cod, haddock, whiting	4.5
Small flatfish	plaice, sole, brill	4.5
Large flatfish	halibut P, turbot P	4.5
Saithe	saithe	4.5
Mackerel	North Sea & western mackerel stocks	5.75
Sprat	sprat	5.75
Not caught	Other prey fish P, other small predatory fish P, rays and skates P	

When running he *Ecosim* policy optimisation method, the underlying n-year dynamic ecosystem model is continuously in operation in the background. This means that ecological parameters inimical to heavy fishing such as long life, low fecundity, slow growth, or reliance on volatile or high trophic level prey, will automatically reduce catches of charismatic species or traditional slow-growing target species to very low values. The different policy objectives available in *Ecosim* mean that a number of different optimisations can be compared. In practice, we have found that runs aiming to optimise only jobs or economics often resulted in unacceptably large (>90%) depletion of some biomasses. Hence, it may normally be best to use three policy options: ecological objectives alone; ecology equally balanced with employment; and ecology, employment and economics equally balanced.

EXAMPLE 'LOST VALLEY' ECOSYSTEM: THE NORTH SEA AS IT WAS IN 1880

The example LV analysis here is based on a published 46-group *Ecopath* model describing the North Sea as it was in 1880 prior to the expansion of steam trawlers (Table 2: Mackinson 2001, see also Pitcher *et al.* 2004). Mackinson describes how historical archives, catch and survey data, and interviews with experts were used to construct this model.

Table 2 shows a portfolio of 11 fisheries set up on the basis of the criteria in Table 1. Relative employment values per fishery were modified from Mackinson (2002). 'Lost Valley' fisheries were assumed to be clean of discards as a result of improved technology. Table 2 also shows seven species groups 'protected' from extirpation in the simulations using the 'mandated rebuilding' option. Weightings applied to the objective functions to achieve equalize three policy goals (ecological goals, an equal balance of ecology with employment, and an equal three-way-mix goal of ecology, employment and economics) are shown

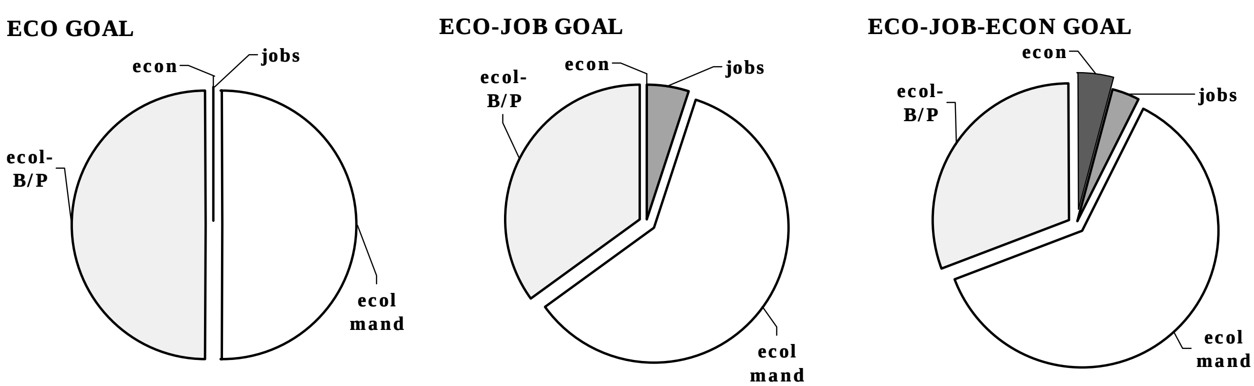

Figure 4. Pie diagrams illustrating relative weightings of conservation (ecol, B/P ratio), mandated rebuilding (ecol mand), employment (jobs) and economic (econ) goals in the optimal fishery searches for the North Sea 1880 ecosystem. Initial figures output by the software for each goal are arbitrary and depend on the units and values chosen as input: hence weightings used in the optimisation are adjusted iteratively so that each of the chosen goals enter equally into the overall objective function. (Weightings are further discussed in Aisworth 2004, this volume.)

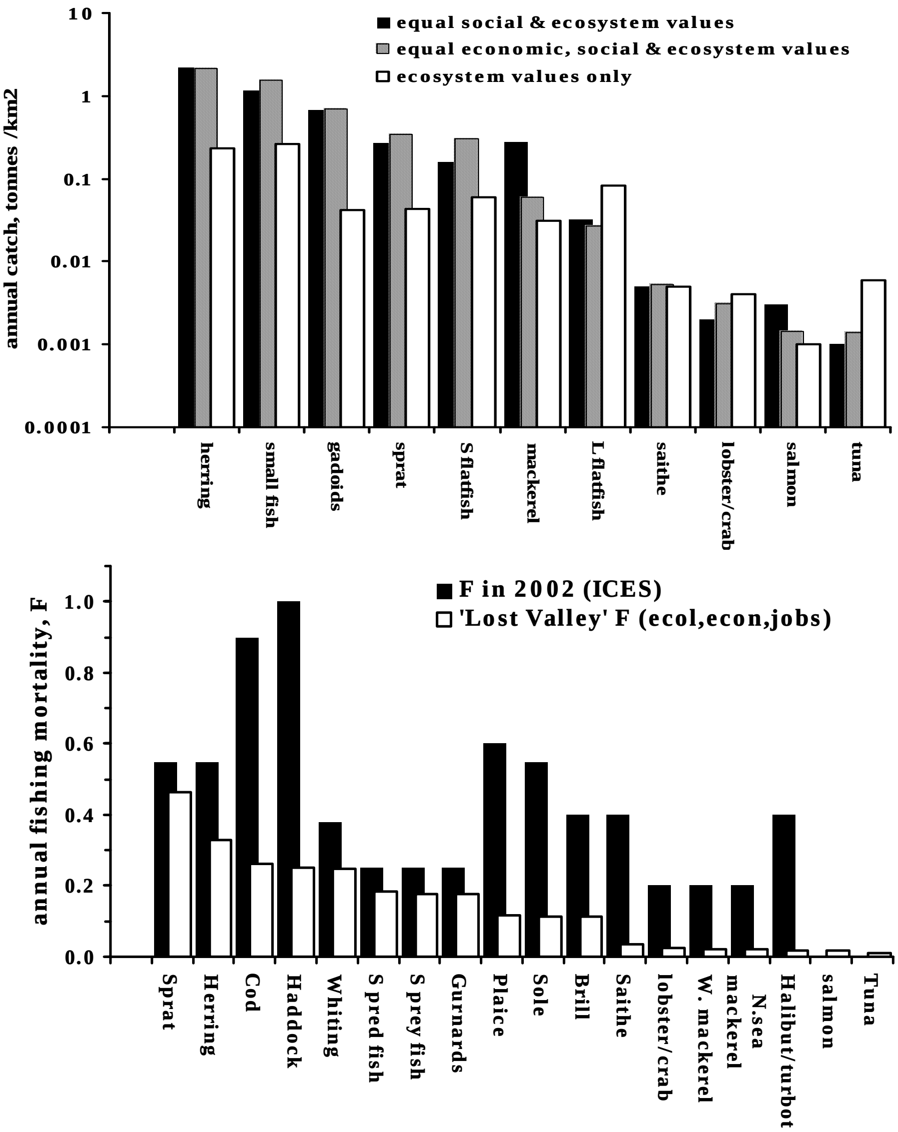

Figure 5. *Upper panel*: Sustainable North Sea 'Lost Valley' fisheries operating in North Sea ecosystem restored to the state of the 1880s. Annual catch rates are shown on a log scale. Dark bars show catches when ecosystem and social objectives are equal, striped bars when a thee-way objective is optimised, light bars show ecosystem objective for function optimisations. *Lower panel:* Light bars show fishing mortalities of modelled groups for equal ecosystem/social/economic policy objectives. Dark bars show approximate fishing mortalities for these groups in 2002 (ICES).

in Figure 4. In all, over 150 simulations were performed, each starting from random values of F. Alternative solutions found by the software were accepted or rejected using the constraints discussed above.

Figure 4 (top) shows the sustainable catch for ecosystem objectives (total catch; around 0.8 tonnes per km^2 per year), for equal ecosystem and employment objectives (catch; 4.8 tonnes per km^2 per year) and the three-way-mix objective (catch; 5.1 tonnes per km^2 per year). For all objectives, the largest fisheries, producing around 70% of the total catch, are for herring, small fish and gadoids, although the large flatfish fishery is third instead of seventh largest (11%) for the pure ecological goal. Fisheries under the two- and three-way mix goals are quite similar. The largest difference is for the mackerel fishery, which is almost ten times larger under the ecology/social goal. Catches in the 'ecosystem alone' fishery are considerably lower, as in the Newfoundland example. This objective reduces the top six fisheries by about 15% compared to the 2- and 3-way mix, while flatfish, lobster and tuna fisheries are about twice as large. The saithe fishery remains about the same for all objectives.

Figure 5 (bottom) plots sustainable fishing mortalities of the main fished groups for the 3-way-mix objective, compared to 2002 estimates of fishing mortality from ICES. While sprat is similar, herring, whiting, and small fish 'Lost Valley' fisheries have fishing mortalities only 30% less than today's value. We note that cod, haddock, plaice, sole, saithe, and both mackerel fishing mortalities are on average 6-fold greater today than our LV simulations suggest is sustainable.

Currently, North Sea cod (Cook *et al.* 1997), plaice, saithe and haddock (ACFM 2002) are heavily depleted and the biomass of several other stocks is not healthy. The LV restored system could clearly support a modest North Sea fishing industry sustainable over long periods, while maintaining reasonable biodiversity and balance. But there are trade-offs in fishing the 'Lost Valley'. Compared to the basic 1880 LV ecosystem, our Lost Valley fisheries reduce 7 biomasses (herring, sprat, horse mackerel, cod, brill, gurnards, seabirds) by more than 25%, but only one (tuna) by more than 50%. Compared to 1880 LV, 19 groups have been reduced in biomass by more than 75%.

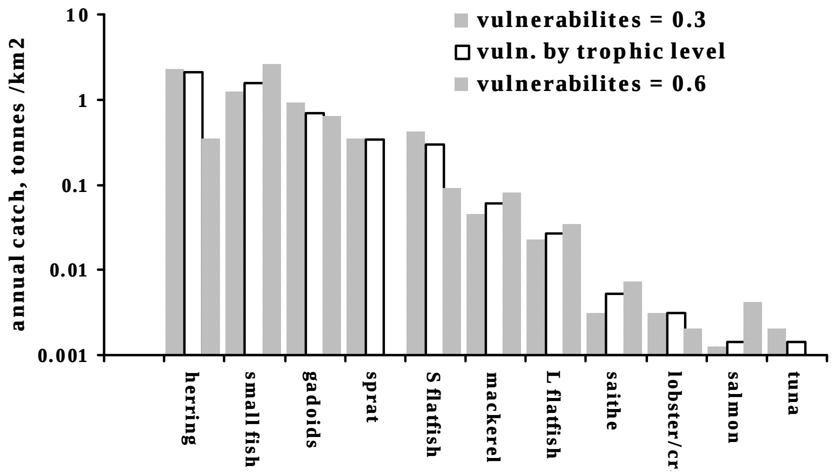

Figure 6. Effect of *Ecosim* predator/prey vulnerabilities on the catch results for the North Sea 'Lost Valley' ecosystem under the 3-way-mix objective. Open bars: vulnerabilities proportional to trophic level. Left shaded bars: vulnerabilities all set to 0.6, a 'top-down' ecosystem. Right shaded bars: vulnerabilities all set to 0.3, a 'donor-control' system.

Figure 6 shows the effect of altering the *Ecosim* predator/prey vulnerabilities. The 3-way-mix objective was used for this comparison. The simulations with vulnerability proportional to trophic level, as above, were compared with a 'top down' system, where v = 0.6, and a 'bottom up' system, where v = 0.3. For the three largest fisheries, changes are relatively minor except for reducing the herring fishery under the 'top down' option by 84%. With one exception (sprat), the LV fisheries remain in the same order of magnitude under all v assumptions. Both sprat and tuna have almost no LV fisheries under the 'top down' option. The direction in which the vulnerability assumption changes the fisheries appears does not appear to be obvious: small fish, mackerel, large flatfish, saithe, and salmon have higher LV fisheries under the top down assumption, while herring, gadoids, small flatfish, and lobster have smaller ones.

CONCLUSIONS

The results presented here are preliminary. Ecosystem simulations like these tend to reveal the superficiality of our understanding of natural aquatic ecosystems and relatively simple ecological processes. The underlying ecosystem models can always be corrected and refined. Actual use of such models has to be tempered with feedback from adaptive management policies. Pitcher (2002b) warns of undue reliance on modelling without such feedback from the real world. Note that it is not suggested that the results reported here provide a realistic goal for current North Sea fisheries. Not only are the *Ecopath* models of past states preliminary, but also there has been no participatory vetting of the LV fisheries and a number of uncertainties have not yet been addressed. However, the example serves to illustrate what may be done with the 'Lost Valley' process.

Changing the vulnerability parameters in the North Sea 1880 LV model had a smaller effect on the overall fishery results than might have been anticipated, although two out of eleven LV fisheries showed large, and three fisheries exhibited moderate differences when vulnerabilities were set to extreme values. To reduce this uncertainly, much more research is needed to obtain parameter values characteristic of each predator-prey interaction.

Using the ecological objective alone in the search routine produces the most sustainable set of LV fisheries, but with smaller annual yields compared to the present day. Using the social or economic objectives alone tends to produce a small number of large fisheries, or instability in the model, because the search engine tends to create jobs or profit by expanding gear sectors with little consideration for distributing catches among the fleets, so long as there is some catch remaining at the end of the 50-year simulation run. Hence, an attempt to emulate real policy choices using equally balanced social, ecosystem and economic objectives is presented. Even then, it is not possible to rely on the software alone to produce biomass trajectories and fisheries that might satisfy the sustainability and social acceptance criteria of a real policy maker. Hence the use of a set of rules to accept or reject solutions offered by the optimisation routine. Fortunately, there were a number of peaks of similar height in the likelihood surface among which one could choose. The overall finding, which is not surprising, is that truely sustainable fisheries in restored ecosystems will very likely produce much smaller yields than those seen during the recent age of fishery expansions (Pauly *et al.* 2002).

The LV fishery solutions confirm that there will always be a trade-off between sustainable fisheries and biodiversity. However, the full LV process presented in this paper ensures that fisheries are sustainable, accepted by local fishing communities, and monitored against unexpected events or incorrect science.

It may be argued that 'Opening the Lost Valley' is unrealistic, because, as yet, it has not been worked out exactly how restoration might be achieved. Focussing on a long-term policy goal, and the benefits that will accrue from its attainment is essential, because it deflects attention from the present-day allocation wars that continually prejudice any attempts at restoration. In parallel with such work in terrestrial environments (e.g., Sinclair *et al.* 1995), restoration of past abundance may require habitat zoning with a mix of reduced fisheries, no-take zones and, perhaps, more proactive management, such as reintroductions of locally extinct species. In addition, the 'Lost Valley' simulations need to be made robust against climate change (see Pitcher and Forrest 2o04, this volume).

This paper does not describe how one might choose amongst alternative "Lost Valley" restoration goals. That choice requires ecological, social and economic criteria. A preliminary approach is discussed in Pitcher (2004), in Ainsworth et al., and Sumaila (2004, this volume), in Sumaila *et al.* (2001) and Pitcher *et al.* (1999). Some case studies for the *Coasts Under Stress* BTF project are currently in progress.

In the face of the disaster witnessed in fisheries over the past 50 years (Pitcher 2001; Pauly *et al.* 2002), only a radical solution stands a chance of succeeding. Many have begun to adopt rebuilding goals. The concepts of 'Back to the Future' and 'Opening the Lost Valley' have a resonance that may serve to guide recovery, and recapture both the biodiversity and wealth that may be provided by healthy marine ecosystems. The 'Lost Valley' reconstruction of whole marine ecosystems to the point where a suite of sustainable fisheries may be chosen provides a set of clear policy goals against which progress can be measured quantitatively. Rebuilding to the state of a 'Lost Valley' is a process that benefits both conservation and fisheries (Pitcher 2002b). Moreover, the 'Back to the Future' approach is in accord with Aldo Leopold's Land Ethic (Leopold 1933, 1949) which states that:

> "A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community."

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EVALUATING THE ECOLOGICAL EFFECTS ON EXPLOITED ECOSYSTEMS USING INFORMATION THEORY

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ABSTRACT

The ecological effects of exploitation on the eastern Newfoundland and southeastern Labrador ecosystem (NAFO Div. 2J3KLNO) were evaluated using information theory. The 1900 model of this ecosystem was subjected to two different scenarios: 1) an increase in fishing mortality of 1% per year for 100 years, or 2) removing fishing from the system for 100 years. The effect of different vulnerability settings on the outcome of these two scenarios was also tested by assuming that the vulnerability of each prey was related to its trophic level, or alternatively the vulnerabilities were kept at the baseline of 0.3. The results show that removing the fishing mortality increase the resilience of the system to an asymptote, while an increase in fishing mortality cause the system to become less resilient over time, until the system becomes unstable after which the resilience increase again. The different vulnerability settings have an effect on the crash of the system in the fishing scenario and on the reduction of some species to very low biomasses in the no-fishing scenario, but does not effect the overall outcome of the resilience.

INTRODUCTION

Information theory gives us a way to measure the emergent properties of an ecosystem. According to Ulanowicz (1997) it "quantifies changes in probability assignment, in the same way that differential calculus quantifies changes in algebraic quantities and "information" refers to the effects of that which imparts order and pattern to a system".

From information theory comes the hypothesis that as a system becomes more specialized its ascendancy would increase, but it loses its "strength in reserve" or resilience (Ulanowicz 1986). The ascendancy measures the size and organizational status of the network of exchanges that occur in an ecosystem (Ulanowicz 1999) and the resilience of a system is defined as its probability of recovery after perturbation

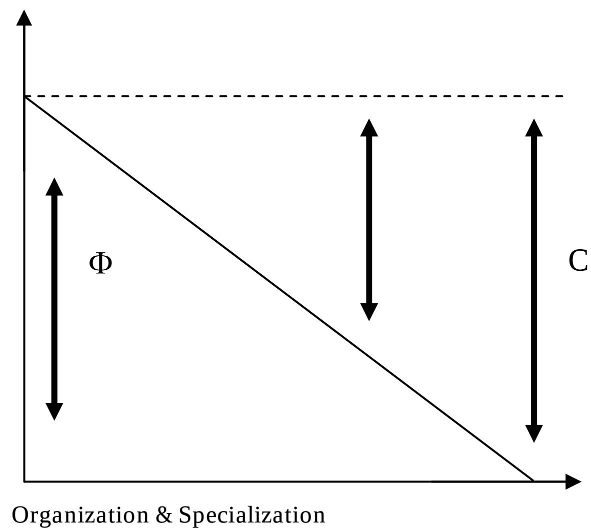

Figure 1. The change in information (on the y axis) as the organization and specialization of the ecosystem increase. The ascendancy (A) increases while the overhead (Φ) decreases. The upper limit to the ascendancy is the development capacity (C).

(Mageau *et al.* 1998). In this paper the assumption is that removing a stressor such as fishing from a ecosystem would increase its resilience, but decrease its specialization, while a constant increase in fishing mortality would reduce its resilience, but increase its specialization. It is therefore hypothesized that the information theory proxy for resilience (the system's overhead, or the compliment to its ascendancy) would thus increase if fishing was removed, and decrease if fishing presume increased.

METHODOLOGY

Information theory

Ulanowicz's (1986, 1997) theory of ascendancy derives from information theory and is illustrated in Figure 1. As the system becomes more specialized and organized its ascendancy (A) increases, with the upper bound of the ascendancy being the development capacity (C). However, as the system becomes more specialized, it looses overhead (Φ). This is a phenomenon similar to "putting all your eggs in one basket".

The disorder or freedom of the ecosystem is defined as the overhead. It is complimentary to ascendancy and calculated by (Ulanowicz 2000) as:

$$\Phi = C - A \tag{1}$$

Heymans, J.J. (2004) Evaluating the Ecological Effects on Exploited Ecosystems using Information Theory, Pages 87–90 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

The development capacity (C) is calculated as:

$$C = TST * H \qquad (2)$$

where TST is the total systems throughput and H is the systems entropy. The TST is calculated (Mageau *et al.* 1998) as:

$$TST = \sum T_{ij} \qquad (3)$$

and systems entropy (H) is calculated as (Mageau *et al.* 1998):

$$H = \sum_{ij} \frac{T_{ij}}{TST} * \log\left(\frac{T_{ij}}{TST}\right) \qquad (4)$$

Finally, ascendancy is calculated as (Ulanowicz, *pers. comm.*):

$$A = \sum_{i,j} T_{ij} \log\left(\frac{T_{ij} B_{.}^{2}}{T_{..} B_{i} B_{j}}\right) \qquad (5)$$

where B_i is the biomass of component i, and a dot as a subscript means that the index has been summed over i.e.,

$$T_{..} = \sum_{i,j} T_{ij} \text{ and } B_{.} = \sum_{j} B_{j} \qquad (6)$$

The *Ecopath* software (2003) still uses formulas of H and A that exclude the biomass, thus entropy (H) is calculated as:

$$H = \sum_{i=1}^{n} Q_i \log Q_i \qquad (7)$$

where Q_i is the probability that a unit of energy passes through i, or

$$Q_i = \sum_{k=1}^{n} T_{ki} / \sum_{l=1,m=1}^{n} T_{lm} \qquad (8)$$

Ascendancy in *Ecopath* is therefore still defined in terms of flow only, or:

$$A = T * \sum_{i,j} \left(\frac{T_{ij}}{T}\right) \log\left(\frac{T_{ij} T}{\sum_{k} T_{kj} \sum_{q} T_{iq}}\right) \qquad (9)$$

The application

The ratio of overhead to development capacity has been linked to the resilience of the system (Ulanowicz 1997, Ulanowicz 1980, Ulanowicz and Norden 1990). The resilience of a system is defined as its probability of recovery after perturbation, while biodiversity stabilizes community and ecosystem processes, but not population processes (Tilman *et al.* 1996, referred to in Mageau *et al.* 1998).

To test this hypothesis of the overhead linked to the resilience of the system, an ecosystem model

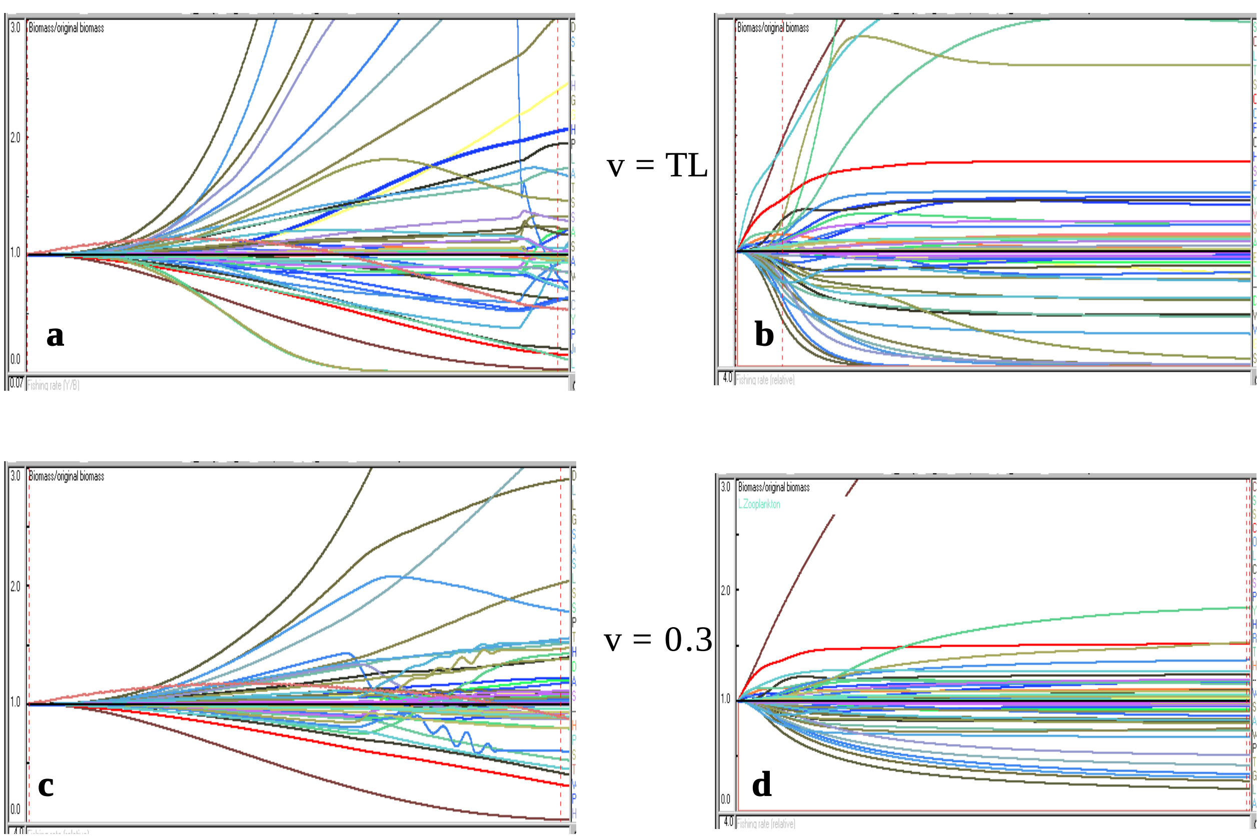

Figure 2. Results from simulating the 1900 Newfoundland model for 100 years without fishing (b and d) and with an increase in fishing mortality of 1% per year (a and c). Vulnerability settings by trophic level with an upper limit of 0.8 and an lower limit of 0.2 are shown in a and b, while c and d show default vulnerability settings at *Ecosim* (0.3).

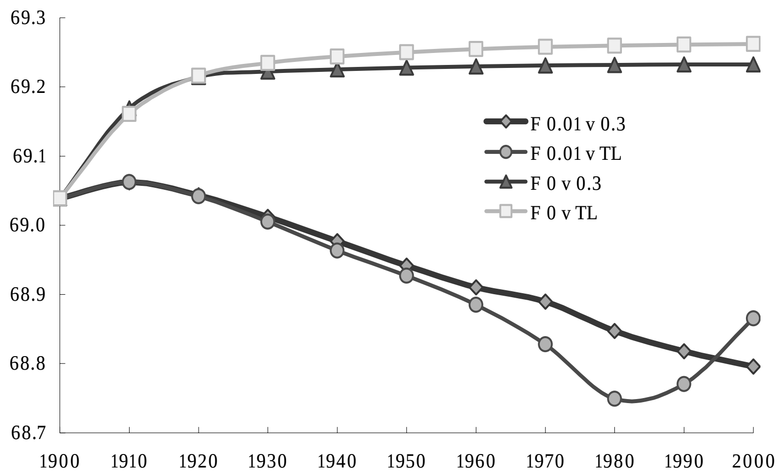

Figure 3. Resilience (ratio of overhead to development capacity) in the four scenarios, without fishing and with an increase of 1% in fishing mortality per year over 100 years and with vulnerability set at *Ecosim* base (0.3) or by trophic level (of prey) with a range of 0.2 - 0.8.

of Newfoundland (2J3KLNO) constructed for the time period 1900-1905 (Heymans and Pitcher 2002) was subjected to two fishing regimes. First, fishing was eliminated totally, and second fishing mortality was increased by 1% each year, for each of the species fished in the 1900-1905 model. The simulations were run for 100 years, and at 10 year intervals a new *Ecopath* model was created, re-imported into *Ecopath* and its network analysis properties calculated, without balancing these models. The ratio of overhead to development capacity (Φ/C) was plotted against time for both scenarios.

When fishing was eliminated from this model, some species seem to go extinct due to the high vulnerability parameters used in the *Ecosim* simulations. For the policy search simulations the vulnerabilities were set equal to trophic level (by prey), with the maximum v = 0.8 and minimum v = 0.2 (Ainsworth 2004, this volume). Resetting the vulnerability parameters to 0.3 (*Ecosim* baseline) eliminated these extinctions. This model was then also subjected to the 1% increase in fishing mortality, to give four scenarios for testing the hypothesis that (Φ/C) is related to the resilience of the system.

Resilience methodology

For the purposes of 'Back to the Future' these policy optimizations were run for 50 years, and at year 50 a new *Ecopath* model was created, re-imported into *Ecopath* and its network analysis properties calculated, without balancing. The resilience obtained from these final models were then compared to the base model resilience to see if they changed markedly from the base model, indicating if the policy regime chosen have increased or decreased the resilience of the system.

RESULTS

The four scenarios are shown in Figure 2 (a-d). Figure 2 show the results of the 1900 Newfoundland model simulated without fishing and with vulnerability settings at trophic level and at *Ecosim* base (0.3), and with an increase in fishing mortality of 1% per year over 100 years, with vulnerability settings at trophic level and at *Ecosim* base (0.3). The ratio of overhead to development capacity (Φ/C) was hypothesized to be analogous with the resilience of the system (Ulanowicz 1997, Ulanowicz 1980, Ulanowicz and Norden 1990). This ratio was plotted against time for all four scenarios in Figure 3.

DISCUSSION

From Figure 1a and 1c it is evident that increasing fishing mortality in the Newfoundland model drives the ecosystem to instability (especially in the case of the higher vulnerability settings, v = TL, Figure 1a). In Figure 1c the changes in the ecosystem are not as severe, due to the reduced effect of the vulnerability parameters, but the system is still dramatically affected. Removing fishing from the ecosystem causes some species to increase and some to decrease (Figure 1b and d), with some extinctions, when vulnerabilities are set equal to trophic level. The model does however stabilize in both instances within 20 or 30 years.

All things being equal, it would be expected that the resilience of the system should increase at first when a stressor such as fishing is taken from the system, up to an asymptote where the resilience of the system would not be affected. From the results in Figure 2 it is evident that the overhead/development capacity (Φ/C) ratio does increase as expected in the first 20 years, when fishing is eliminated from the system.

Conversely, the (Φ/C) ratio decrease when fishing mortality is increased (after an initial small increase). In the case of the vulnerability parameters being set to *Ecosim* base (0.3) this decrease is nearly linear over time. In the case of the vulnerability parameters of each prey being set to trophic level (range 0.2-0.8), the (Φ/C) ratio decrease more dramatically over the final half of the simulation, and is at its lowest level in 1980, just prior to the system crash (Figure 1a). After the crash in the 1980s, the (Φ/C) ratio increase again to levels similar to that of 1960.

According to Ulanowicz (1986), the (Φ/C) ratio shows the increase in freedom (disorder, strength in reserve) as oppose to the organization and specialization of the system. Thus, as the fishing mortality increase, and the ecosystem seem to have quite a few species increasing in biomass (Figure 1a and c), the system seems to become more specialized and organized, while loosing freedom and resilience (Figure 2). However, the system is unable to sustain this specialization, and it crashes (Figure 1a), after which its resilience start to increase (Figure 2). These results therefore support the assumption that the overhead/development capacity (Φ/C) ratio is an indication of resilience of this ecosystem.

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Note: *This paper is an earlier version of:*

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MODIFYING KEMPTON'S SPECIES DIVERSITY INDEX FOR USE WITH DYNAMIC ECOSYSTEM SIMULATION MODELS

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ABSTRACT

The Q-90 statistic, a variant on Kempton's Q index, is used to measure the effects of hypothetical harvest strategies on the biodiversity of the restored Lost Valley ecosystem. The statistic represents the slope of the cumulative species abundance curve between the 10 and 90 percentiles. In applying Kempton's method to *Ecosim* results, functional groups are considered 'species' and their biomass, sorted into bins, is analogous to the number of individuals (as when compared to field sampling studies). A Visual Basic algorithm generates an annual Q-90 value based on *Ecosim*'s output CSV file; this allows us to monitor biodiversity over the course of the simulation. Comparing the biodiversity trajectory generated by different harvest strategies, this technique provides us another method to evaluate the success of the harvest plan from an ecological perspective. This methodology is meant to complement previously described economic valuation procedures.

The 'Lost Valley' approach (Pitcher 2004 this volume, Pitcher *et al.* 2004) assumes that conservation efforts have restored the marine ecosystem to some historical level of abundance. Through *Ecosim*'s policy search routine we have generated strategies to harvest the restored system according to a variety of ecological, economic and social priorities (see Ainsworth *et al.* 2004, this volume).

Using gaming scenarios, *Ecosim* returns suggested fishing efforts for each gear type in the base *Ecopath* model that will harvest the ecosystem sustainably over the course of the simulation and maximize benefits according to the desired objective. In this paper we develop a procedure to monitor the effects of those harvest strategies on the biodiversity of the restored system over time.

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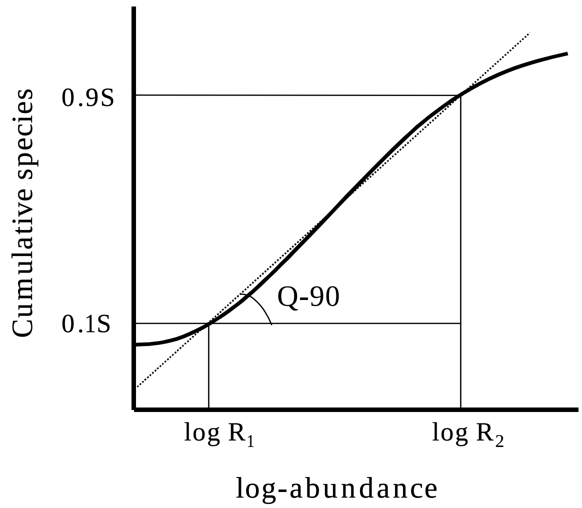

Figure 1. Representation of Q-90 statistic. S is number of functional groups in reference model; R_1 and R_2 are lower and upper 10 percentiles of the species abundance distribution. Modified from Kempton and Taylor (1976).

METHODS

Biodiversity Index

Species diversity is measured here by the Q-90 statistic, a variant on Kempton's Q index (Kempton and Taylor, 1976). Kempton's Q index describes the slope of the cumulative species abundance curve. The index is robust against changes in sample size (provided that very small samples are avoided), is not dependant upon the assumption of a particular species abundance model, is not biased by very abundant or very rare species, and expresses both speciosity and evenness (Magurran 1988).

Q-90 statistic

In the case of field sampling, Kempton and Taylor suggest using the inter-quartile slope of the species abundance curve in order to circumvent problems arising from the inclusion of tails (which may be long and include a high number of low-abundance species). In applying this methodology to *Ecosim*, tails become less of a problem since we there are almost no low abundance functional groups in the base model. Our Q-90 statistic therefore represents the slope of the cumulative species abundance curve between 10 and 90 percentiles, rather than quartiles (Figure 1). Each functional group in the model represents one "species" and the biomass of the functional groups, sorted into bins, serves as a proxy for the number of individuals in that species. The statistic is defined by the following relationship:

$$Q90 = \frac{½ n_{R_1} + \sum_{R_1+1}^{R_2-1} n_R + ½ n_{R_2}}{\log(R_2 / R_1)}$$

Where n_R is the total number of functional groups with abundance R; R_1 and R_2 are the representative biomass values of the lower and upper 10 percentiles in the abundance distribution; n_{R1} and n_{R1} are the number of functional groups that fall within the R_1 and R_2 bins, respectively.

The lower and upper 10 percentiles are chosen such that:

$$\sum_{1}^{R_1-1} n_r < 0.1 \bullet S \leq \sum_{1}^{R_1} n_r$$

$$\text{and } \sum_{1}^{R_2-1} n_r < 0.9 \bullet S \leq \sum_{1}^{R_2} n_r$$

Where S is the total number of functional groups in the model.

Applying Q-90 to Ecosim output

Ecosim returns the functional group biomass data for each simulation year in a comma delimited text file (CSV). However, at present, the program does not permit extinctions; it instead returns a low non-zero value for critically depleted groups. Therefore, every harvest scenario will contain the same number of functional groups as in the base model. To increase the sensitivity of the index to group depletions, a filter is passed over the biomass profile each year of the simulation. If the biomass of a given functional group falls below a reference value, that group is considered "extinct" and is omitted from the Q-90 calculation – this will reduce the measured biodiversity of the system. In evaluating Back-to-the-Future past and present ecosystems, the undepleted biomasses found in the most pristine ecosystems (typically represented by pre-contact models) are chosen as reference values, and an arbitrary fraction of that biomass defines the extinction threshold. The threshold is typically set to 60% of the unfished biomass, but this value may be reduced when evaluating severely depleted systems. For example, the present-day Newfoundland ecosystem has been more heavily depleted compared to its pre-contact counterpart than has Northern British Columbia (these models are described in Ainsworth *et al.* 2002). A lower extinction threshold is therefore required in the former to improve the resolution of the biodiversity index.

Description of the algorithm

A Visual Basic algorithm reads biomass from *Ecosim*'s output CSV file and converts the monthly data into annual averages. A user-defined number of bins are established that represent the complete range of functional group biomasses. The biomass of each functional group is then sorted into its appropriate bin as a count; this serves as a proxy for the number of individuals in that group. If any group falls below its reference biomass, it is omitted from the procedure. Bins may be linear or logarithmic; in the case of the latter each bin is 10% larger than the previous. The upper and lower 10 percentiles are determined as the bins in which 10% and 90% of the functional groups occur. The Q-90 statistic is calculated and plotted for each year in the simulation.

The statistic is most useful for evaluating *Ecosim* output created from the same or similar static models. For instance, the affects of alternative harvest strategies on the same *Ecopath* model may be evaluated, or the affects of analogous strategies on several related base models (e.g. models representing different time periods, but containing equivalent groups).

CONCLUSIONS

The modified Kempton's Q statistic provides a convenient means to judge the affects on biodiversity of a hypothetical harvest strategy and allows us to monitor one aspect of ecological health over time. In terms of the Lost Valley, this technique complements two other ecological valuation methodologies: the ascendancy index of Heymans (2004) and Cheung and Pitcher's (2004) technique to estimate sub-extinctions within composite functional groups. Together, these methods can monitor ecological consequences of a proposed Lost Valley harvest strategy, and when paired with the economic evaluation described in Ainsworth and Sumaila (2004), allow us to thoroughly evaluate the harvest strategy. Once we have described the economic and ecological attributes of a given Lost Valley scenario, we are able to provide management with an objective tool to weigh potential benefit with the costs of restoration.

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An Index Expressing Risk Of Local Extinction For Use With Dynamic Ecosystem Simulation Models

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Abstract

This paper derives a least squares empirical relationship to enable prediction of the likelihood of local extinction (= extirpation) of the most vulnerable species that has been grouped with other species into one functional component ('box') in a dynamic ecosystem simulation model (*Ecopath*-with-*Ecosim*).

Introduction

The effect of fishing has become a conservation concern, following cases of local extinctions and extirpations of marine species as result of fishing (Dulvy *et al* 2003, Sadovy and Cheung 2003). Restoring a marine ecosystem from its current over-exploited state and sustainable management of the rebuilt system is an innovative way to prevent fishing from driving marine species to extinction (Pitcher *et al.* 2004). An approach termed 'Back to the Future' (BTF), which integrates ecosystem modelling, socio-economics analysis, community participation in policy exploration and evaluation (Pitcher 1998, Pitcher and Pauly 1998, Pitcher *et al.* 2004), is being developed. It aims at restoring depleted marine ecosystems back to a previous lower exploited and healthy state, which can provide long-term ecological, social and economic benefits to the present and future generations.

The BTF approach relies strongly on the use of ecosystem modelling tools, *Ecopath* with *Ecosim* and *Ecospace* (*EwE*) (Walters *et al.* 1997). In the model, biota in marine ecosystem are modelled as functional groups. Therefore the model does not directly address issues relating to biodiversity change in the ecosystem, except at the functional group level. Particularly, extinction (regionally or globally) of a species within a functional group would not be revealed. Therefore, the risk of species extinction or extirpation associated with fishing cannot be explicitly dealt with when evaluating different policy options to restore and exploit the ecosystem. However, this could be overcome by developing an index which can indicate the extinction risk of species within the functional groups under different fishing patterns.

Cheung, W-L. and Pitcher, T.J. (2004) An Index Expressing Risk of Local Extinction for Use with Dynamic Ecosystem Simulation Models. Pages 94–102 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

Table 1. Attributes of growth rate and productivity that are related to vulnerability of marine species to extinction as suggested from published literature (Musick 1999, Roberts and Hawkins 1999).

Related attributes/parameters	Vulnerability to Extinction High	Vulnerability to Extinction Low
Intrinsic rate of increase (r)	Low	High
Longevity (tmax)	Long	Short
Natural mortality rate (M)	Low	High
Production biomass	Low	High
Von Bertalanffy growth (k)	Low	High
Fecundity	Low	High
Age or size at sexual maturity	Old or Large	Young or Small
Reproductive frequency	Semelparity	Iteroparity

Life-history characteristics of a species or functional group relate to their risk of extinction. Previous studies identified growth rate and productivity as important characteristics that affect the vulnerability of marine species to extinction (Musick 1999, Roberts and Hawkins 1999), and these factors can be further subdivided into a number of attributes (Table 1). These attributes can generally be incorporated in the production rate and production biomass of a population. In *Ecopath*, production rate and production biomass are explicitly expressed as the production to biomass ratio (P/B), and the biomass of each functional group. Therefore, under certain fishing rates and other factors being equal, it is expected that P/B ratio should negatively correlate with the extinction risk of a population, or positively correlate to the time required for it to become extinct. Moreover, rare low biomass species are suggested to be more vulnerable to extinction (Musick 1999), and the P/B ratio is negatively correlated to extinction risk (Table 1). Therefore, it is expected that species with lower initial biomass will be more vulnerable to extinction.

If the above propositions hold, species with different P/B ratios and initial biomasses, which have been grouped together in the functional group of a model, should become extinct at a different rate if they are subjected to a similar intensity of fishing. We also expect to see an empirical relationship between the time when each species becomes extinct and the P/B ratio and initial biomass of the species. Moreover, by assuming that the change in overall biomass of the model group is a function of the change in abundance of each species within the group, change in group biomass can be used as indicator

Table 2. Parameters for sub-groups investigated in the hypothetical *Ecosim* model. For further details see text.

Functional Group	Scenarios	Sub-group	P/B				Biomass (t km^{-2})			
Apex predators	3 sub-groups	Apex 1	1.099	1.041	0.983	1.157	0.018	0.015	0.012	0.009
		Apex 2	1.157	1.157	1.157	1.157	0.018	0.018	0.018	0.018
		Apex 3	1.215	1.273	1.331	1.157	0.018	0.021	0.024	0.027
	7 sub-groups	Apex 1	0.636	0.983	0.810	1.157	0.005		0.008	
		Apex 2	0.810	1.041	0.926	1.157	0.006		0.008	
		Apex 3	0.983	1.099	1.041	1.157	0.007		0.008	
		Apex 4	1.157	1.157	1.157	1.157	0.008		0.008	
		Apex 5	1.331	1.215	1.273	1.157	0.009		0.008	
		Apex 6	1.504	1.273	1.388	1.157	0.010		0.008	
		Apex 7	1.678	1.331	1.504	1.157	0.011		0.008	
Mesopelagics	3 sub-groups	Meso 1	0.557	0.546	0.516	0.607	0.71	0.73	0.743	0.844
		Meso 2	0.607	0.607	0.607	0.607	0.844	0.844	0.844	0.844
		Meso 3	0.637	0.668	0.698	0.607	1.266	1.055	0.945	0.844
	7 sub-groups	Meso 1	0.334	0.516	0.425	0.607	0.308		0.362	
		Meso 2	0.425	0.546	0.486	0.607	0.326		0.362	
		Meso 3	0.516	0.577	0.546	0.607	0.344		0.362	
			0.607	0.607	0.607	0.607	0.362		0.362	
		Meso 1	0.698	0.637	0.668	0.607	0.380		0.362	
		Meso 2	0.789	0.668	0.728	0.607	0.398		0.362	
		Meso 3	0.888	0.698	0.789	0.607	0.416		0.362	
Benthic fishes	3 sub-groups	Benthic 1	0.07	0.071	0.072	0.074	0.440	0.450	0.455	0.463
		Benthic 2	0.074	0.074	0.074	0.074	0.463	0.463	0.463	0.463
		Benthic 3	0.096	0.089	0.081	0.074	0.602	0.556	0.509	0.463

of species extinctions.

In this study, the above hypotheses were tested by comparing results obtained from simulations of a hypothetical *Ecopath* model. Species within a group were split into individual groups in the model and results obtained from *Ecosim* simulations were compared with those obtained from a model without sub-dividing the functional group. An empirical model was then developed to calculate an extinction index that can be used to approximately estimate the occurrence of a species extinction event.

METHODOLOGY

A hypothetical *Ecopath* model, supplied with the software, the 'ocean-test model', was used to generate simulation results (details of the ocean-test model are summarized in Annex 1). The functional groups: apex-predators, mesopelagics, benthic fishes, and large-zooplanktons were split into three and seven sub-groups. Each sub-group was assumed to be a composite species of the corresponding functional groups, with the same diet composition, production to consumption ratio (P/Q), fished at the same intensity, but with varying biomass and P/B ratios (Table 2).

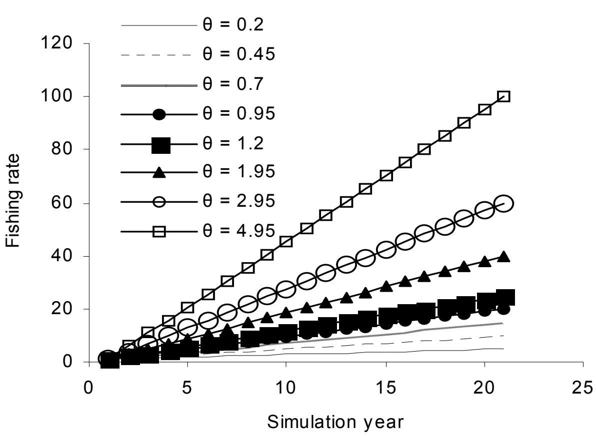
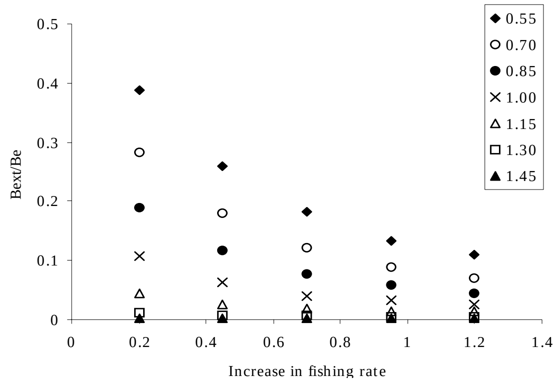


Figure 1. Patterns of fishing rate (%) in the *Ecosim* simulation of the 'Ocean-test Model'. The average increases in fishing rate are shown in the legend.

Ecopath models developed for each of the above scenarios were simulated under a range of fishing patterns in *Ecosim* (Figure 1). The time-series of biomass changes in each simulation were recorded. The results were expressed as a ratio of the sum of biomasses of all sub-groups at simulation time t (B_t), to the sum of biomass of these groups in the *Ecopath* base model (B_e). We recorded this B_t/B_e ratio and the simulation time when each of the sub groups became extinct (B_{ext}/B_e). Extinction of a sub-group was defined as when its biomass was reduced by more than 99% its initial base model level.

Input parameters of the models and simulations were plotted against the B_{ext}/B_e values and evaluated with regression analysis. The independent variables include the P/B ratios (Φ_i), the biomass (B_i) of individual sub-groups (i), the standard deviations of the P/B ratios (δ_j), the biomasses (γ_j) of the sub-groups (j), and the average rate of increase in fishing rate (θ). A regression model with B_{ext}/B_e as the dependent variable was developed from simulation results of the apex-predators, mesopelagics and benthic



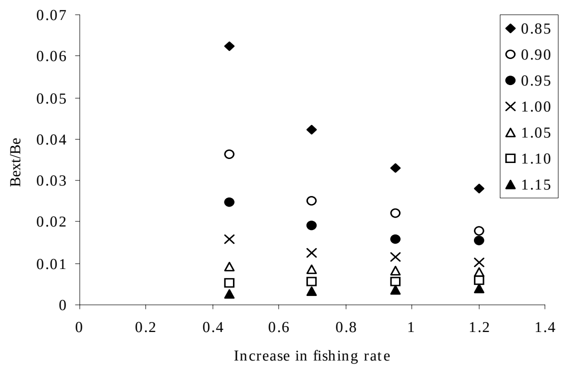


Figure 2. Plots of the ratio of model group biomass to initial biomass at extinction, Bext/Be (y-axis) resulting from different increases in fishing rate, θ (x-axis). Species (sub-groups) with different P/B ratios within the model groups are shown in the legend. Upper panel shows results from apex predators group with a standard deviation of the P/B ratio = 0.125. Lower panel shows mesopelagics group with sd = 0.066.

fishes. Results from simulations of the large-zooplanktons were not include in the regression as they were used to test the validity of the regression model.

RESULTS

A total of 433 data points were generated from the *Ecosim* simulations of the apex-predators, mesopelagics and benthic fish model groups. Analysis of the data suggested that the observed B_{ext}/B_e obtained from the simulations could be explained by four components in the regression model.

(1) *Fishing rate component (G)*

From the data, there is a consistent relationship between the increase in fishing rate (θ) and the observed B_{ext}/B_e. Data obtained from simulations of the apex-predators and mesopelagics are shown as examples in Figure 2, which can be fitted with a logistic model:

$$G = [a/(b^* \theta + c)] + d^* \theta \quad (1.1)$$

where a, b, c and d are coefficients determining the shape of the relationship, θ is the average rate of increase in fishing rate, and G is a function of B_{ext}/B_e:

$$B_{ext}/B_e = f(G) \quad (1.2)$$

(2) *P/B component*

The shape of the curve from equation 1.1 varies with the P/B ratio (Φ, normalized to the mean P/B ratio of the model group, Figure 2). Therefore, it is suggested that Φ is a function of coefficients a, b, c and d. The simulated data suggest that Φ is non-linearly related to coefficient a, and linearly to coefficients b, c and d (Figure 3). As such, it is assumed that:

$$a = m_1/ \Phi + n_1 \quad (2.1)$$
$$b = m_2{}^* \Phi + n_2 \quad (2.2)$$
$$c = m_3{}^* \Phi + n_3 \quad (2.3)$$
$$d = m_4{}^* \Phi + n_4 \quad (2.4)$$

where m_i and n_i are constants.

Setting the model group standard deviation of P/B ratios (δ) and mean P/B ratio (α) as independent variables while Φ and other factors are kept constant, we found that a second degree polynomial of δ and α are functions of B_{ext}/B_e. So:

$$B_{ext}/B_e = f(\alpha^* \delta^2) \quad (2.5)$$

(3) *Biomass component (H)*

The two sub-models above cannot fully explain the results obtained from the simulations when biomasses of the sub-groups are independent variables. A plot between the biomass (normalized to the mean) of the sub-groups (B_i) and B_{ext}/B_e of the corresponding model groups suggests a non-linear relationship between the two. The shape of this relationship is affected by the increase in fishing rate (θ) (Figure 4). Hnec we get:

$$H = s^*/[(1-B_i/t)/(B_i{}^* \theta)] - v \quad (3.1)$$

where s, t and v are constants, and H and the standard deviation of the sub-group initial biomasses (γ) are functions of B_{ext}/B_e:

$$B_{ext}/B_e = f(H * \gamma) \quad (3.2)$$

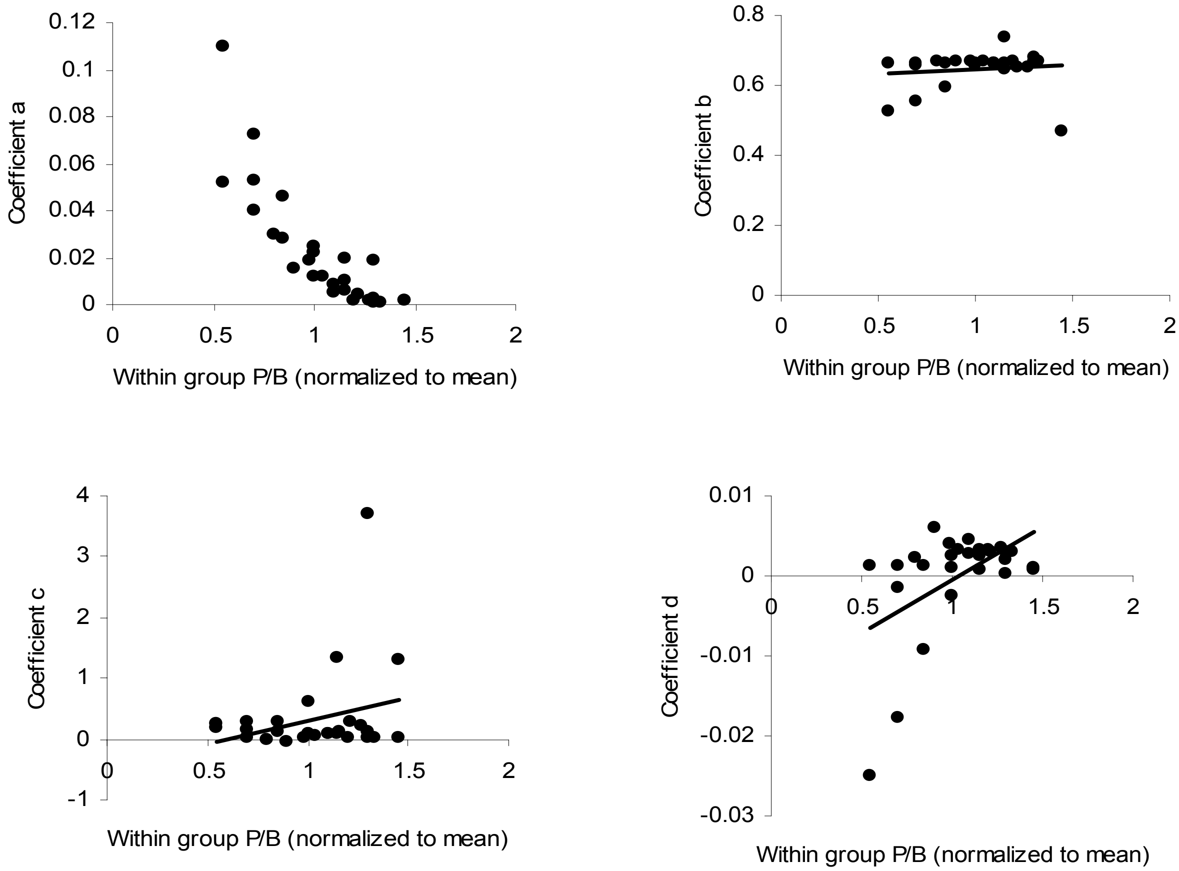


Figure 3. Plots of the coefficient for the P/B component model against P/B ratio of the sub-groups representing within-group species. Coefficient a has a non-linear relationship with the P/B ratio, while the relationships between coefficients b, c, and d with the P/B ratio are less clear, but are assumed to be linear.

(4) Extinction index component (B_{ext}/B_e)

The above results support our proposition that the risk of extinction, or the time at when extinction would occur, (expressed as B_{ext}/B_e) is dependent on the P/B ratio, initial biomass and fishing rates. Summarizing from equations 1 to 3, we suggest that:

$$B_{ext}/B_e = c_1 * G * \alpha * \delta^2 + c_2 * H + c_3 * \gamma + c_4 \qquad (4)$$

where c_i are constants, and B_{ext}/B_e must be greater than or equal to zero.

All the constants from equations 1 to 3 were obtained by fitting equation 4 to the results generated from the test simulations using a least squares method (Table 3). The coefficient of determination of the best fit is 90.2% (Figure 5a). When the biomass-dependent component is separated from the model (Figure 5b), the model explains over 97% of the variations in these groups from the ocean test *Ecopath-with-Ecosim* model.

Table 3. Values of the coefficients in the local extinction empirical model. The coefficients are estimated by fitting the model to the observed simulation data using least squares.

Coefficient		**Value**
P/B component		
	m_1	31.336
	n_1	-14.989
	m_2	-6.780
	n_2	9.458
	m_3	1.157
	n_3	0.361
	m_4	-2.757
	n_4	1.124
Biomass component		
	s	1.11
	t	1.186
	v	0.0153
B_{ext}/B_e component		
	c_1	0.131
	c_2	0.224
	c_3	0.00143
	c_4	0.00991

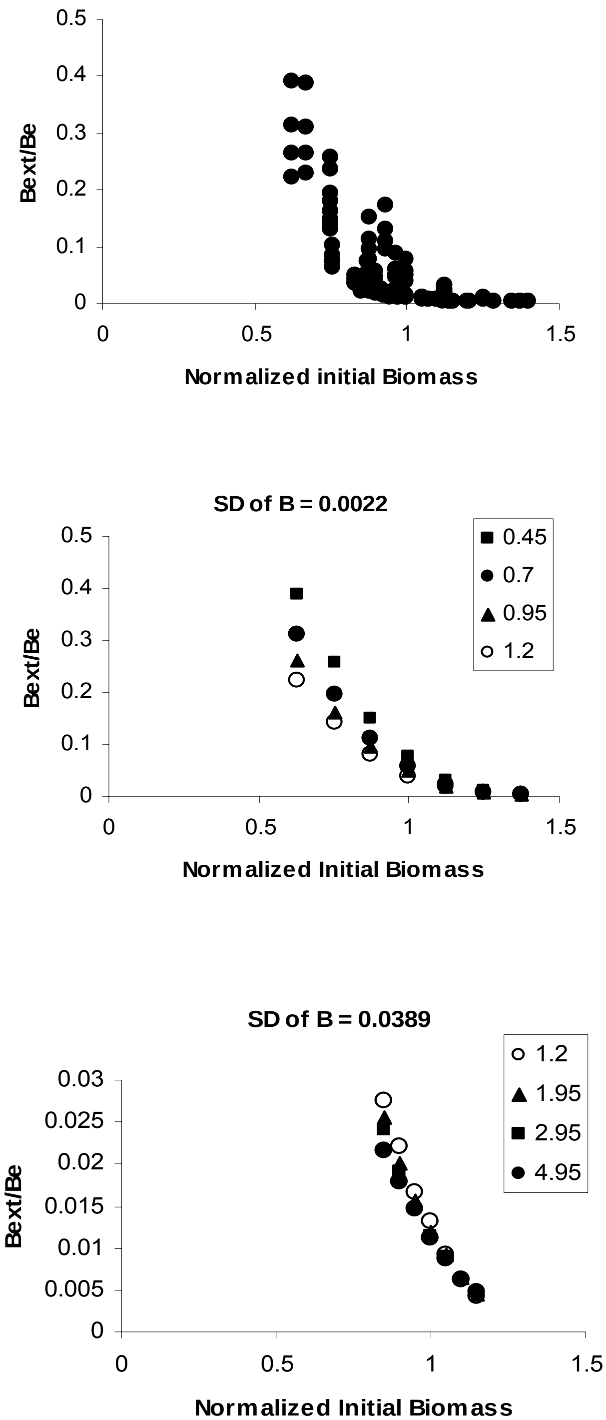


Figure 4. Plots of ratio of biomass at extinction to initial biomass of the within group species (Bext/Be) against the initial biomass of the species (normalized to the mean biomass of the functional group) (a) Top: all simulations data from different biomass, P/B ratio and fishing rates (N=151); (b) Middle: data with the standard deviation of biomass of the sub-groups (SD) = 0.0022; (c) Bottom: with SD = 0.0389.

Applying the model

Therefore, it is suggested that if the biomasses of the sub-groups (=species) are assumed the same, only the non-biomass dependent component should be used.

The estimated B_{ext}/B_e can then be used to determine when a species within the functional group may go extinct, given the conditions above. For example, in the hypothetical example, large zooplanktons were fished with a constant fishing rate of 18 times the *Ecopath* base fishing rate for 21 year. The extinction time for the 10 within functional group species that have different P/B ration, were predicted by the model (Figure 5).

The algorithm also applies to scenarios in which the increases in fishing rate are not constant. In a hypothetical scenario (Figure 7a), first, local peaks of fishing rate were identified and the average change in fishing rate (θ) between consecutive peaks was calculated, including the first peak from the original values at simulation time zero. B_{ext}/B_e of the species within the model group were obtained from each calculated θ, and compared with the simulated biomass of the functional group to see if extinction occurs before the particular peak of fishing rate was reached (Figure 7b).

Probability of local extinction

In many *Ecopath* models that have been constructed, information on the P/B ratio and biomass of individual species within a functional group are often unavailable. Therefore, B_{ext}/B_e could not be estimated using equation 5. Here, a surrogate approach was developed in which B_{ext}/B_e can be estimated by using a Monte Carlo approach to sample the P/B ratios of the species within a model group. A given range of P/B ratios and a pre-specified mean P/B ratio is all that is required. Since there is no evidence that P/B ratios within a model group are normally distributed, a rectangular prior distribution of P/B ratios is used. However, other distribution types can be employed according to different model structures.

A probability distribution of the percentage of species going extinct can be obtained from the Monte Carlo simulation. Moreover, the average time at when the first within-group species extinction occurs can be estimated. Distributions of the likelihood of extinction of the functional group 'Large Demersal Non-reef Associated Fishes' in a Hong Kong ecosystem model (1950s) are shown as example (Figure 8, Buchary and

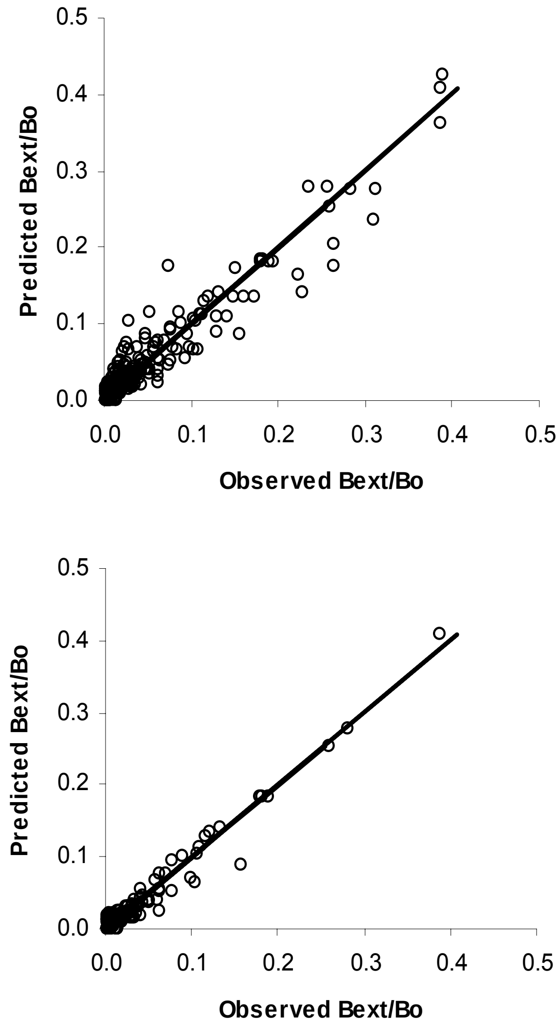


Figure 5. Comparisons between the ratio of biomass at extinction to initial biomass of within functional group species (Bext/Be) as predicted by the empirical models (equation 4) and Bext/Be observed from the *Ecosim* simulations; (a) Top: all data points (N = 432) R^2 = 0.902; (b) Bottom: data points with equal initial within group species biomass (N=281) R^2 = 0.972. The solid line represents exact agreement between the predicted and observed data.

Cheung, *unpublished*). The ecosystem was exploited under three sets of fishing rates that were found form optimality searches to maximize the ecological, economic and social values from the fisheries (see Ainsworth *et al.*, Pitcher 2004, this volume, Pitcher *et al.* 2004).

DISCUSSION

The model developed in this study is an attempt to estimate species extinction in the trophic mass balance model in which occurrence of species extinction in dynamic simulations are masked by the aggregation of species into functional groups. One of the problems in the latter is that when fishing strategies are evaluated in terms of their ecological, social and economic benefits, the ecological impact of fishing on a particular functional group may not be significant. However, it may pose serious threats to the survival of one or more of the within group species which possess characteristics rendering them vulnerable to extinction. Therefore, the extinction model can be used as one of the ecological indicators in evaluating the ecological effect of fishing strategies.

It is encouraging that the outcome of our empirical model agrees with existing views about the characteristics and factors that affect the vulnerability of extinction in marine species (Roberts and Hawkins 1999; Dulvy *et al.* 2003). For example, species with a lower production rate and production biomass will be more likely to go extinct first. The model fits well with the simulation data used to develop the model and provides reasonable predictions of extinction events within functional groups.

It should be noted, however, that the empirical model is based on numerous assumptions and approximations. The data which is used to fit the model is generated from a hypothetical *Ecopath* and *Ecosim* (*EwE*) model. *EwE* has its own sets of assumptions (Walters *et al.* 1997), and therefore the uncertainty of the results given by the empirical model will be magnified. It would be desirable if empirical data from known cases of marine species extinction could be used to develop the empirical model. However, reported cases of marine species extinction are insufficient to undertake the analysis in this study.

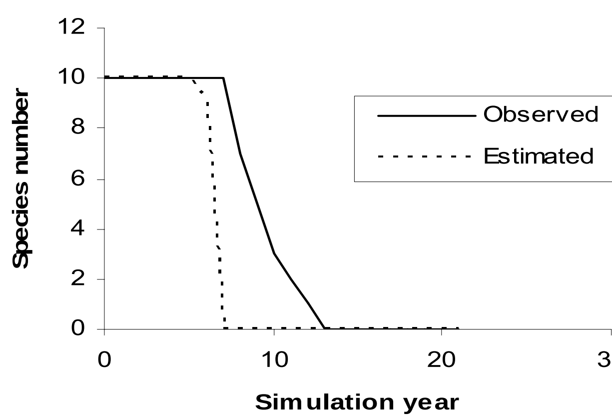


Figure 6. The change in species richness of the 'large-zooplanktons' group under a constant fishing rate 18 times the initial rate (10 species initially). Species were considered extinct if they dropped below 99% of their initial biomass. The solid line is the observed change from *Ecosim* simulation, while the dotted line represents the changes in species numbers predicted by our extinction model.

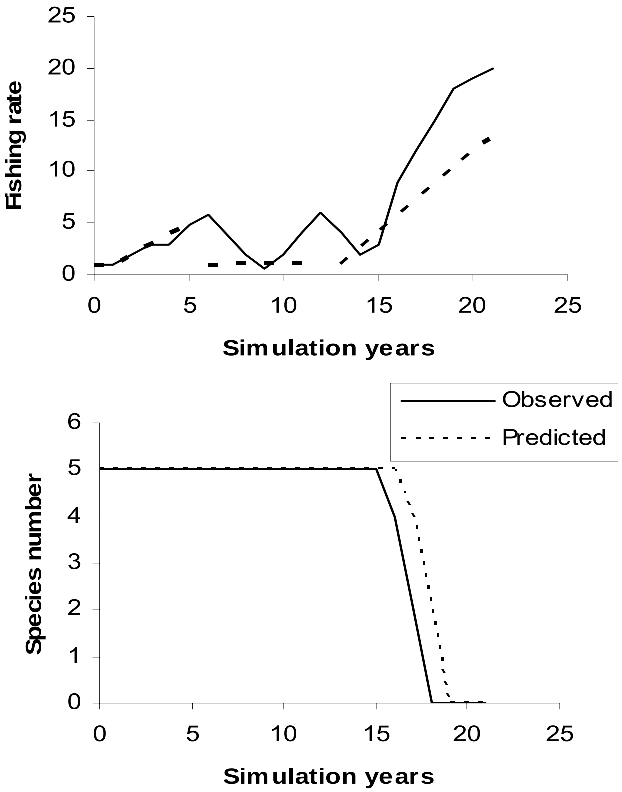


Figure 7. The change in species richness of the Apex predator group under fluctuating fishing rate. (a) Top: the change in fishing rate in the *Ecosim* simulations (solid line) and the between peaks increase in fishing rate (θ) (dotted line); (b) Bottom: species were considered extinct if they drop below 99% of their initial biomass. The solid line is the observed change from *Ecosim* simulation, while the dotted line represents the changes predicted by the extinction model.

EwE is determined by many more parameters than those being modelled in this empirical model. For example, vulnerability factors, which determinate the rates of exchange between vulnerable and non-vulnerable biomass of each functional group, are not taken into account in the empirical model (see Ainsworth 2004, this volume). Therefore, results obtained from the empirical model are only approximate.

Application of the empirical model should be restricted to fishes and invertebrates. Since the model is developed based on an extinction criterion of 99% reduction from the initial biomass, this may be too conservative for higher marine vertebrates or even for some marine fishes and invertebrates (Dulvy *et al.* 2003). Revision of the model can be undertaken should the extinction criteria be adjusted.

Furthermore, there are others factors which will affect the extinction vulnerability of marine species. For instance, degradation of critical habitats, as a result of destructive fishing, will have direct threats to the survival of the species (Musick 1999; Roberts and Hawkins 1999; Dulvy *et al.* 2003). Such factors are not taken into account in the empirical model.

Because of the assumptions and approximations of the empirical model, it does not produce, and should not be seen as producing, accurate prediction on the time and likelihood of species extinction under a given fishing intensity. Other more rigorous analytical method, such as the various population viability analyses (Boyce 1992; Brook *et al.* 2000), can be used if more accurate predictions are sought.

On the other hand, the small number of parameters required for the empirical model allows a convenient application, in particular for ecosystems where fisheries and ecological data are insufficient or species diversity is high which renders it difficult to model individual species as separate functional groups.

Moreover, the model can be used as an indicator to compare the possible effects of different fishing strategies in affecting species extinction risk. This is particularly useful in conducting 'Back to the Future' analyses in which alternative fishing strategies are evaluated and compared for their possible ecological, social and economic benefits and risks that can result.

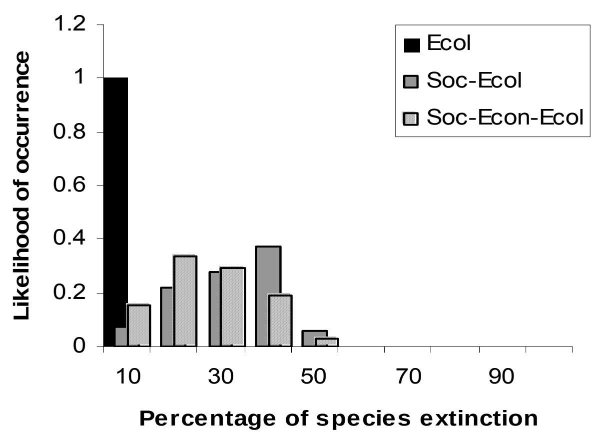


Figure 8. Distributions of the likelihood of extinction within the functional group 'Large demersal non-reef associated fish', which consists of 25 species, from three *Ecosim* simulations of a Hong Kong 1950s model. Fishing rates in the three scenarios aimed to maximize the ecological benefits (black), social and ecological benefits (shaded) and social, economic and ecological benefits (diagonals) from the ecosystem (from Buchary and Cheung, unpublished).

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ANNEX

Annex Table 1. Basic input and output parameters for the “Ocean test model”. Bolded values were estimated from *Ecopath*.

Group name	Trophic level	Biomass (tkm^{-2})	P/B	Q/B	Ecotrophic efficiency	Fishery catch (tkm^{-2})
Apex predators	**4.26**	0.055	1.157	14.951	**0.930**	0.020
Mesopelagics	**3.35**	2.533	0.607	2.748	**0.912**	0.147
Epipelagics	**3.27**	0.516	1.991	9.230	**0.960**	0.020
Benthic fish	**2.67**	1.388	0.074	0.324	**0.861**	0.020
Benthopelagics	**2.61**	0.600	0.104	0.431	**0.942**	0.020
Zooplankt.large	**2.60**	9.864	0.466	2.684	**0.827**	0.020
Benthos	**2.05**	4.772	0.108	0.382	**0.590**	0.020
MicroZooplankt.	**2.00**	2.434	19.812	96.561	**0.456**	0.020
Phytoplankton	**1.00**	0.900	393.435	-	**0.695**	0.000
Detritus	**1.00**	1.000	-	-	**0.011**	0.000

Annex Table 2. Diet composition matrix of the “Ocean test model”.

No.	Preys\Predators	1	2	3	4	5	6	7	8	9	10
1	Apex predators	0.048								0.048	
2	Mesopelagics	0.100	0.100	0.100						0.100	0.100
3	Epipelagics	0.752	0.050							0.752	0.050
4	Benthic fish				0.150						
5	Benthopelagics					0.150					
6	Zooplankt.large	0.100	0.250	0.400		0.200				0.100	0.250
7	Benthos				0.400	0.050		0.050			
8	MicroZooplankt.		0.600	0.400			0.600				0.600
9	Phytoplankton			0.100			0.400		1.000		
10	Detritus				0.450	0.600		0.950			

How Do We Value The Restoration Of Past Ecosystems?

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The restoration of depleted/degraded marine ecosystems can be seen as a re-investment in natural capital that entails high short-term costs for benefits that, at least in business terms, will come in the distant future. This time gap between costs and benefits makes it particularly important to determine the costs and benefits of such a project through time to help determine the value of the undertaking. Determining the costs, and especially, the benefits of marine ecosystem restoration is quite challenging. This is because the benefits can be many and diverse; and they may accrue to both current and future generations. Proper valuation of ecosystem restoration will require the extension of current valuation methods, and the development of innovative new approaches. Sumaila and Charles (2002) suggest key questions and issues that need to be addressed regarding the value of restoration include:

What are the benefits (economic, ecological, social, cultural)?
What are the costs?
Over what time frame are benefits and costs measured?
What is the intergenerational flow of these benefits and costs?
How do we deal with discounting of future benefits and costs?
What about equity issues - do the benefits of restoration reach those who suffer the costs?
Who receives the benefits (fishers, First Nations, general public …?
Who incurs the costs (fishing industry, impacting industries, e.g., logging, pollution, urban growth, taxpayers?
What about the differing levels at which benefits and costs occur: individuals and corporations (e.g., resource users), communities, regions?

In measuring benefits, we must take into account all types of benefits (and costs), including consumptive uses (fishing, mineral extraction, etc.); non-consumptive uses (e.g., observation of wildlife, notably through tourism); non-use/existence value, the inherent value placed on the very existence of the ecosystem; and option value, the value placed on maintaining the marine ecosystem for possible future economic uses (see Sumaila and Bawumia 2092).

In measuring benefits, we must take into account the direct net benefits accruing from all relevant economic activity, e.g., fisheries, tourism, extraction of non-renewables, the non-use benefits, existence value and option value; all of these must be measured at the appropriate scale – the individual, as well as social and community benefits, including the spin-off benefits that may arise in the regional economy (e.g., increased post-harvest activity as a result of a more productive fishery).

Efforts at determining values from environmental and natural resources, in general and ecosystem restoration, in particular, have received some attention recently (e.g., Costanza *et al.* 1997, Weitzman 2001, Sumaila 2001, Sumaila and Walters 2003, 2004, Sumaila *et al.* 2001). An application is described in Ainsworth and Sumaila (2003), but more methods need to be developed.

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ECONOMIC VALUATION TECHNIQUES FOR BACK-TO-THE-FUTURE OPTIMAL POLICY SEARCHES

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ABSTRACT

We use conventional and intergenerational models of discounting to measure the economic success of each BTF restoration scenario in terms of net present value (NPV). The NPV term condenses the flow of future benefits into a single expression, and includes a time component to reflect the interests of an investor: with immediate benefits contributing heavily to the term, and far-off benefits discounted exponentially with time. The intergenerational model of discounting considers the needs of future generations better than the conventional model by including the arrival of new stakeholders each year. These entrants bring a renewed perspective on future earnings, partially resetting the discounting clock. Future work will weigh the economic success of each restoration scenario against the costs of achieving restoration.

INTRODUCTION

The economic cost associated with restoring the marine ecosystem to some level of its former diversity and abundance must be weighed against the additional benefit that the restored system would tender. Although costs and benefits may be measured in ecological and social terms as well (other papers in this volume consider these), we argue that economic considerations will take centre stage in determining the feasibility of any actual long-term conservation agenda (Ainsworth and Sumaila 2004).

We have therefore developed methodology to rank the *Lost Valley* ecosystem restoration goals, and their associated optimal harvest profiles, in terms of net present value (NPV) offered by the conventional and intergenerational (IG) approaches to discounting (Sumaila and Walters, 2004). The NPV term condenses the flow of future benefits into a single expression, while introducing a time component that reflects the interests of an investor: weighing immediate benefits heavily in the calculation, and discounting far-off benefits exponentially with time.

However, under the conventional discounting model, the future stock condition is worth so little in net present value (at any practicable level of discounting), that there emerges a tendency to focus on short-term benefit. Ainsworth and Sumailia (2003) postulate that this effect may have contributed to the Atlantic cod collapse. Therefore, we also value the BTF scenarios under the intergenerational discounting (IG) model of Sumaila and Walters (2004), which takes into account the needs of future generations better than the conventional model. The IG formula considers a continuous interlacing of generations, where devaluation of future benefit is counter-weighted each year by the addition of 1/G stakeholders, where G is the human generation time. The new entrants bring with them a renewed perspective on future earnings, partially resetting the discounting clock. Thus, the intergenerational approach will assign a high value to harvest scenarios that spread out benefits over several decades, while the conventional approach will favour scenarios that provide immediate profits at the expense of the standing resource.

Results from this analysis are presented in Ainsworth *et al.* (2004a) for northern BC evaluations, and Heymans *et al.* (2004) for Newfoundland. For information on *Back to the Future* (BTF) optimal policy search methodology, refer to Ainsworth *et al.* (2004b).

METHODS

Fishing mortalities per gear type, which are determined by an optimal policy search routine for each restoration period, fleet structure and harvest objective, are held constant in a 50-year dynamic *Ecosim* simulation. The resulting time series of absolute biomass is used to calculate landings (since they are not directly reported in the output CSV file). We assume the ecosystem reaches equilibrium after 50 years of harvest. The end-state values of biomass and harvest are then maintained for another 50 years in steady state. The first half of the simulation represents a development phase in the newly opened *Lost Valley* fishery, the second half represents a settlement phase.

Total catch per functional group for each year is converted into gross income by multiplying landed tonnes by wholesale market price. BC prices per functional group (Table A1) are based

Ainsworth, C. and Sumaila, U.R. (2004) Economic Valuation Techniques for Back-To-The-Future Optimal Policy Searches. Pages 104-107 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

on SAUP (2002), and modified by Pitcher (pers. comm.). These were converted to US dollars assuming an exchange rate of US $0.63 per Canadian dollar. For the BC models, price is also affected by gear type according to the estimated multipliers in Table A1. Newfoundland price per functional group is based on average Atlantic Canada values from 1995-1999 (DFO, 2002), and are shown in Table A.2 in US dollars. For Newfoundland models, functional group prices are the same for all gear types.

Non-market prices for northern BC (Table A.3) were obtained from Beattie (2001). These refer to estimated revenues from wildlife viewing, scuba diving and kayaking in the case of marine mammals and from sporting operations in the case of recreational species. Non-market values were not included in the Newfoundland models.

Cost is subtracted from calculated gross income to determine profit. Costs are assumed equal to 60% of gross income, based on DFO (1994). The annual profits over 100 years are then condensed into a single figure, the net present value (NPV), according to the following discounting methods.

Conventional discounting calculates NPV according to:

$$NPV = \sum_{t=0}^{T} \frac{NB_t}{(1+\delta)^t}$$

Where NB_t is net benefit in year t, δ is the discount rate and T is 100, the total number of simulation years.

Intergenerational discounting (Sumaila and Walters 2004, 2003, Sumaila 2001) employs the following relationship:

$$NPV = \sum_{t=0}^{T} \frac{NB_t}{(1+\delta)^t} \cdot \left(1 + \frac{t}{G}\right)$$

where G is human generation time (~20 years). For all discounting operations, discount rate was taken as 4% per year.

DISCUSSION

Optimal harvest profiles that slope upwards (with most harvest occurring late in the dynamic simulation) perform relatively better under intergenerational discounting than profiles that slope downwards (where most benefit is taken early). The former situation should correspond to optimal harvest profiles based on the 1950 and 2000 model baselines. Their conservative optimal fishing patterns, delivered by the policy search routine, will allow these depleted systems to rebuild, and the greatest harvests will be taken late in the simulation. The latter situation should correspond to harvest profiles based on the 1750 and 1900 baselines. As these represent more pristine ecosystem conditions, their optimal fishing patterns will aggressively mine the system in order to increase productivity; greater harvests will be taken early.

We expect the most lucrative policies to be identified by the optimal policy search routine under the economic objective, followed by the social objective, the mixed objective, the ecological objective and the portfolio log-utility objective (Walters *et al.*, 2002). We also expect the pre-contact ecosystem to generate greater benefits than 1900, 1950 or 2000 systems, since it contains the highest levels of abundance (Ainsworth *et al.*, 2002).

Future work will apply these results to a cost-benefit or cost-effectiveness analysis in order to weigh potential benefits against the costs of restoration (Ainsworth, in prep).

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For discussion after the oral presentation of this paper, see page 138.

ANNEX TABLES

Table A2. Prices (US$ per kg) for Newfoundland fisheries.

Group Name	$/kg
Cod (> 35 cm)	1.02
Cod (≤ 35 cm)	1.02
American plaice (< 35 cm)	0.85
American plaice (≤ 35 cm)	0.85
Greenland Halibut (> 65 cm)	1.17
Greenland Halibut (≤ 65 cm)	1.17
Yellowtail Flounders	0.85
Witch flounder	0.85
Winter flounder	0.85
Skates	0.25
Redfish	0.36
Transient mackerel	0.31
Demersal Bentho-Pelagic Piscivores (>40 cm)	2.06
Demersal Bentho-Pelagic Piscivores (≤ 40 cm)	2.06
Demersal Feeders (> 30 cm)	0.88
Demersal Feeders (≤ 30 cm)	0.88
Lumpfish	3.23
Greenland cod	1.02
Salmon	0.50
Capelin	0.17
Herring	0.12
Transient Pelagics	8.62
Small Pelagics	0.31
Shortfin squid	0.32
Arctic squid	0.32
Large Crabs (> 95 cm)	3.15
Small Crabs (≤ 95 cm)	0.57
Lobster	7.50
Shrimp	1.72
Echinoderms	1.56
Bivalves	1.03

Table A3. Non-market values used for northern BC models.

Group Name	Value/unit biomass
Mysticetae	0.8
Coho salmon	9.85
Chinook salmon	13.13
Inshore rockfish	0.27
Shallow water benthic fish	0.01
Infaunal carnivorous invertebrates	0.01

Table A1. Prices for northern BC fisheries. *Prices in $US. Price per species has been increased by the gear-type multiplier (bottom row).

Group Name	Groundfish Trawl	Shrimp Trawl	Shrimp Trap	Herring Seine	Halibut Longline	Salmon Freezer Troll	Salmon Wheel	Rockfish Live	Crab Trap	Clam Dredge	Aboriginal	Recreational
Transient salmon						2.48	2.48				1.65	
Coho salmon						1.44					0.96	19.15
Chinook salmon						3.7					2.47	49.39
Ratfish	2.09	2.09										
Dogfish	0.35	0.35				0.35						
Pollock	0.31											
Eulachon		1.26									1.26	
Adult herring				0.29								
Adult POP	0.81											
Inshore rockfish	0.81				0.81	0.81		8.06				16.13
Adult picivorous rockfish	0.81					0.81						16.13
Adult planktivorous rockfish	0.81					0.81						
Juvenile turbot					0.2							
Adult turbot	0.2	0.2			0.2							
Juvenile flatfish					0.73							
Adult flatfish	0.73	0.73			0.73							
Juvenile halibut					2.56							51.16
Adult halibut					2.56						2.56	51.16
Adult Pacific cod	0.67				0.67							
Adult sablefish	0.63				0.63							
Adult lingcod	1.06				1.06			1.06				21.29
Shallowwater benthic fish		0.52	0.52	0.52								
Skates	0.14	0.14			0.14							
Large crabs	4.54								4.54			
Small crabs									3.64			
Commercial shrimp		3.07	3.07									
Epifaunal invertebrates										1.42		
Gear-type multiplier	1	1	1	1	1	1.5	1.5	10	1	1	1	20

An Employment Diversity Index Used To Evaluate Ecosystem Restoration Strategies

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Abstract

We develop a social equity index based on the Shannon-Weaver entropy function for use in BTF optimal policy investigations. The index measures employment diversity across fishing sectors and ranges from from zero to one, where zero indicates no diversity (all fishing effort is concentrated in a single sector) and one indicates maximum diversity (fishing effort is distributed evenly among all sectors). This employment diversity index complements the social utility measure delivered directly from *Ecosim*: total employment.

Introduction

The employment diversity index presented here, after the methodology of Attaran (1986), was used to evaluate the simulated harvest profile offered by various restoration scenarios described in Heymans (2003) and Ainsworth (2004). Based on the Shannon's entropy function (Shannon and Weaver 1949), this measure describes the diversity of employment across fishing sectors.

The entropy function is defined as:

$$D(E_1, E_2, \ldots E_N) = -\sum_{i=1}^{n} E_i \log_2 E_i$$

where,

n = the number of (possible) fishing sectors active in the ecosystem,

and,

E = the proportion of total employment that is located in the ith fishing sector.

The measure is normalized across sectors with respect to their maximum possible diversity so that $D(E_1, E_2, \ldots E_n)$ ranges from 0 to 1. D=0 indicates that all fishing activity is concentrated in a single sector, and 1 indicates the maximum possible employment diversity, with all sectors contributing equally to employment (all *Ei* equal).

Or,

$$D(E_1, E_2, \ldots E_n) = \left(-\sum_{i=1}^{n} E_i \log_2 E_i\right) \Big/ MAX(D(E_1, E_2, \ldots E_n))$$

Application to Ecosim

A *Visual Basic* algorithm uses this descriptor to assess the annual employment diversity of the dynamic 50-year harvest schedule for each optimal policy suggested by the EWE policy search routine (see Ainsworth *et al.* 2004). Beginning with *Ecosim*'s output CSV file, total value per gear type is calculated as the sum of all functional group landings, multiplied by gear-specific prices. Total value per gear type is converted to relative number of jobs using an estimated 'jobs per catch value', as described in Ainsworth *et al.* (2004). Employment per sector (E_i) is then calculated as a fraction of total employment.

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EVALUATING FUTURE ECOSYSTEMS: A GREAT STEP BACKWARD?

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"Those who do not remember the past are condemned to repeat it"
George Santayana (1863-1952)

ABSTRACT

The Goal of Back to the Future is to restore some past level of abundance and diversity. The first objective is to engage scientists, managers, policy makers and the maritime community in developing the best possible computer models of present and past ecosystems. The second objective is to assign ecological and social as well as economic value to past and present systems, so that collaborators can set restoration goals. New valuation techniques, while innovative, use prices and costs from today's fleet to value past systems. This paper asks how we might harness the creative potential of the collaborators to design new fisheries that make sense in terms of the ecosystems and human communities that depend on them. A 'capital/interest' approach is suggested where the biomass essential to maintain productive potential and species of social and cultural importance are considered as natural and social capital, and, as such, not subject to commercial harvest.

'Back-to-the-Future' has strong ethical and participatory elements (Haggan 2000, Haggan *et al.* 1998), one goal of which is to find new ways for a very broad constituency to work on assigning ecological as well as social values when comparing ecosystem states. In brief, ecological value is assigned by giving fish in the water some value relative to those caught. For instance, one could assign equal value to fish in the ocean to those caught (Sumaila *et al.* 2001). Social value is assigned by including the value to future generations (Sumaila and Walters 2004).

One major problem that arose at the December workshop in Prince Rupert related to eulachon, an important food and trade item with high social and cultural value to First Nations. The past ecosystem models presented at the workshop showed very high dollar values for eulachons, derived from the only existing commercial fishery on the Fraser River. First Nation participants made it clear that they did not want a monetary value put on an integral part of their culture and subsistence economy.

How then can we assess, or indeed compare the real value of ecosystem components whose predominant values are non-monetary? This raises the question of 'Ecosystem Justice' addressed by Brunk and Durham (2000) in 'Just Fish: Ethics and Canadian Marine Fisheries' (Coward *et al.* 2000). Sumaila and Bauwumia (Ibid.) argue convincingly that the market cannot guarantee justice for ecosystem components that have no 'monetary value'.

Costanza and colleagues (1997) valued global ecosystem, or 'life support' services such as oxygen production at $US33 trillion/year, or almost double global GNP of $US18 trillion. The Costanza approach is related, as it values quantities that cannot be bought or sold, but is not directly comparable as it assigns dollar values

A 'CAPITAL-INTEREST' APPROACH

It seems to be a given that money is the only 'yardstick' that economists can readily apply. It is certainly a 'currency' that today's decision makers readily appreciate. Those who deal in money have a shrewd idea of the value of capital,. They also see it as something that should be conserved. Consider endowment funding where the interest from a significant capital amount is used to finance ongoing activities, cover core operations and maintain the principal against inflation, or indeed add to it over time. For example, the David and Lucile Packard Foundation dispensed ~$US614 million in 2000 (www.packfound.org) based on capital assets of approximately $9.8 billion. We might then consider the spawning biomass of species necessary to maintain a

> **Can quotas protect ecosystems?**
>
> Quota fisheries are seen by many fisheries managers as a way to protect the desired species. However quota holders have no incentive to protect other ecosystem components. Indeed the scientific uncertainty of existing stock assessment may require quotas that are so conservative that foregone catches could wipe out economic gains (Walters and Pearse 1996). Other authorities (Anderson 1994; Turner 1997) point to high-grading as an inherent problem of quota systems.

Haggan, N. (2004) Evaluating Future Ecosystems: A Great Step Backward? Pages 109-111 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

desired ecosystem state as 'natural capital', MPAs would be another way to protect such natural capital. This can certainly be valued (Sumaila and Walters 2004, Sumaila *et al.* 2001), but could be protected by laws and regulations designed to protect resources in perpetuity.

Similarly, we might consider a category of 'social and cultural' capital to protect species such as eulachons and whatever amount of other species are necessary to maintain the culture and existence of First Nations (see Lucas 2004, this volume), and indeed aspects of the lifestyle of other maritime communities. Brody (1988) showed that subsistence hunting by interior British Columbia tribes had significant monetary value by quantifying the cost of equivalent foodstuffs and the value of furs, handcrafts and guiding. Nothing in Brody's work suggests that the tribes would have accepted money in lieu of these traditional activities (see Sumaila 2004, this volume).

FISHING RESTORED ECOSYSTEMS: KEEPING THE OPTIONS OPEN

A second problem arose as a result of using prices and costs from today's fisheries to value past ecosystem states. Hence, we drag existing fisheries structure back with us, ending up with 18 fisheries (16 existing and 2 new ones). This effectively perpetuates today's fleet structure and high degree of specialization where billions of dollars worth of vessels (to say nothing of license values) lie idle for most of the year. It also perpetuates existing divisions, forcing people to defend existing gear types instead of putting their minds to a fresh approach. The unfortunate example picked by the team for the December Prince Rupert workshop (Power, 2003, Power *et al.* 2004, this volume) simply illustrates the problem of forcing people to defend an existing structure rather than having the freedom to design new fisheries (or re-establish ancient methods such as selective trap and weir fisheries) in their home waters. An unfortunate consequence of the valuation approach *as applied* is to negate the opportunity provided by *Back to the Future* to take a new look at how to harvest restored systems.

A better question might be: if we could restore the abundance and diversity of the 1750s ecosystem, how would we harvest it – forgetting that we're 'salmon scientists' or 'halibut scientists' or gillnetters or trawlers or herring or halibut fishermen? Might we not want to consider more local, multi-species fisheries with multi-purpose vessels, where fisheries would be a year-round activity.

What about a form of area licensing that makes sense in terms of the ecosystem and the human communities, rather than an arbitrary line on a map? Such a system would 'vest' the interest in the resource in First Nations and other stable communities that have a long-term interest in maintaining productivity. This is important, as ownership by large corporations, or what Ommer (2000) characterizes as 'footloose' capital runs a real risk that large corporations would see economic sense in catching the last fish and investing the proceeds in ventures that will provide their shareholders with a higher rate of return.

We might also want to concentrate on methods that maximize value rather than volume, for instance, a 6.5 oz can of sockeye branded as 'Copper River Red' sells for $US 8.50 (www.copperriverred.com and see Simeone 2004, this volume), or, the value of live rockfish for the restaurant trade.

There is clear agreement on the need for flexibility in designing sustainable and responsible fisheries of the future. The criteria suggested by the CUS BTF team provide a start (see Pitcher 2004, this volume). But the challenge for *Back to the Future* is to find ways to improve and facilitate this with the participation of local fishing communities.

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Incorporating First Nations' Values into Fisheries Management: A Proposal for Discussion

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An attempt to include First Nations values into fisheries management is not an easy task. This is because First Nations values with respect to fisheries are very many and diverse, the values accrue in both direct and indirect ways; in tangible and intangible ways; in monetary terms and non-monetary terms; values can accrue to both the current and future generations (see papers by Lucas and by Simeone 2004, this volume). As daunting as the task of this paper is, we nevertheless have to devise methods and approaches that would enable us incorporate First Nations values into Canada's fisheries management. This is necessary to help us manage Canada's fishery resources in most equitable way.

There are two possible ways of approaching the problem of valuing and incorporating First Nations values into Canadian fisheries management. First, one may attempt to determine all First Nations values from marine ecosystems in dollar terms. Second, one can instead aim to incorporate First Nations values from marine ecosystems without valuing them in monetary terms. Both of these approaches have their advantages and disadvantages. The economic literature is full of methods to help implement the former approach. This implies that there are ample if not adequate tools available for determining values, both monetary and non-monetary from marine ecosystems. This can be counted as an advantage of this approach. A disadvantage of this approach is that First Nations do not believe their values can be adequately captured in monetary terms, and so the approach lacks credibility among its most important constituency (see Haggan 2004, this volume).

The advantage of the latter approach is precisely the fact that it has credibility among First Nations people, because it does not seek to put monetary values on the benefits they derive from marine ecosystem. A disadvantage of this approach is that it is not entrenched in the literature, so new approaches need to be developed to help implement it. The task of this note is to propose a modeling approach that can help us, technically, to include First Nations values into Canadian fisheries management.

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Proposal: How to Incorporate Values Without Valuing in Dollar Terms

The proposed approach is based on a simple idea, that is, it imposes First Nations requirements (however, it may be determined) as an extra constraint within the stock dynamics of a single species model, or within a full-fledged ecosystem model. In this way First Nations values from fishery resources are incorporated before any commercial fishing is allowed. This approach actually provides a technical means by which to implement what has been Canadian law for many years – the Canadian Fisheries Act specifically stipulates that once the requirements for conserving Canada's fisheries resources are met, the next priority for Canadian fisheries management is to meet the requirements of First Nations before that of the commercial fishing sector.

To see how this may be incorporated in the stock dynamics of a fish stock, consider the equation below:

$$n_{0,t} = R_t \ ,$$

$$n_{a,t} = (sn_{a-1,t-1} - \psi n_{a,t}) - h_{a,t}, \qquad \text{for } 0 < a < A,$$

$$n_{A,t} = [s(n_{A-1,t-1} + n_{A,t-1}) - \psi n_{A,t}] - h_{A,t}, \qquad n_{a,0} \quad \textit{given}$$

where R_t is the recruitment of age 0 fish to the habitat in period t $(t=1..T)$; $n_{a,t}$ is the stock size of age a $(a=0..A)$ fish in period t; the parameter s is the age independent natural survival probability of cod; ψ is the fraction of the stock of a given age a fish in period t that is reserved for the First Nations; $n_{a,0}$ denotes the initial number of age a fish; and $h_{a,t}$ is the total harvest function for the commercial sector of a given age group in a given year.

Depending on the objective of fisheries management, an objective function with the

Table 1. Results from the hypothetical model. For further detail, see text.

	Scenario 1	**Scenario 2**
Harvest 1 (1000t)	177 ($131 million)	124 ($46 million)
Harvest 2 (1000t)	196 ($307 million	141 ($156 million)
First Nations (1000t)	235	350
Biomass (1000t)	1210	809

above stock constraint can be computed and/or simulated to determine the appropriate allocation of the harvestable biomass to the commercial sector under the constraint that the allocation to First Nations is met.

A simple hypothetical example was simulated for a hypothetical single species fishery with three parties (agents or players) that exploit the fish. The three groups are First Nations fishers and two groups of commercial fishers, each with common interests. The stock dynamics of the fish are represented by the above equation.

It is assumed that the management objectives for this fishery are assumed to be twofold. First, allocate a portion of the harvestable biomass to the group of First Nations fishers. Second, allocate the remaining harvestable biomass to the two commercial fishers groups such that the sum of discounted profits they make is maximized. Using assumed biological and economic data, this hypothetical model is run using the software package *Powersim*. The outcome of the simulation is presented in Table 1 for two scenarios of quota allocated to the First Nations group – scenario 1: an average annual allocation of 235,000 tonnes, and scenario 3: an annual allocation of 350,000 tonnes. Table 1 shows the amount of harvest (discounted profit) the commercial groups make annually under the two scenarios. The table also reports the standing biomass under the two scenarios.

Since the numbers are derived from a hypothetical model no practical meaning should be ascribed to them – the exercise is meant only to illustrate how the proposed method may be implemented. It is worth mentioning that this approach can easily be implemented in multispecies and ecosystem models. In particular, it should be straightforward to incorporate this into *Ecopath* with *Ecosim*.

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ABORIGINAL VALUES

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Thank you. My name is Kla-kisht-ke-is, and I am from what you call the Hesquiat Nation. Within Hesquiat there are nine major groups that make up the tribe. Most tribes in British Columbia are made up like that. As you go up north, the tribes are divided into four clan-type arrangements. My area on the West Coast of Vancouver Island is an important part. It faces the Pacific Ocean.

I want to start off by saying that at one point in our life, River's Inlet was a very major part of the activity of our tribe. Many of the coastal tribes ended up in River's Inlet. The man that taught me a lot, Alec Games, he wrote every day about what he saw. He became a packer. He was packing fish in River's Inlet. It was there that many First Nations got to know each other. They exchanged many songs that are still sung today.

I want to talk about how we see things. If you are in Nuu-chah-nulth territory, the first thing you will hear is all of the tribes and chiefs saying, "everything is one for us". The second thing you will hear is about us as individuals: "all is one for us". Why do we talk that way? It is because of our understanding of the way things are. Our forefathers told us that one of the most important elements in life is rain. It plays a vital role in our territory in terms of the huge rivers and lakes that flow into the ocean. It is the belief of our ancestors that the mountains, the different variety of trees, and the grass and herbal medicines all contribute to the health of the ocean and the banks and food chain that makes up our territory. That is an understanding for us. So people say the centre of our life lies in this ocean. This is where all of our health comes from - all the species you heard about here and how we harvested them.

As a young child growing up in Hesquiat, I was there until I was five years old. Everyone in our tribe had a canoe or two or three. There were different sizes meant for different kinds of weather. Some were only for fishing - there were huge canoes for traveling and others were for whaling. We had different kinds of canoes. One was 8 feet long and it was just for me. We spent a lot of time in the ocean. It was an important part of the entertainment. My father and grandfather knew when the cod fish were spawning, and after every storm we went walking on the beach. I knew what I was going to find because we were going to find codfish roe. That was important for the family. It was a habit for me to do after every storm. The other thing that my father used to say is that when tides are extremely low, he knew where to go for octopus. So from an early age, I knew how to find it and how to grab and kill it instantly. That was a natural diet for me.

Kla-kisht-ke-is, Chief Simon Lucas, from the Hesquiat Nation, Vancouver Island, was awarded an Honorary Doctorate from the University of British Columbia in 2002, and is an Adjunct Professor in the Fisheries Centre, UBC, where he has lectured on Traditional Knowledge and traditional ecosystem management. *Photo: Martin Dee, Telestudios, Vancouver.*

We had huge mussels. One of the things that happened every night is that a guy whose nickname was White Man, one of the things he always did was take mussels in a huge pot. Everyone would go there to feast on mussels every night. The next thing I knew I was living on a place called Addison. That was where I understood my dad's activities. It was there that I went to the ocean, and understood that he always knew where to go for fish like rockfish and cod. In

Lucas, S. (2004) Aboriginal Values. Pages 114–116 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

my young days, the cod was huge. He knew the migration routes of different stocks of the river.

Also important to understand in terms of value is that the ocean is extremely valuable to our people. In Nuu-chah-nulth where I come from, we do worship that has a lot to do with self-discipline and thanking and conversing with the Creator every day. I knew where to go in the river system. It is still being done there today. One of the rules about it is that you are not to watch anyone else do their worship. That is the law we have. You are not to watch because it is private. The other part of it was to dive into the ocean every day, and it deals with respect and cleanliness. I used hear the term "dirty Indians" when I went to school. I do not understand this because we swim a lot. Hemlock bark turns a little soapy and we used it for the preparation for the hunt of whales.

Sperm whales were hunted for their richness in oil. The ceremony was a one-year affair. You had to have abstinence. You had to be away from your wife and talk to the Creator every day. One of the things that came out of it was self-discipline so there was no glory or dominance over the whale. You are getting it for your grandchildren so they will be healthy, so you ask the Creator that you do not go above your values. That valuable tradition almost got lost when we went into the residential schools. We are lucky that some of our people went underground so that the values of the people were kept. We have people in our tribe who never spoke English and never went to school. There was a guy named Martin John that never spoke English. My grandfather, he could speak English well, but he lived off the resources all his life. Do you know how he died? He died from the common cold when he was 90. That was the only sickness he had. He had perfect teeth and all his hair.

Our values included what we were going to be. We had no fridges and no stores in my community. So I knew everyday there was something new with my dad. If we wanted fresh clams we would have to walk a mile and a half, two miles to get them. My people knew the value of eelgrass. In Hesquiat Harbor, there used to be a massive spawning area there. We had a lot of problems with crab fishermen and long-liners. All they do is apply to the Department of Fisheries and Oceans for a license. There is no education process today about the values that make up that territory when that person goes for a license. There is nothing. All they do is buy a license.

When they first did gillnetting of herring, we went to one of the old chiefs, Felix Michael, and took him to the beach on the first day of the herring fishery. We wanted to see how he was going to react. There were hundreds of nets in his territory that has fed his people for a thousand years. He asked, "What are they doing? Don't they know that the herring are going to spawn and we are going to live off them?" When they go for a license, there is no understanding of value. In that place, Queen's Cove, we used to go to the Chief's territory and see him because behind the reserve was a huge pool, a mile long and a metre deep. There was so much herring there when I was young that we would just take a bucket and scoop them up. That is what he always saw. When that old man died, they took so much herring out that the herring stopped going there.

There is an area in Nuu-chah-nulth territory where three tribes use the banks. What the name of the bank refers to is that there was so much halibut in that bank that every evening the halibut came out of the water to flap their tails in the water. There was so much herring and everything else there. The foreign fishing fleet thought they would never destroy it, but they did. La Perouse Bank became extinct. There was a time you could travel on that bank which was 27 miles from Ucluelet. What happened to that area? Unfortunately our people's intelligence was not well regarded in those days. We have inlets that relate to that area because we know where the fish go.

I lived in Hot Springs Cove. Once in a while the halibut come right close there so we know where they go. There was a time when I went from Hot Springs to a reef where we could get cod and different kinds of snappers. We cannot do that anymore. What they did not realize when they invented drag technology is that they could catch fish in deep water. Technology is a very dangerous weapon to fish. I know because I was in the commercial fishery. I learned the traditional way of fishing, which is traveling along the coast, but when the fishery on sockeye became heavy, people started to phone San Francisco to know what the water temperature in British Columbia will be. The migrating salmon stocks tend to bite at 58 degrees Fahrenheit. When that was found out, they did not have to take their time looking for stocks. They knew where to go immediately.

There was an archaeological dig several years ago. There is an assumption by scientists that if something goes a little wrong, it is terrible. In Addison, they found bluefin tuna in an archeological dig. The people say that our temperature used to change. We had bluefin right in Zeballos. Another tribe said that there were bluefin there. The scientists believe that now, but it would have been nice if they had talked to the First Nations beforehand to see what went on in their territories.

I am seeing erosion of the values that we had. Our elders believe that the herring stock was one of the most important stocks to the ocean. It fertilized the bottom and fed all of the different species that went through our part of the world, like rockfish. So if I had herring, I also had fish that ate herring. Our people were involved in the fishery even though we understood that something was going to go wrong. Fortunately, the Department of Fisheries and Oceans supported our argument in Hesquiat. We wanted no-take on herring in Hesquiat Harbor. We did not need a Marine Protected Area. It is the common mind. We are the ones who understand what is going on. Creating a Marine Protected Area is good, but who is going to enforce it? Who is going to watch it? In our system, I have an oceanfront. In the days of old, like in the 1870s or 1880s, it was still exercised. No one could fish in the area that belonged to me, especially those from other tribes, but people from my own tribe could. Then we were faced with having to be economically competitive in this world so we started to harvest everything we could without conscience.

The other thing that is important in terms of value is what our people are now talking about, which is how much we have changed since Father Perbont came. We did not know he would have so much impact on us. My tribe bought flour there. The ladies were excited about the sacks. They dumped the flour and kept the sacks. They did the same with potatoes - they dumped it right there on the seaweed. After they did that, our people said that there were huge potatoes that grew right on the shoreline. In terms of what has happened to us since then - and it is important for you to know why values are important - our people are leading in every sickness in British Columbia. We went from eating fresh food to eating canned meat every day. This happened over a very short period of time, 150 years compared to the ten to fifteen thousand years that we have been eating fresh seafood. In an archaeological dig that went back 5000 years, they discovered that nothing had changed over the years. All the skulls still had their teeth. The only thing they found was a trace of arthritis. One guy got a hold of our blood under the pretence of studying arthritis, but we are getting the blood back now. But I do not want to give you the impression that what you are doing is not valued.

The leadership is saying that we value technology but we want to combine it with the traditional values. When you look at me and ask where I come from, I come from the West Coast of Vancouver Island. There are lots of things that bother me there now.

We used to be the dominant species over the things that moved in Nuu-chah-nulth. Now there is another dominant species: sea otters. Because of them, there are no more clams and no more urchins. When they replanted sea otters, they did not ask us how to control them. We have decided to harvest the sea otters, but we have to do it in a humane way. There is a loss of sea otters and sea lions around the world, but in our territory there are too many of them. There are problems with people who think differently but who do not live there. We are having problems with the animal rights people who say sea otters have a right to live. Well, we have a right to live too. We do not want people to forget that there is a human aspect to whatever decision is made. We want to be part and parcel of the decisions about our home.

Nuu-chah-nulth is setting a precedent. For 5 years we have discussed what we can do protect the resources in our territory. We had chiefs who realized we could not do it alone, so we got some non-natives involved. We respect their values. I think that we have some ways to go. We went from riding in canoes to fishing in seine boats. We know what happened between the canoe and seine boat. I hope I have given you some information on why values are so important to us.

The Editor did not wish to disrupt Chief Lucas' narrative with citations, but readers may be interested in reading more about some of the topics raised in the following papers in this volume.

Bluefin Tuna: Orchard, T.J. and Mackie, Q. (2004) Environmental Archaeology: Principles and Case Studies. Pages 64–73 .

Sea otters: Pitcher, T.J. (2004) The problem of extinctions. Pages 21–28.

Sustainable gear types: Pitcher, T.J. (2004) Why we have to open the lost valley: criteria and simulations for sustainable fisheries. Pages 78–86.

Traditonal knowledge and culture: Simeone, W. (2004) How traditional knowledge can contribute to environmental research and resource management. Pages 74–77.

Values: Haggan, N. (2004) Evaluating Future Ecosystems: A Great Step Backward? Pages 109-111..

Values: Sumaila, U.R. (2004) Incorporating First Nations values into fisheries management: A proposal for discussion. Pages 112–113.

How We Carried Out The Back-to-the-Future Community Interviews

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Abstract

The Back to the Future team interviewed forty-eight community members from Prince Rupert and Haida Gwaii, British Columbia in 2001 and 2002. Commercial, aboriginal and recreational fishers contributed, also processors and others who are familiar with the marine habitat of northern British Columbia. The local ecological knowledge was recorded in a Microsoft Access database, including interviewee demographic information, fishing experience and extensive biological information on 129 marine species (mammals, birds, fish and invertebrates). The relative change in abundance perceived by the fishers is of special importance in 'Back to the Future' methodology. Respondents also answered a *Rapfish* questionnaire, in which they judged the relative sustainability of their primary fishery in ecological, economic, social, technological and ethical fields.

Introduction

The Back-to-the-Future (BTF) team from the UBC Fisheries Centre interviewed forty-eight community members from the Prince Rupert region and Haida Gwaii, BC. Thirty-four interviews were conducted at the Crest Hotel in Prince Rupert during July 2001; nine were at the Highliner Inn in December 2001; and a research associate conducted five more interviews on Haida Gwaii in early 2002 (see Ainsworth 2002).

Interviewees represent a broad cross-section of commercial, recreational and aboriginal fishers as well as processors and others who are familiar with the marine ecosystem of Hecate Strait, Dixon Entrance and Queen Charlotte Sound (DFO areas 1-10). As the local ecological knowledge (LEK) gained from these meetings was to be used in improving detailed computer models of the region, we did not select participants randomly. Instead, we sought the community members most knowledgeable about the system, relying initially on personal recommendations from partners and colleagues in the region, and then on referrals from other interviewees.

Participants were told about the nature of the Back to the Future project and a meeting time was arranged by telephone. We described how we were gathering LEK to be used in constructing, verifying and fine-tuning computer ecosystem models. In the case of our first Prince Rupert trip, we indicated how the models would be used to manufacture gaming scenarios, representing an optimal profile of exploitation that will maximize benefit according to various experimental policy objectives. The improved models and example scenarios were presented to community members during our December trip. At that workshop, *Lost Valley* policy exploration took centre stage, (Pitcher 2004), but some additional interviews were conducted. The contents and outcomes of the December workshop are summarized in Pitcher *et al. (*2002) and achievements discussed in Power *et al.* (2004).

Two or more researchers conducted each interview. Participants were told that they could decline to answer any question, or discontinue the interview at any time. With their permission, we made an audio recording. Respondents were assured that their information would be processed to preserve anonymity. They signed a permission slip allowing us to use the information in our described capacity, in accordance with UBC Ethical Committee requirements. Finally, they signified whether they wished to be credited with their contribution or remain anonymous. Interviewees are acknowledged in Ainsworth (2004b).

Methods

Section 1: Back to the Future

Appendix A shows part one of the interview form, where demographic information was recorded, such as age, occupation, number of generations in the area, etc. Fishing experience was documented, including where and when they had fished in each sector, what type of gear was used, whether they owned their boat and where they learned to fish.

We showed the interviewees flashcards with images of 129 mammals, birds, fish and invertebrates (listed in Appendix B). Flashcards can be viewed on our website at www.fisheries.ubc.ca/projects/btf/. On the back of each flashcard was a physical description of the animal and other identifying information (e.g.,

Ainsworth, C. (2004) How we carried out 'Back-to-the-Future' Community Interviews. Pages 117–125 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

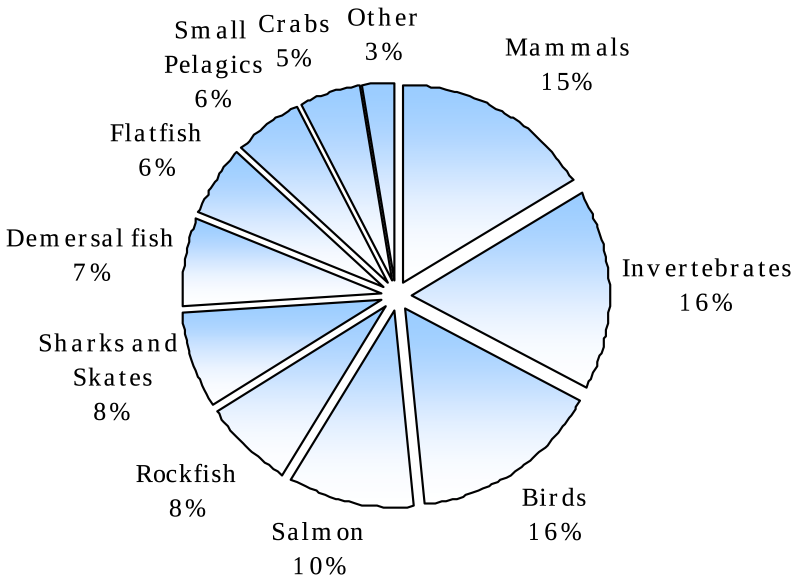

Figure 1. LEK comments from the Prince Rupert community interviews, breakdown by taxonomic group.

range, habitat, habits). With a nautical chart on hand, we went through the species list, asking respondents the following questions about each creature.

1. Is the animal observed locally? Where is it observed on the map? During what season or month?
2. Has the abundance increased or decreased during their career, and by how much. (i.e. increased <1X, 1-3X, 3-10X, >10X, or decreased <50%, 10-50%, >10%).
3. What other common names is the animal known by?
4. What gear types are used to catch this animal?
5. Where did you learn this information?

Respondents were free to provide answers for as many of the listed species as they wished, and in as much detail as they wished.

Section 2: *Rapfish*

The second part of the interview, asked of fishers only, consisted of the *Rapfish* questionnaire in Appendix C. We asked fishers to rank the sustainability of their primary fishery in 8-10 attributes in each of 5 fields: ecological, economic, social, technological and ethical. The *Rapfish* analysis, short for Rapid Appraisal of Fisheries, uses multi-dimensional scaling to ordinate the fisheries' scores into an overall measure of sustainability for each field. The relative sustainability of each fishery can then be compared and other differences identified. Results from the *Rapfish* analysis and a more complete description of the technique appears in Ainsworth (2004a).

RESULTS

Section 1: Back to the Future

In total, 2145 comments were received; 57% concerned mammals, invertebrates, birds and salmon. Figure 1 shows the breakdown of comments.

The anecdotal comments from Section 1 (Back to the Future) were reduced to votes of 'increase', 'decrease' and 'stable' for use in the models. Ainsworth (2004b) describes how the interview information was processed and incorporated into the ecosystem models (Ainsworth *et al.*, 2002).

Verbatim comments were entered into a Microsoft Access database, along with demographic and career information. Personally identifying information was not included; respondents were given only an interview number. The database is cross-referenced by the following fields: sector, gear type, target species, fishing years, locales and number of generations in the fishery. Erfan (2004) provides a more complete description of the database, which also includes historical records. One can search the database by species on our BUS-BTF website: http://fisheries.ubc.ca/projects/btf/

Section 2: *Rapfish*

A *Rapfish* analysis, based on the July and December Prince Rupert interviews, was conducted by Ainsworth (2004). Power (2003) analyzed the ethical component of the *Rapfish* forms from Prince Rupert and Haida Gwaii respondents.

CONCLUSIONS

Ainsworth (2004a, 2004b), Ainsworth *et al.* (2002) and Power (2003) have so far used only a fraction of the LEK information collected for this report. There remains detailed socioeconomic and biological data that can be applied to future BTF analyses, including unique and valuable spatial information. Pending approval from the UBC Ethics Committee, the processed LEK records will be offered online to other researchers. Hopefully, also available through the BTF website will be online interview forms to allow invitees to contribute directly to a growing knowledge base.

As projects evolving at the Fisheries Centre call on LEK information to supplement scientific data, the infrastructure we have assembled in this report will become an important tool. Besides consolidating and preserving vital community knowledge, we may establish criteria by which we can assess the quality of our own data sources - challenging them with an independent authority and identifying where fishers' perceptions depart from accepted scientific data.

REFERENCES

Ainsworth, C. (2002) What the Interviews have Shown. Page 35 in Pitcher, T.J., Power, M.D. and Wood, L. (eds) (2002) Restoring the past to salvage the future: report on a community participation workshop in Prince Rupert, BC. Fisheries Centre Research Reports 10(7): 56 pp.

Ainsworth, C. (2004a) *Rapfish* Analysis of 10 Northern BC Fisheries Based on Fishers' Perception. Fisheries Centre Research Reports (*results volume*).

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Pitcher, T.J., Power, M. and Wood, L. (eds) (2002) Restoring the Past to Salvage the Future: Report on a Community Participation Workshop in Prince Rupert, BC. Fisheries Centre Research Reports 10(7): 55 pp.

Power, M. (2003) Fishing for Justice: A Groundwork for Ethical Fisheries Policy in Canada. PhD Thesis. Resource Management and Environmental Studies. University of British Columbia, Canada.

Power, M.D., Haggan, N. and Pitcher, T.J. (2004) The Community Workshop: how we did it and what we learned from the results. Pages 125–128 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

For discussion after the oral presentation of this paper, see page 146.

Appendix A – Personal information

Interview Schedule # 1

Subject ID #
Chart #
Date:
Location:
Interviewers:

Fishing Experience

Check all that apply:

- ☐ Commercial fishery
- ☐ Recreational fishery
- ☐ First Nation (type?) _______________
- ☐ Boat owner past or present?
- ☐ DFO
- ☐ Processor
- ☐ Conservationist
- ☐ Other (explain)

Year when started fishing: Age range: (<30) (30-50) (50+)

Last Season Fished:

Number of years fished? (0-5) (5-10) (10-20) (20-30) (30-40) (40+)

Number of generations family has been in the fishery:

Always in this community/region?

Sectors fished?

Offshore (Hecate Strait, Dixon Entrance, Queen Charlotte Sound, West Coast Haida Gwaii more than 1 km from shore)

	Crew years	Skipper years	Primary Species
Trawl			
Trap			
Longline			
Troll			
Other			

Inshore (Coastal inlets)

	Crew years	Skipper years	Primary Species
Seine			
Gillnet			
Troll			
Trawl			
Hook and line (longline)			
Trap			
Dive			
Other			

Who taught you how to fish?

APPENDIX B – SPECIES LIST

Mammals

1 Sea otters
Enhydra lutra
2 River otter
Lutra canadensis
3 Dall's porpoise
Phocoenoides dalli
4 Harbour porpoise
Phocoena phocoena
5 Pacific white sided dolphin
Lagenorhynchus obliquidens
6 Northern right whale dolphins
Lissodelphis borealis
7 Killer whales
Orcinus orca
8 Sperm whale
Physeter macrocephalus
9 Northern fur seals
Callorhinus ursinus
10 Northern elephant seals
Mirounga angustirostris
11 Steller sea lions
Eumetopias jubatus
12 Harbour seals
Phoca vitulina
13 California sea lions
Zalophus californianus

Birds

14 Gulls
Family: Laridae
15 Cassin's auklet
Ptychoramphus aleuticus
16 Rhinocerous auklet
Cerorhinca monocerata
17 Tuffed puffin
Fratercula corniculata
18 Common murrelet
Uria aalge
19 Marbled murrelet
Brachyramphus marmoratus
20 Pigeon guillemot
Cepphus columba
21 Merganser
Mergus serrator
22 Pelagic cormorants
Phalacrocorax pelagicus
23 Northern fulmar
Fulmarus glacialis
24 Sooty shearwater
Puffinus griseus
25 Double-crested cormorant
Phalacrocorax auritus
26 Common loon
Gavia immer
27 Grebes
Family Podicipedidae
28 Lesser snow goose
Anser caerulescens
29 Bald eagle
Haliaeetus leucocephalus

Salmonids

30 Sockeye salmon
Oncorhynchus nerka
31 Chum salmon
Oncorhynchus keta
32 Pink salmon
Oncorhynchus gorbuscha
33 Coho salmon
Oncorhynchus kisutch
34 Chinook salmon
Oncorhynchus tshawytscha
35 Steelhead trout
Oncorhynchus mykiss
36 Atlantic salmon
Salmo salar

Forage fish

37 Sandlance
Ammodytes hexapterus
38 Pacific herring
Clupea harengus pallasi
39 Rainbow smelt
Osmerus mordax
40 Longfin smelt
Spirinchus thaleichthys
41 Surf smelt
Hypomesus pretiosus
42 Pile perch
Rhacochilus vacca
43 Shiner perch
Cymatogaster aggregata

Flatfish

44 Halibut
Hippoglossus stenolepis
45 Arrowtooth flounder
Atheresthes stomias
46 Rock sole
Lepidopsetta bilineata
47 Dover sole
Microstomus pacificus
48 English sole
Parophrys vetula
49 Petrale sole
Eopsetta jordani
50 Rex sole
Glyptocephalus zachirus
51 Butter sole
Isopsetta isolepis
52 Yellowfin sole
Limanda aspera
53 Starry flounder
Platichthys stellatus
54 Curlfin sole
Pleuronichthys decurrens
55 Pacific Sandab
Citharichthys sordidus
56 Sand sole
Psettichthys melanostictus

Rockfish

57 China rockfish
Sebastes nebulosus
58 Copper rockfish
Sebastes caurinus
59 Quillback rockfish
Sebastes maliger
60 Pygmy rockfish
Sebastes wilsoni
61 Tiger rockfish
Sebastes nigrocinctus
62 Black rockfish
Sebastes melanops
63 Puget Sound rockfish
Sebastes emphaeus
64 Silvergray rockfish
Sebastes brevispinis
65 Yellowmouth rockfish
Sebastes reedi
66 Canary (Orange) rockfish
Sebastes pinniger
67 Chilipepper
Sebastes goodei
68 Redstripe rockfish
Sebastes proriger
69 Bocaccio
Sebastes paucispinis
70 Sharpchin rockfish

Sebastes zacentrus
71 Stripetail rockfish
Sebastes saxicola
72 Widow rockfish
Sebastes entomelas
73 Rosethorn rockfish
Sebastes helvomaculatus
74 Yelloweye rockfish
Sebastes ruberrimus
75 Yellowtail rockfish
Sebastes flavidus
76 Blue rockfish
Sebastes mystinus
77 Harlequin rockfish
Sebastes variegatus
78 Darkblotched rockfish
Sebastes crameri
79 Northern rockfish
Sebastes polyspinis
80 Splitnose rockfish
Sebastes diploproa
81 Pacific Ocean perch
Sebastes alutus
82 Rougheye rockfish
Sebastes aleutianus
83 Shortraker rockfish
Sebastes borealis
84 Shortspine Thornyhead
Sebastolobus alascanus
85 Longspine Thornyhead
Sebastolobus altivelis

Bottom fish

86 Pacific cod
Gadus macrocephalus
87 Sablefish
Anoplopoma fimbria
88 Ratfish
Hydrolagus colliei
89 Lingcod
Ophiodon elongatus
90 Sculpin
Myoxocephalus spp.
91 Eelpout
Bothrocara spp.
92 Kelp poacher
Agonomalus mozinoi

Pelagic fish

93 Eulachon
Thaleichthys pacificus
94 Pollock
Theragra chalcogramma

Sharks

95 Spiny dogfish
Squalus acanthias
96 Large sharks
Galeorhinus spp.

Skates and Rays

97 Deepsea skate
Bathyraja abyssicola
98 Longnose skate
Raja rhina
99 Starry skate
Raja stellulata

100 Pacific electric ray
Torpedo californica

Squids

101 Opal squid
Loligo opalescens
102 Nail squid
Onychoteuthis borealijaponica
103 Flying squid
Ommastrephes bartramii
104 Red squid
Berryteuthis magister
105 Giant squid
Dosidicus gigas

Crabs

106 Dungeness crab
Cancer magister
107 Red crab
Cancer productus
108 Snow crab
Chionoectes spp.
109 King crab
Lithodes spp.
110 Hermit crab
Pagurus spp.
111 European green crab
Carcinus maenas

Shrimp

112 Sidestripe shrimp
Pandalopsis dispar
113 Pink shrimp
Pandalus borealis
114 Humpy shrimp
Pandalus goniurus
115 Pacific ocean shrimp
Pandalus jordani

Bivalves

116 Abalone
Haliotis katschatkana
117 Butter clam
Saxidomus gigantea
118 Horse clam
Tresus capax
119 Blue mussel
Mytilus edulis
120 Pacific oyster
Crassostrea gigas
121 Spiny scallop
Chlamys hastata
122 Rock scallop
Crassadoma gigantea
123 Pink scallop
Crassadoma rubida
124 Pacific geoduck
Panopea generosa

Other invertebrates

125 Red sea urchin
Strongylocentrotus fanciscanus
126 Green sea urchin
Strongylocentrotus droebachiensis
127 Purple sea urchin
Strongylocentrotus purpuratus
128 California sea cucumber
Parastichopus californicus
129 Giant Pacific octopus
Octopus dofleini

APPENDIX C – *RAPFISH*

Respondent #:

Fishery:
Species: *Gear Type:*
Area:

Ecological analysis
Ecological attributes reflect how the fishery impacts sustainability in terms of the ecology of the exploited fish and their ecosystem. Fisheries management practices that increase the risk of overexploitation, quickly change trophic levels etc. are scored towards the 'bad' end of the scale while fisheries management practices that protect the species or ecosystem score towards the 'good' end of the scale.

1. What is the exploitation status of this fishery?**
   a. under-exploited
   b. fully-exploited
   c. heavily exploited
   d. over-exploited
   e. almost completely collapsed
2. What is the recruitment variability (COV) of this fishery? **
   a. low (less than 40%)
   b. medium (40-100%)
   c. high (greater than 100%)
3. Is the trophic level of the catch in this fisheries sector of the ecosystem decreasing? (Indirect information, such as the average size of the fish caught decreasing, can help to score this attribute.) **
   a. no
   b. somewhat or slowly
   c. rapidly
4. How many legal jurisdictions (including international waters) does this species move through during its life?
   a. 1 to 2
   b. 3 to 4
   c. more than 4
5. Is there evidence of geographic range reduction for this species? Is the animal found in few places now than previously?
   a. no
   b. a little
   c. a lot or quickly
   d. almost complete
6. Has the average size of the fish being caught changed in the past 5 years?
   a. no
   b. yes, a gradual change
   c. yes, a rapid large change
7. Are many of the fish caught before they reach maturity?
   a. none
   b. some (more than 30%)
   c. lots (more than 60%)
8. How much of the catch is (discarded) bycatch? (as percentage of target catch) (If the target catch + retained by-catch is a low percentage of the catch, then discarded by-catch is high (i.e. bad).)
   a. low (less than 10%)
   b. medium (10-40%)
   c. high (more than 40%)
9. How many species are caught (target and by-catch)?
   a. low (10 or fewer species)
   b. medium (10 to 100)
   c. high (more than 100 species)
10. What is the primary production of the area? (in g C/m^2/year) **
   a. low (0 to 50)
   b. medium (50-90)
   c. high (90 to 160)
   d. very high (more than 160)

** For these attributes, in most cases data will come from other sources such as FAO website, FishBase, etc., rather than through interviews. Document other sources.

Economic analysis:

Economic attributes reflect how fisheries management practices impact the economic sustainability of the fishery and related human communities, as ultimately predicted on ecological sustainability. Therefore in a *Rapfish* analysis scores at 'good' end of the scale of an attribute reflect economic sustainability and are not a risk to the fishery or ecosystem, whereas the 'bad' end of the scale may be a risk. A fishery where the average wage of a fisher is above the average national wage scores towards the 'good' end because there is an incentive or likelihood that fishers will manage for sustainability to ensure that their wages remain high or improve.

1. Is this fishery profitable? How profitable? (Include subsidies)
   a. Highly profitable
   b. Marginally profitable
   c. Break even
   d. Losing money
   e. large losses
2. How important is this fishery in the economy, in comparison to other industries or sectors (of the area in question)?
   a. low
   b. medium
   c. high
3. Do fishers make more or less than the average person?
   a. Much less
   b. Less
   c. About the same
   d. More
   e. Much more
4. Is entry to this fishery limited (formally or informally)?
   a. Open access
   b. Almost no limitation
   c. Very little limitation
   d. Some limitation
   e. Very limited
5. Do participants in this fishery have a marketable right/quota/share?
   a. No
   b. Some
   c. A mix of property rights
   d. Full Individual Transferable Quotas, Community Transferable Quotas, or other property rights
6. In just this fishery, is fishing mainly: (consider only this fishery, not all fishing activities)
   a. Casual
   b. Part-time
   c. Seasonal
   d. Full-time
7. Compared to all other fisheries in the same area as this one, what percentage of employment is in this fishery and related activities (such as processing, selling, etc.)?
   a. Less than 10%
   b. 10-20%
   c. More than 20%
8. Do the profits from this fishery stay locally, or do they go elsewhere? Where?

a. The profit mainly stays here in the local area
b. Profit mainly stays within this country, but not locally
c. Profit mainly leaves the country

9. Where is the market for the fish caught in this fishery?
a. Mainly local or national
b. Mainly national or regional
c. Mainly international

10. Are subsidies provided to support the fishery, and if so how much? (include hidden subsidies, such as unemployment insurance, fuel subsidies, etc)
a. No subsidies
b. Some subsidies
c. Large subsidies
d. The fishery depends on subsidies
e. The fishery would likely not continue without subsidies

Ethical analysis:

Ethical analysis within *Rapfish* is designed to analyse fisheries for five types of justice: creative, productive, ecosystem, restorative, and distributive. Creative justice includes issues such as fair management of the fishery; productive justice and ecosystem justice consider treatment of and behaviour within the fisheries ecosystem; restorative justice covers the repairing of previous damage; distributive justice deals with how the resource is shared. The package of ethical attributes assesses fisheries based on these various ethical concerns, and integrates sustainability on many levels, including ecological and social.

1. Do the people who fish in this fishery live close to the area of the fishery, or do they come from a distance? Have they fished in the fishery for many generations, or are they new to the fishery?
a. Fishers live far away and have only recently begun to fish in this fishery
b. Fishers live far away and have fished in this fishery for some time
c. Fishers live near the fishery and have fished in this fishery for some time
d. Fishers live near the fishery and have fished in this fishery for a long time (several generations)

2. Are there alternatives to the fishery for employment within the community? For example, are there other industries in which people could work rather than in the fishery? (Do not consider processing or other activities which depend on the fishery to survive.)
a. No, there are no alternatives forms of employment in the community
b. There are some alternatives to the fishery
c. There are many choices for employment in the community, beyond the fishery

3. Is entry to the fishery based on traditional or historical access to the fishery?
a. Traditional/historical access to this fishery is not considered at all
b. Traditional/historical access to this fishery is considered
c. This is a traditional indigenous fishery

4. Are fishers included in the management of this fishery?
a. No, not at all
b. Fishers are consulted in management
c. There is co-management in this fishery, with government leading the way
d. There is co-management in this fishery, with the community leading the way
e. There is co-management in this fishery, with all groups being equal

5. Has there been damage to the environment in which the fish live (the fish habitat)? Have there been efforts to correct that damage?
a. There has been much damage to the fish habitat
b. There has been some damage to the fish habitat
c. There is no damage happening now, and there are no attempts to correct damage
d. There have been some efforts at correcting damage to the fish habitat
e. There have been many efforts at correcting damage to the fish habitat

6. Has there been damage to the fisheries ecosystem? For example, have some types of fish disappeared or others appeared because of activities within this fishery? Have there been efforts to correct that damage?
a. There has been much damage to the fisheries ecosystem
b. There has been some damage to the fisheries ecosystem
c. There is no damage happening now, and there are no attempts to correct damage
d. There have been some efforts at correcting damage to the fisheries ecosystem
e. There have been many efforts at correcting damage to the fisheries ecosystem

7. Are there illegal activities within this fishery, such as illegal catches, poaching, or transshipment of catches?
a. No, none
b. Yes, some
c. Yes, lots

8. Is there discarding and/or wasting of fish caught in this fishery?
a. No, none
b. Yes, some
c. Yes, lots

Social analysis:

Social attributes reflect how fisheries management practices impact the sustainability of the society or community associated with that particular fishery, as ultimately predicated on ecological sustainability. In a *Rapfish* analysis the ‘good’ end of the scale of an attribute reflects social sustainability but l0w risk to the fishery or ecosystem, whereas scores at the ‘bad’ end may reflect a risk. Therefore a fishery where fishers can influence fishery regulations scores towards the ‘good’ end of the scale, while a fishery where there is conflict with other fisheries or industries scores towards the ‘bad’ end of the scale.

1. In this fisheries, do fishers work as:
a. Individuals (including as for a commercial company)
b. Families
c. Community groups (such as in a co-operative

2. Has the number of people involved in the fishery over the past 10 years increased? (Including fishing-related activities such as processing.)
a. Not very much or not at all (less than 10%)
b. Yes, a little, by 10% to 20%
c. Yes, a fair amount, by 20% to 30%
d. Yes, quite a lot, by more than 30%

3. How many households in the community are involved in the fishery?
a. Fewer than a third
b. Between one and two thirds
c. More than two thirds

4. How much do people in this fishery know about the fishery resource and its ecosystem and environment?
a. Not very much

b. Some
c. Quite a lot

5. Compared with others in the area, what is the level of education of most people in this fishery?
   a. Below average
   b. About average
   c. Above average
6. Is there conflict between this fishery and other fisheries or industries (such as oil drilling, tourism, etc.)
   a. No conflict
   b. Some conflict
   c. A lot of conflict
7. How much influence do fishers in this fishery have on actual fishery regulations?
   a. None or almost none
   b. Some
   c. A lot
8. In this fishery, what percentage of family income comes from this particular fishery?
   a. Less than half
   b. More than half, but no more than 80%
   c. More than 80%
9. Do family members sell and/or process the fish caught?
   a. No
   b. Yes, but very few relatives participate (1 to 2 people)
   c. Yes, but maybe only 2 relatives participate
   d. Yes, maybe 3 relatives participate
   e. Yes, many relatives participate – four or more

Technological analysis:

Technological attributes capture appropriate technologies that minimize risk to sustainability of the fishery. Therefore when devices are used to improve the catching power these fisheries score towards the 'bad' end, while a fishery that uses technology such as ice to prevent waste or reduce by-catch scores towards the 'good' end of the scale.

1. During a fishing trip in this fishery, how many days would you normally spend at sea, on average?
   a. One day or less
   b. Two to four days
   c. Five to eight days
   d. Eight to ten days
   e. Eleven or more days
2. Are landing sites for this fishery:
   a. Widely dispersed
   b. Somewhat centralised (limited)
   c. Very centralised (limited)
   d. The fishery is conducted by a distant-water fleet that rarely or never lands the catch locally
3. Is the catch processed (for example, gutting, filleting, salting, etc.) at all before being sold?
   a. No, not at all
   b. Yes, but just a little
   c. Yes, there is a lot of processing
4. How much and in what way is the catch handled onboard?
   a. No special handling
   b. Some handling (such as salting or boiling)
   c. Very specialised handling (such as flash freezing or champagne ice)
   d. Live tanks are used
5. Is the gear used in this fishery:
   a. Passive
   b. Active
6. Are there devices, mechanisms, or methods of handling the gear used to increase selectivity?
   a. None or few
   b. Some
   c. Many
7. Are fish attraction devices used in this fishery?
   a. No
   b. Bait is used
   c. Other fish attraction devices are used
8. What is the average length of vessels in this fishery?
   a. Under 5m
   b. Five to 10m
   c. Ten to 15m
   d. 15 to 20m
   e. Bigger than 20m
9. Have fishers altered gear and vessel to increase catching power over past 5 years?
   a. No
   b. Yes, but very little
   c. Yes, a little
   d. Yes, some
   e. Yes, a lot and/or quickly
10. Does the gear used in this fishery result in unwanted side-effects?
   a. No unwanted side-effects
   b. Some unwanted side-effects
   c. Yes, many unwanted side-effects
   d. The fishery is dominated by destructive fishing practices

The Community Workshop: How We Did It, And What We Learned From The Results

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Introduction

The Back-to-the-Future (BTF) approach, approach emphasises the importance of community participation and the need to treat different systems of knowledge with respect (Haggan 2000, Haggan *et al.* 1998, Salas *et al.* 1998). This is consistent with the aims of the *Coasts Under Stress* project (CUS: www.coastsunderstress.ca), of which the current Hecate Strait project is a part. To date, the CUS BTF project has involved people from the northern British Columbia region in two stages: the first Hecate Strait BTF project built models of the present ecosystem and that of 100 years earlier, and was based on one workshop with First Nations, fishers, scientists and other local experts (Haggan and Beattie 1999). Community involvement in the current project started with interviews with fishers, First Nations, conservationists, and others with detailed local knowledge of the fisheries ecosystem (see Ainsworth 2004, this volume), primarily conducted in July 2001, and subsequently through a community workshop.

The community workshop, entitled 'Back to the Future in the Hecate Strait: Restoring the Past to Salvage the Future', was held at Prince Rupert's Highliner Inn, December 4-6, 2001 (Pitcher *et al.* 2002). The aims of the workshop included presenting to the community the work that the Back to the Future team had completed (including what had been done with the information shared with the team during the interview process), and explaining what work was yet to be done. Furthermore, the workshop provided an opportunity for the team and community to engage in discussions about the *Coasts Under Stress* project (Pitcher and Haggan 2002).

Power, M.D., Haggan, N. and Pitcher, T.J. (2004) The Community Workshop: how we did it and what we learned from the results. Pages 126–129 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

The Community Workshop

Preparation

The workshop represented the latest in a series of steps in the Back to the Future process (Pitcher 2004a, 1998). In autumn, 2000, the Back to the Future team conducted science workshops in both British Columbia and Newfoundland[1], during which the input of scientists with species-specific knowledge could be received and further incorporated into the planned *Ecopath* ecosystem models (Pitcher *et al.*, 2002). For the Hecate Strait region, four ecosystem models were constructed, each representing a different time period: 1750, 1900, 1950, and 2000.

In July 2001, six members of the Back to the Future research team travelled to Prince Rupert, British Columbia, and conducted interviews with those who would have, and were willing to share, detailed local environmental knowledge (see Ainsworth, this volume). The information shared during these interviews was added to the historical database constructed by Aftab Erfan (Erfan 2004), and then used to cross-validate and strengthen the existing models.

Ecosim simulations were run based on two fishery fleet structures: the present fleet structure ('Today's Fleet') and today's fleet structure but without draggers and gillnetters ('Team's Choice'). These two simulations, demonstrating the fishing impacts of each fleet structure on each of the four ecosystems, were used during the workshop as a basis of discussion and exploration (Buchary and Sumaila 2002).

Who was there?

In addition to all those interviewed in July, 2001, other community members and representatives of related organisations were invited to attend the December workshop. All interviewees were sent a letter detailing the time, place, and programme of activities of the workshop. Attendees included the Tsimshian Tribal Council (represented by the President Ms. Deborah Jeffrey), the City of Prince Rupert (represented by Councillor Cyril Stephens), fishers from several First Nations, commercial gillnet fishers, draggers, trawl and line fishers, representatives of the World Wildlife

[1] As part of the Fisheries Centre's contribution to the *Coasts Under Stress* project, Back to the Future projects are being conducted in both British Columbia and Newfoundland. (See Pitcher, 2004b, this volume.) This paper will be limited to the British Columbia component.

Fund and the Northwest Maritime Institute and a number of local biologists and researchers. (A full list of participants is given in Pitcher *et al.* 2002)

Rather than costly advertising, the Back to the Future team relied mainly on word-of-mouth to spread notice of the workshop throughout the area, and through the organisations mentioned above.

The first day of the workshop suffered a low attendance, in part due to a snowstorm the day before. Indeed, a majority of the Back to the Future team were late arriving due to inclement weather, and the beginning of the workshop was delayed as a result. Subsequent days witnessed markedly increased attendance, for reasons to be detailed below.

Who was not there?

The workshop was well attended by First Nations and commercial gillnet and trawl fishers. Salmon seine fishers, trawlers and sport fishers were conspicuously absent, leading to the ready choice of scenarios that excluded these fisheries. Other absentees included the Department of Fisheries and Oceans and agencies of the BC government. This was a significant problem because the BTF philosophy is based on including all interests in the ecosystem, including the general public.

What happened?

Day one of the workshop opened with a series of presentations from the Fisheries Centre's Back to the Future team. These presentations included an overview of the approach and methodology of Back to the Future, as well as more detailed presentations on the four *Ecopath* models and the *Ecosim* simulations (of 'Today's Fleet' and 'Team's Choice' fleet structures for each ecosystem) and planned workshop activities.

Throughout the workshop, posters highlighting the team's work lined the perimeter of the meeting room. Miniature (letter-sized) versions of these posters were also distributed to workshop participants. In addition to the formal, structured discussions of the workshop, informal conversations over coffee and shared meals provided opportunities for team members to hear and respond to thoughts and concerns of workshop participants, and contributed to the growing sense of trust between the UBC group and the community members.

Formal small-group discussions occurred mainly on day two of the workshop, when participants were divided into five (self-selected) working groups. Each working group included at least one, and usually two, BTF team members. Four of the five groups were asked to discuss the four potential ecosystems and to develop group a consensus as to which ecosystem was preferred for a rebuilt ecosystem. Furthermore, the four working groups were asked to decide what fishing fleet structure would be desirable in the rebuilt ecosystem; the four scenarios to come out of the working groups would then be simulated by the Back to the Future team and presented before the conclusion of the workshop. By coincidence, each group selected a different ecosystem goal, such that all four modelled ecosystems were represented, and the fleet structures recommended by each group were unique (Power 2002a). The fifth group was tasked with an examination of the four basic *Ecopath* models.

Once each of the four working groups identified their preferences, day two of the workshop closed, and the Back to the Future team set about simulating those preferences using *Ecosim*. Day three of the workshop featured the presentation of the results of those simulations[1], and wrap-up discussion.

In addition to structured workshop activities, members of the Back to the Future team also conducted additional interviews to complement those done during the July visit.

The 'Team's Choice' Controversy

As noted above, day one attendance was somewhat disappointing, but increased markedly on days two and three. The increase may primarily be attributed to what has come to be known as "the Team's Choice controversy" (Power 2002b). One of the two fishing fleet structures modelled in *Ecosim* was based on the actual present fishing fleet, but with a blanket exclusion of all draggers and gillnetters. In labelling this scenario as "Team's Choice", the Back to the Future team inadvertently gave the impression that a decision to exclude them from all possible future fisheries had already been reached. The team explained that this was not the case, but the damage had already been done.

As a result of this miscommunication, on day two, the meeting room was flooded with angry gillnetters and draggers. Clearly, word quickly

[1] A survey, designed to gauge community preferences regarding the rebuilt ecosystem and the structure of the fishery fleet to operate in that rebuilt ecosystem, was also conducted (and the interim results presented) during the workshop. For more information, see Power (2002).

spread throughout Prince Rupert that this group from the UBC Fisheries Centre was recommending the closure of the dragger and gillnet sectors! The second day of the workshop thus began with the irate, suspicious fishers venting their frustration at the Back to the Future team. Eventually we managed to explain that we were harmless academics who had made an honest mistake, not secret agents of government sent to shut them down. Following abject apologies for the inappropriate word selection, the fishers granted our request for a fool's pardon. Many stayed on for the rest of the workshop.

Attendance thus increased quite significantly, and this potentially disastrous mistake on the part of the team had one positive side-effect – a broader representation amongst workshop participants.

However, this incident illustrated the importance of giving full and complete consideration to all aspects of the planning of this sort of activity. The label, "Team's Choice", was unfortunate in that it gave the false and unintended impression that the Fisheries Centre team had already reached a decision. Furthermore, it seemed that community members were genuinely apprehensive that somehow Fisheries and Oceans Canada would act upon such recommendations.

What We Learned

The Prince Rupert meeting was the first time that ecosystem modelling had been used to run scenarios suggested by participants. Recognising the inherent value of community input, particularly as a basic tenet of BTF, it is hoped to be followed by similar workshops in this and other Back to the Future projects, and as such, important lessons were to be learnt.

The most important lesson learnt was the value of planning. Countless hours were spent preparing for the workshop, not only in preparing the models and supporting materials and in extending invitations, but also in determining the overall structure of the workshop and assigning section responsibilities to team members. Clearly, the extensive planning was crucial to the successful functioning of the workshop (notwithstanding Mother Nature's best attempts at preventing the arrival of the team!). However such comprehensive planning is extremely time-consuming, and as a result we were unable to spend enough time on some items.

This was the case with the survey conducted at the workshop; being that the survey was dependent upon the time-hungry models, insufficient time remained for testing the survey materials and as a result the survey itself was unsuccessful (see Power 2002a for discussion).

Furthermore, despite all the detailed planning by the whole team, we failed to foresee the problems raid by the 'Team's Choice' label for one of the two fleet structures modeled. The cost was finding ourselves in a roomful of angry fishers. While the miscommunication had the positive yet unintended consequence of provoking significantly improved workshop attendance, this occurred at the expense of trust and good-will, at least initially. We were fortunate that good-will was restored.

Finally, again relating to workshop attendance, we learnt that word-of-mouth is not necessarily sufficient. Unfortunately, due to budgetary constraints, wide-spread paid advertising was not an option for this workshop. The reliance on word-of-mouth meant that some groups were very well represented and others not at all. Paid advertising – and, if possible, coverage in the local media – might have led to broader representation and should be budgeted in future community workshops of this type.

The Prince Rupert Community workshop provided opportunities, including the informal opportunities nestled within the formal structure, for increased interaction between the community and the researchers. The cultivation of such trust and understanding will help future collaboration between 'town and gown' for the benefit of the fishery, and for those who depend on it in various ways.

Overall, the workshop was judged a success. The Fisheries Centre's BTF team was given the opportunity to present back to the community an analysis of the information they had previously supplied. The BTF team showed that it is possible to present the restoration of past ecosystems as a practical policy goal, and showed that this approach can aid discussion of the shape of the fishery – and fishery ecosystem – of the future.

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For discussion after the oral presentation of this paper, see page 145.

ROUND TABLE DISCUSSIONS FROM THE BACK-TO-THE-FUTURE SYMPOSIUM FEBRUARY 2002: ISSUES IN POLICY, VISUALISATION AND PRESENTATION

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ABSTRACT

At the symposium hosted by the Fisheries Centre and held in Vancouver in late February, 2002, round-table discussions were convened to focus on the team's approach to presenting our work to the community and whether this approach could actually change policy. Overviews were presented and followed by open discussion with symposium participants. This round table was divided into three sections: the first, Chaired by Melanie Power, addressed the issue of "How can we represent complex models to local communities: what we have done and what have we learned? Examples of what we did"; the second, Chaired by Eny Buchary, "How can we represent policy searches to local communities: what we have done and what we have learned". The third discussion, Chaired by Nigel Haggan, discussed whether the BTF approach stood any chance of actually changing fisheries policy. This section is a transcript of these discussions, edited for clarity and consistency.

INTRODUCTION: THE COMMUNITY WORKSHOP

Co-operation with local communities is an essential component of the Back-to-the-Future (BTF) approach. In the Hecate Strait CUS BTF project, the community has thus far been invited to participate on two occasions: firstly, through interviews by which detailed local knowledge held by community members could be shared with researchers; and secondly, during a workshop held in the community of Prince Rupert, during which time the researchers were able to reflect back to the community how the information shared had been incorporated and applied, and to seek guidance from the community on what preferences exist for the fishery of the future.

The workshop presented unique challenges, in that the researchers wished to share with the community complex ecosystem models. The task, then, was to explain to an audience that would include many with little or no previous experience with models the basics of the *Ecopath* approach, the approach taken and data used to develop the models, and finally what the models said. While recognising that some workshop participants may be very interested in the detailed workings of the models, it was also necessary to ensure that all participants had a basic working understanding of the models and their outputs to enable meaningful discussions.

This was accomplished in a number of ways. Firstly, members of the team made oral presentations describing the Back to the Future approach, the basics of *Ecopath* modelling, and the modelling results. Secondly, oral presentations were reinforced with printed materials. Large posters lined the meeting room, summarising the main points of the oral presentations, and letter-sized versions of these posters were made available to all workshop participants. Finally, over coffee and shared meals, researchers and community members engaged in informal discussions. These provided additional opportunities to answer questions or to explore various aspects of the BTF work.

Workshop participants were asked to consider what they would prefer for their fishery – both in terms of rebuilding goals (in terms of temporal ecosystem as modelled) and fishing fleet structure. This was to be accomplished through (self-selected) working groups. The Fisheries Centre's team would then model the groups' preferences and present the results on the closing day of the workshop. Five working groups were established; four were asked to discuss preferences, as described above, while the fifth worked with the Fisheries Centre's modellers to discuss the *Ecopath* models in details. This fifth group thus provided the opportunity for those interested in the inner workings of the models to explore these issues in more detail.

How can we represent complex models to local communities: what we have done and what we have learned? Examples of what we did. *Chair: Melanie Power*

Russ Jones
Did many people write on the posters [at the Prince Rupert community workshop]?

Melanie Power
Some people did; I am not sure how many.

James Wilson
Do you think the way you have done things ameliorates the concerns Charles [Menzies] was

Power, M.D. and Pitcher, T.J. (2004) Round Table Discussions from a Back-to-the-Future Symposium at UBC, February 2002: Issues in Policy, Visualisation and Presentation. Pages 130–135 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp

expressing [in an earlier discussion] and do you think this is a good way to get information from the fishers?

Melanie Power
We made some mistakes but all in all we built up a relationship with the community. We had time to interact and get to know one another. One person even took us out to see his boat. I think it does help more to speak informally than to talk over a straight interview.

Sheila Heymans
I think it has made it more logical for the people why we are doing this sort of thing. The community will have a better idea of what we are trying to do.

Melanie Power
When we left Prince Rupert, there was a lot more understanding on both sides.

Nigel Haggan
We would like to have feedback on how to present material to people.

Barb Johnson
Did you just do one-day interviews? Have you had contact with the people again? I know that our elders remember a lot of things after [this type] of interview. Is there any going back after the interview?

Nigel Haggan
No. In the first Hecate Strait workshop in 1995 we got recommendations on the people we should have there. We created a model based on what they told us and we sent a report back to them. We did not have the resources to go back to do it again, although we would have liked to. It has taken five years to get enough through the *Coasts Under Stress* project for a very few more visits.

Melanie Power
Everyone whom we interviewed in July was invited to the workshop in December. So we did speak to them again, not just in the [initial] formal interview.

Cyril Stephens
The workshop in December was a very good beginning; otherwise how do you get to know the needs of the people in the community, the politics that come with [those needs] and the problems they create? I like where you came from but you fell short on the advertisement and getting to all the outlying communities from the whole of the northwest. There are a lot of fishermen in that area but they were not there. Their data was missing. The other part that I think was not good was that we spoke mostly of trawlers and seiners but not about the sport fishermen. The commercial fishermen have changed to accommodate the sport fishermen where there is the big money. You need to know the scale of the catch from the sport fishermen and the graph will be complete.

Tony Pitcher
We have a paper tomorrow on the sport fishing problem, which Robyn Forrest has been working on.

Melanie Power
Those concerns were addressed in the [Fisheries Centre Research] Report [detailing the December workshop].

Tony Pitcher
We only had the resources to go to one community so we went to Prince Rupert. If this project is renewed, we should at least look into getting into other coastal communities.

Nigel Haggan
We are fortunate to get good support from *Coasts Under Stress*. I think BTF is a good set of tools for First Nations and other people to develop a collective understanding of marine ecosystems and the flow of benefits a restored ecosystem can generate as opposed to what it does now. Unfortunately we have a shoestring budget. We were afraid that if we advertised we would get a bigger workshop than we could handle. We are interested in making these models and how they work intuitively understandable. The first time I ran across *Ecopath*, it struck me that this is the first scientific tool that looks at ecosystem connections the same way as First Nations. It is still highly technical. How do we make it accessible?

Erin Alcock
How have you been dealing with the local taxonomy? A lot of people have different names for the same kind of fish.

Nigel Haggan
We can't do it at this level. There is a wealth of information on the fine scale but we need to aggregate some data.

Melanie Power
During the interview we did ask people if they knew the fish by any other name. We have captured it where we could, but I am not sure how much we have been able to use it.

Nigel Haggan
The first report on Hecate Strait has a paper on the information content of Tsimshian language names. We need to incorporate it in the models but it is challenging.

Kim Wright
A model is only as good as the information you put in it. How did you determine that you had enough information to run an accurate model? Is this something that will keep going on?

Nigel Haggan
Once we have a model that we can run backwards through time and recreate what we know was there, we begin to have something workable. You can tune the model to real time data and you can make predictions as robust as single species assessment.

Russ Jones
I think it is a good idea to use pictographs but I found the posters very confusing, particularly when trying to find out what has changed. It was hard to compare. It might be better to do it by species and stack it up so it is more like a graph or picture graph.

Melanie Power
We focused on species that are commercially and culturally important.

Russ Jones
The other thing was that although the graphs were meant to help you with the questionnaire [for the survey which was also conducted during the workshop], it was still really hard.

Melanie Power
Is focusing on a few species that were important a valid approach? That sounds ok.

How can we represent policy searches to local communities: What we have done and what we have learned. *Chair: Eny Buchary*

Nigel Haggan
If we could rebuild the system that we like, how would we fish it? We can run simulations to maximise what we want but the criterion is to maintain the ecosystem state. What is the best mix of fisheries then?

Quentin Mackie
Can you set up real time simulations?

Eny Buchary
It is not that straightforward because we are doing [both] economic and ecological analyses. It can take too long to do. We could do it real time [only] if we used a simplified subset.

Tony Pitcher
An [ecosystem] simulation runs through in a minute, but it can take half an hour to do one run of a policy search.

Quentin Mackie
Go the other way around – say what is the policy and see what are the ecological outputs.

Eny Buchary
That would only give you the ecological output. For the [*Ecosim*] optimisation routine you need to put weights on ecological, social and economic values and it is not that straightforward.

Tony Pitcher
We can have more done in advance, then show the results at the workshop.

Sheila Heymans
We can use what we have and simplify it. Perhaps aggregating into a smaller ecosystem might help. For example, you can put all rockfish in just one group – many people do not need to know there are four groups.

Nigel Haggan
I am in favour of that. In order to value the system you need some costs and prices of the fishery. If we find ourselves back in the 1750s and ignore the fisheries we have today, we can ask what kind of fisheries we would like to have.

Tony Pitcher
At Prince Rupert, we put in a fishwheel in one of the simulations as a hypothetical gear type, to see whether the simulation picked it up as an important gear type. And it did.

James Wilson
Isn't it a search for the Holy Grail though? Isn't it all relative to personal positions? Having a fish wheel is great but how does it fit into our society? Who benefits and who pays?

Nigel Haggan
The commercial fishery that we have is an artefact of bad evolution – is that what we want to do if we can rebuild it? I think not. We don't want to force people to defend their gear type.

Tony Pitcher
Charles Menzies gave a paper at the [Putting Fishers' Knowledge to Work] conference [in

August, 2001] on traditional stone-built traps. We can include that kind of gear in the model.

Nigel Haggan
We need to unlock the creativity of fishermen – how would we do it if we had carte blanche?

Russ Jones
I think that is the wrong policy question to bring to a group that has an interest because it brings in the issue of allocation and it is divisive. I would suggest running different case scenarios before the meeting and see how much difference there is in the outcome. You can then ask people about refinements and preferences rather than having them making up things and coming to a consensus.

Melanie Power
We got into trouble for doing just that because [we were seen as targeting the trawlers and gillnetters].

Russ Jones
You asked people to look at one simulation and then to come up with some other simulations. What you did was based on allocations [between fishery participants]. There are various other issues.

Tony Pitcher
Allocation is in effect done by the optimisation procedure. They did not like the results.

Russ Jones
You are still asking them to make an allocation.

Quentin Mackie
I'd say just follow that up. Your simulation is a tool for educating people about complex interactions. It does not matter whether they like the situation or not or if the results are good or bad. Keep the results qualitative – have a simple and a complex model and people will put in their comments.

Nigel Haggan
We would like to bring these things organically to the communities. Instead of bringing a snapshot to a community, we would like to have something that will bring scientists out of their corners into the communities to work until all are satisfied. But we do not have enough resources. The *Oceans Act* calls for ecosystem management, precautionary management and extremely broad-based consultation. It seems to me that by engaging scientists, First Nations, stakeholders, managers and policy makers in simulating ecosystems and asking 'what if' questions you can satisfy most of the criteria in the *Oceans Act*, but you need Fisheries and Oceans Canada to divert a big chunk of its bilateral consultation funds. The problem is not the size of the computer but the lack of resources to do return interviews and bringing people to work in the model for a collective ownership.

Tony Pitcher
The interface needs a complete [public-friendly] front end [if we are to encourage confidence in the modelling].

Russ Jones
The other thing to look at is what other policy questions would engage people better? If we do not have forage fish, will we have high value fisheries? What about Marine Protected Areas? People can think about these kinds of questions. I guess the model isn't ready to answer them.

Nigel Haggan
Actually it is.

Can we actually change policy using BTF?
Chair: Nige lHaggan

Nigel Haggan
Fishers in Prince Rupert were asking if there were any possibility at all that DFO would pick this up. Will it help to make them (DFO) take whatever steps are necessary to rebuild the natural resources and to reverse this decline we are talking about? Can it be done given the trend for larger capital ownership and the fact that small-scale fishers have had to sell out? What are people's thoughts and feelings about that?

Rashid Sumaila
The point of entry into the discussion is: Do people want to do anything? Do they really care? Can this help people to see things differently?

Nigel Haggan
Who are these 'people' anyway? It is not the coastal communities that drive the decisions; it is the voting public. Do they care sufficiently? I would suggest that for the first time, public concern about conservation is starting to counterbalance the industry lobby.

Cyril Stephens
You keep talking about going to a community and getting their input. In the north coast most of the communities are the fishing industry. But no matter how much you scream to look out for salmon, the policy makers are not connected to the salmon industry and it is they who make

decisions for the people who are out on the coast. The DFO are not connecting and that affects depletion and the whole ecosystem. The dollar affects all that too. When a fisherman has only ten days to make his livelihood for the year, you lose that focus because you are thinking about today. Where we want to be tomorrow gets lost in the management system – that has always been there and will be there for a long time.

Rosemary Ommer
Coasts Under Stress is talking to DFO to develop an internship program. Students from *CUS* will be sent to work with DFO to understand the policy makers' world. They send us their people and we would send them to the people on the coast so they can no longer claim that they do not know what is happening at the local level. I don't think it would have worked out if we did not do it both ways. Once that policy wall is cracked a little it will work. But that takes time and I don't know how to survive in the meantime.

Sheila Heymans
Coasts Under Stress needs very strong public relations in order to get the 'Powers That Be in Ottawa' to act. We need a PR drive to explain to the general population out there, for example the people in Saskatchewan, what the problem is and what effects it has on their children's future and so we can get them to vote for the right people.

Rosemary Ommer
People in Saskatchewan are dealing with their own problems that are not unlike what is going on in the coast. We need a lot of evidence and a lot of insemination. There were people in Saskatchewan listening to the radio programs and giving their views on the fishery crisis. I got the impression that people are more aware than I realized.

Bill Simeone
It seems to me that you have to make this much more international. In Alaska there is a terrible depletion of salmon in rivers and nobody knows what is really happening, or how it is related to global warming and fisheries in the high seas. If they are depleting the resources out there, all our efforts here would be for naught. This needs to be much bigger.

Art Sterritt
The question is whether you want to do it and whether the time is right. There has never been a better time from the perspective of the local communities because the commercial fisheries have wiped them out. Communities are looking for places to build their future. Many of the people you have engaged in Prince Rupert are not talking about their future but about their present. I have less optimism in coming up with a solution for Prince Rupert than, for example, in Kitasoo, where people have already reached rock bottom and are rebuilding their future. Prince Rupert still has something to go on. If you focused your efforts and research getting commercial fishermen out of there you are likely to have less of a social contest.

Nigel Haggan
In terms of Back to the Future as a policy agenda, we have always wanted to get the policy makers, DFO and the communities to work with these simulations. The big industry is staying away and it is only now that DFO is becoming more interested. We really need to get these players working with these simulations. We need to say these are the consequences if you persist with these actions.

Tony Pitcher
I am still confident enough to think that Back to the Future can change policy. This is something that is science-based, evidence-based and community-based. Whether it is River's Inlet or whether it is Prince Rupert, if we can get the consent and support in broad terms of people living on the coast, then I think the people who make policy will be forced to listen. It could happen. If we don't do this, the alternative is to have people hanging on to today's buck as we saw in Prince Rupert or people who are affected by massive depletions. So if you get people saying let us restore to what was there in 1950s, it actually puts a tangible policy goal in place. If we could get good PR behind this, I think public support can come in.

Rosemary Ommer
There is a countrywide CBC program that goes coast to coast. For example, a lady in the prairies was phoning in and talking about the way that prairie farms are surviving like the BC coast fisheries. Rural and coastal people always have had the same issues but they are traditionally pitted against each other. This is the time to do it. There is enough sensitivity and there have been enough disasters.

Art Sterritt
I have a comment about your executive exchange program. The reality of the policy that exists today was based on an exchange about sixteen or twenty years ago between the industry and government. That is when that last exchange of knowledge was done and that has driven the agenda. You have still those same people. The industry is paying for politics in many ways. It is

still there. So if you do not find some way to break that log jam in there, what the little fisherman has to say is going to be insignificant. You may need to change the knowledge base on the DFO side if you want a change.

Rosemary Ommer

That's what the CUS2 program will do if it can get launched.

Nigel Haggan

We'd really like to put these ecosystem models into almost a videogame format to get them out into school systems so that people can run scenarios. It is the people's mind for conservation that will turn DFO around. During the development of the commercial fishery, DFO and the industry were two sides of the same coin. But since then you have other kinds of interest groups like conservationists and the sport fishers, and the recognition of First Nations' rights through the constitution and Supreme Court decisions. The system is struggling to accommodate this. If we can get all the players together to participate in a restoration agenda, there is some hope.

Rashid Sumaila

It is a neat concept because it is not just a conservation argument; it is also economic and social. We can go to the public saying if you don't do anything now, you will not preserve this way of life.

Nancy Turner

There are a lot of parallels between fisheries and forestry. In forestry we see clearing of big old trees and replacing them with smaller trees. Is there any Back-to-the-Future in forestry?

Rosemary Ommer

Coasts Under Stress is in forestry as well. I would like to bring some Back-to-the-Future into it.

Quentin Mackie

It is ironic that in terms of community development, the push for conservation of the forest came from the Lower Mainland and Victoria. There was a lot of protest from the northern forest communities. This should be a red flag. Turning fisheries over to communities could lead to that kind of confrontation.

Nigel Haggan

We want policy makers and communities to run those future scenarios.

Art Sterritt

I have been involved in forestry which has agreed to move to ecosystem-based management. The reality is that you cannot look at ecosystem management without looking at a full ecosystem. For ecosystem-based forestry management, you need to look at the coast and the sea; otherwise you only have some parts of the information. The drive for ecosystem management came from the communities, particularly the First Nations in the North. It was they who brought in NGOs like Greenpeace. This project is headed by the First Nations and the government. The other thing we are looking at is marine use planning and First Nations will also support that. The federal government is not interested in doing it themselves because it is too massive. We will do a pilot project exactly as we did for forestry and talk to the industry to see if they buy into it.

Summary of Key Discussion Points

One theme in particular carried through all portions of the round table discussion, that being the value of simplification. It was suggested that it might be helpful to provide detailed information to communities on only a select few species, notably those which are culturally or commercially important, as these would represent more tangible trade-offs within the community. Similarly, information on other species could be aggregated.

Other concerns raised during the discussion revolved around the need to follow-up on interviews with members of the community, and to aim for greater geographical breadth. While the research team would like to be able to meet with people in diverse locations and to be able to follow-up on the interviews, they have so far been unable to do so due to financial constraints.

Finally, a concern was raised regarding the divisiveness inherent in allocation debates. Although the BTF team has not endeavoured specifically to address allocation between fleets or fishers, the model simulations in effect produce an allocation between user groups. It was pointed out that those involved in the workshop would be affected by allocation disputes and thus such a *de facto* debate could impede rather than encourage meaningful discussion. In a related vein, the need for an easier means to address 'what if' questions has become apparent. To be able to more quickly and more transparently address the community's queries and concerns would be of great benefit to both the community and the research team.

RAPPORTEURS' REPORT ON DISCUSSION AT THE BACK TO THE FUTURE SYMPOSIUM, UBC, FEBRUARY 2002

Rapporteurs:
Amy Poon and Yvette Rizzo
UBC Fisheries Centre

ABSTRACT

This section reports edited discussions following 32 oral papers presented at the symposium on BTF held at UBC in February 2002. An Annex shows the Symposium programme. Papers from the symposium that covered methodology are published in this report, while symposium papers reporting results will be published in a subsequent CUS-BTF 'results' volume.

Each oral paper commences with title and presenter followed by edited questions and comments.

Introduction to Back-to-the-Future.
Tony Pitcher and Eny Buchary

Cyril Stephens

You say that the United States has taken things to another level on the north coast area. I am wondering if this team has gotten together with anyone from Alaska. Up in the northern coast, the two countries are always butting heads in the catch area. There can be a scenario where one is drawing too much from the fish population while the other is trying to enhance it. It is important to have the two countries working on same level; otherwise, there will still be depletion.

Tony Pitcher

We have tried talking to the Alaskans several times and were halfway to getting a joint project, but it actually has not happened due to several reasons. The work is way beyond the capacity of a few scientists and their graduate students. This has to be a team project because it involves a huge amount of work. Even with the team we have, there was a great struggle to cover everything. Someone is always going to stand up and point out something we did not cover. It could be a social scientist, a fisher or a fisheries scientist. The amount of money needed even for the existing project is considerable, so if we were to try to do things jointly with the Alaskans, we would need a lot of money.

Nigel Haggan

This work cannot be done on a species-by-species basis. Many are saying they want to take an ecosystem approach, but are still essentially working on single-species methods on both sides of the border. They have not accepted that ecosystem tools have developed to the point where they can be used.

Constructing Models of the Past.
Sheila Heymans and Tony Pitcher

Charles Menzies
Was the number of Beothuk that you quoted for just one area or for the whole of Newfoundland?

Sheila Heymans
That was for all of Newfoundland.

Charles Menzies
Based on my knowledge of the Hecate Strait/British Columbia area, that number seems very conservative.

Sheila Heymans
There are estimates of anything between seven hundred and fifty thousand people. Ms Marshall said that maybe a thousand would be a maximum for the whole of Newfoundland given the environmental conditions. A lot of the diet was salmon and caribou.

Charles Menzies
Were the Beothuk a complex hunter-gatherer society, or a simple hunter-gatherer society? I am concerned because that is really a conservative number, especially compared with the west coast.

Sheila Heymans
I don't know what kind of society the Beothuk had, but they cannot be compared to BC coast people because conditions are very mild and resources abundant here. If you are in Newfoundland in January you will see that there cannot have been many people there. The snow is up to 2 meters high and there are few sources of food. In winter it is more like arctic tundra for Inuit. There is a paper on how I constructed the numbers for the model that is available in draft form.

Tony Pitcher
There is also a paper which has shown, using

Poon, A. and Rizzo, Y. (2004) Rapporteurs' Report on Discussion at the Back-to-the-Future Symposium, UBC, February 2002. Pages 136–155 in Pitcher, T.J. (ed.) Back to the Future: Advances in Methodology for Modelling and Evaluating Past Ecosystems as Future Policy Goals. Fisheries Centre Research Reports 12(1): 158 pp.

stable isotope analysis, that the diet of First Nations in Newfoundland was largely marine, mostly seals – with a lot more seals than you have used in this model.

Sheila Heymans
Yes, but the paper referred to an Inuit population three thousand years ago, when there were more Inuit and they mostly ate seals, while the Beothuk were more recent colonists and were not so bound to seals!

Coasts Under Stress: Knowledge of the past as the basis for future policy.
Rosemary Ommer

Kevern Cochrane
You said that going 'Back to the Future' is an ideal and clearly it is. The reality of what you are talking about must involve trade-offs and costs as well as the underlying benefits. Those costs will have to be sacrificing things that people take for granted today. In the developed world of the 20th and 21st century, we pursue economic growth and wealth. Canada is a perfect example: cars, television, DVDs, and very high standards of education. All of that is coming from wealth creation and we are likely going to lose some if we move towards sustainability. Has anybody done or are you thinking of doing an investigation into what the costs of moving into sustainable development would be assuming the current technology?

Rosemary Ommer
Yes, but not in the input-output model you are thinking of. Rashid Sumaila has done a lot on it. We have codes and we also have principles. If tradeoffs have to be made they should be agreed upon and not imposed. People will make tradeoffs for something they believe in, but they will resent tradeoffs that are imposed on them. I recently talked to a twenty year old man in Newfoundland who did not wish to move to the mainland or to Toronto. This was when it was the policy to move people to the mainland. When I asked why he wanted to stay, he said, "I just want to live and work in Newfoundland, I don't need to fish, I am perfectly happy to do other work but I want to stay in Newfoundland". He was thinking of taking up ecotourism. We tend to have a picture of tradeoffs as something that will decimate us. We need to think of tradeoffs as something that takes us forward, something crucial for our economic well being. But for this we need the hard figures and I believe those are possible to get.

Charles Menzies
You put a lot of emphasis on looking to local communities for knowledge on sustainability. What about those communities that are a product of a resource extraction industry? How would you include this type of community in some form of stewardship of the resource? Do you trust that they have the wisdom to do that?

Rosemary Ommer
We have single-industry towns in Newfoundland as well. Communities will tell us whether they want to stay or move on. A community that does not have much history invested in the area might just wish to move on. I will put stress on local communities. The problem with policy making is that we don't listen seriously enough. Even single resource communities are resourceful. If we inject education in these communities, we are assisting them to make choices. First you ask communities what they want, and only then discuss whether or not it is possible.

Seaweed and the Past.
Nancy Turner

Nigel Haggan
One of the things we need to come to terms with in this project is how we can use this fine-scale knowledge to improve our understanding of the entire ecosystem. There are other First Nations communities out there with huge amounts of fine-scale information and, if we had the time and funds, we would like to spend time with all of them. However, the work we are doing is large-scale.

Nancy Turner
I think of the wave again. This is a wave that can be used to get a focus on the type of scale that you are looking for. I will have to think a lot more about this to give you an answer.

Nigel Haggan
It is a real challenge. The *Sea Around Us* project has made a big splash with modeling results for the North Atlantic ecosystem and an analysis of Chinese fisheries. On the one hand we are working at an enormous scale, and on the other we have some extremely detailed information. Maybe what we need is a sub-set in the *Coasts Under Stress* project to deal with this.

Tony Pitcher
Simply speaking, we can include the estimate of seaweed harvest into our Hecate Strait model - we have not done that yet.

Rosemary Ommer
Barbara Neis is working with specific local ecological knowledge on the coast on exactly this problem. She is working with various villages up and down the coast and looking at mapping and building structures. Local knowledge must be made general in order to be able to share it in a usable way. At the end of the day we are working with a multiplicity of structures. I hope that, along with the techniques that will allow us to move with the local communities, we shall be able to have systems that protect the local communities.

Nigel Haggan
Our modelling is cumulative. We cannot simulate one seaweed patch, but we could aggregate the 'patches' for seaweed and other species and factor them into the simulation. Similarly our modelling is not able to detect the impact of one salmon farm, but it could determine the impact of a large number of salmon farms.

Why we have to open the Lost Valley.
Tony Pitcher

No questions asked.

How can we value the restoration of the past.
Rashid Sumaila

Tony Pitcher
Your algorithm implies that discounting of future benefits would depend on the level of harvesting. Therefore, with the very high present-day catch, discounting in the future would have very little difference from the normal method. If there is low catch, then there will be a huge difference. However, it does not sidestep the problem of what is the optimal approach and that would be thrown back at the biologists.

Rashid Sumaila
A model has to be bio-economic. The benefits are driven partly by the biology while the economics drive the prices. The cost part is a combination of biology and economy, which tells you what to do in terms of what to restore. The level of the present-day catch will affect the future scenario.

Nigel Haggan
There is a policy issue as to who should re-invest into natural capital. If the fishery is owned by big industry, their best return may well be to fish it out and re-invest the proceeds in other sectors that will make more profit for their shareholders. If ownership is vested in stable communities, than there is a long-term perspective and sustainability is more secure.

Rashid Sumaila
And when the responsibility is invested in the country, then taxpayers will pressure the government to sustain the resources.

Kevern Cochrane
When you gave the reasons for a discount rate, you did not include uncertainty about the future. I think uncertainty is one strong additional drive to the discount rate for fisheries. If I were a fisherman I would set aside money, not fish, for my grandchildren because of the uncertainty of the resources in the future. How can I minimize that uncertainty?

Rashid Sumaila
The uncertainty is built in the discounting model – the impatience of the people reflects uncertainty.

Making sense of Ethnographic research for resource mangers and fisheries, or why a fisherman takes three hours to answer a simple question.
Charles R Menzies

Nigel Haggan
Long term relationships between researchers and communities are useful, but there are obvious constraints with time and money. We want to involve these communities in a long-term exploration of possible policies and outcomes, and not just do a one-time interview. We accept the criticisms you made; however, I have to note that our survey was designed by a well-known social scientist.

Tony Pitcher
I agree with most of what you say. I have a Argentinian colleague who once walked along the beach with Einstein. That one meeting drove this person's whole career. I guess a one-night stand is OK if it is influential.

Duncan Stacey
I would like to add two more points to reinforce your arguments. I have been studying fishermen for twenty years and I was told knowledge is learned, wisdom is earned. If you don't ask the right question you don't get the right answer. Fishermen are expert players in Bull**** poker – they will run you around without telling you the truth, although in many cases they believe in what they are saying.

Principles of environmental archaeology. Quentin Mackie and Trevor Orchard

Sheila Heymans
Quantitative as well qualitative information is necessary because we need to know how much of one species people would have eaten at that stage.

Quentin Mackie
If your concern is to get a picture of what people were eating, then yes I agree. I recall seeing the rising number of sea otters in your restoration model. Well, we find sea otters wherever we dig, but quantitatively it is hard to turn those bones into numbers – our normal focus is to infer from what is in the middens to what goes into people's mouths.

Tony Pitcher
One of the things we really need to know is the relative abundance. I know that archaeologists have statistical methods to turn midden data into numbers of fish, birds or otters. That would be very helpful.

Quentin Mackie
The bones are accumulating because of a cultural process. Relative species numbers can be biased. So if people just happen to love herring, than you get a lot of herring at the site and no rockfish. It is hard to get around that. If you have some indicator species that sets the general structure of the food web, maybe you can go around the back door. The cultural filter is hard to get around. Normally that is what we are trying to find out, but in this case it is an obstacle.

Tony Pitcher
What sort of uncertainties are there in the statistics that change the number of bones into number of fish?

Quentin Mackie
The problem is not the counting. It is adding them up in some way that is meaningful. If you assume that one bone represents one fish, your estimate is likely to be biased towards animals with a lot of body parts or with body parts that are identifiable. For example, it will take you a lifetime to discriminate between different rockfish while salmon identification always boosts their number. So you look for unique body parts. You ask what is the minimum number of individuals that will produce such a number of body parts. That is extremely conservative. I could talk forever about the problems!

Filling in the Blanks: the oral history of Haida Gwaii Herring. Russ Jones

Cristina Soto
I am really curious about the spatial distribution of spawning. You quoted someone saying they have come back. It may be a fascinating study to get more information on the possible locations of spawning and where the fishery occurred. Women have been involved with spawning on kelp.

Russ Jones
There is a spawn sites database at the DFO that goes back to the thirties. There is also a catch database to make comparisons. I did try to interview some women, but the couple I approached declined and there was a shortage of time so I did not pursue it. They were involved in preparing and selling it. It would be quite hard with oral history to show that because it does not cover abundance.

Cyril Stephens
When you compare the early days in the 1940s to now, you know and herring fishermen know that when it is noisy, herring die. As the population and technology grew in Skidegate Inlet, there was more traffic and it may have become too noisy for the herring and so they had to move. That is why the population dropped down so much – because of the technology and population growth.

Russ Jones
Overfishing was also a big factor – there was no spawning for over three years. The thing is that the stock did come back after that. There is a lot of traditional knowledge about how herring move from one place to another.

Case studies in environmental archaeology Gwaii Haanas and the Aleutian Islands. Trevor Orchard and Quentin Mackie

Tony Pitcher
The evidence you provided for otters being the keystone species is really neat. We need to check if our model reflects the reality of that switch in keystone species.

Nigel Haggan
Do you have evidence about where those bluefin tuna remains come from?

Quentin Mackie
They are all over the coast from Washington State and even on Haida Gwaii.

Tony Pitcher
They would be in Hecate Strait too?

Quentin Mackie
There are a couple of papers written on this. Richard Ingles spoke to the Mowachaht people who knew a lot about it. These people remember a lot of detail: when the water conditions were right, the bluefin tuna would chase their prey along the coast and the Mowachaht followed them by following their phosphorescence. This is not a fluke. It was a rare event but it happened enough times for people to know and remember. There are about seventeen archaeological sites that refer to this.

Sheila Heymans
The length-frequency calculations that you did were also very interesting. Some parameters in the models (e.g., Q/B) require knowing the maximum possible length of the fish. The longest fish you referred to is 30% longer than the 'official figures' that we use [*from databases like Fishbase, Ed.*], and that will make a big difference.

Quentin Mackie.
Trevor Orchard has developed regression formulae for those seven species. All you have to do is plug in the numbers. He found that one formula covers all rockfish. That is interesting because there are lots of rockfish in every coastal archaeological site.

The Northern BC historical and interview database for BTF.
Aftab Erfan

Peter Johnson
Can you link your data to a GIS program?

Aftab Erfan
I don't know if there is enough spatial data in the database for a link to a GIS.

Tony Pitcher
We are hoping to make it available on the web as part of the project. We are not trying to link it to GIS at the moment, but we are trying to link these comments to a map of the ecosystem. That is something that will take even more programming.

Nigel Haggan
If we get it on the web, we can also ask people to send information that will subsequently be validated. Aftab did a tremendous job last summer on one set of interviews, we need to find a way for people to provide more information.

Ecosystem Models of past and present: Northern BC.
Cameron Ainsworth

Russ Jones
I wondered if you looked at reduction fishery catches. There was a lot of herring removed in relatively few years. There were few reduction fisheries in Haida Gwaii before the 1950s. It will give you a lower limit to compare.

Cameron Ainsworth
Do you think that 1950 is too low because of the impact of the reduction fisheries?

Russ Jones
Yes. There were a few years where sixty thousand tonnes were removed from just one location. Now the estimate is just 20 thousand for the whole area. Reduction fisheries kept going on for a considerable time and that must have reduced the biomass by a lot.

Cameron Ainsworth
The model is an average of 1950 to 1955 and it covers the whole of the study area.

Stephanie Henri
The same thing applies to the eulachon. There is a major crisis with these fish. There have been no eulachon for the last four years. Four years ago we had one run and seven years before that no run at all. I would like some more information on the eulachon.

Tony Pitcher
Eulachon is a very hard group to build in a model because they come in to spawn and the rest of the year they are in the ocean. The relative numbers are very uncertain and it is hard to get the biomass. Generally we let the mass-balance part of the model estimate eulachon biomass, but there is a lot of uncertainty in the estimate.

Nigel Haggan
Getting DFO and other agencies to buy into it should allow us to get the information that we need for the eulachon. At the moment, that is as good as it gets.

Ecosystem models of past and present: Newfoundland.
Sheila Heymans

Kim Wright
I am curious about the overhead you mentioned. How is it calculated?

Sheila Heymans
It is calculated from the sensitivity index formula per group. It comes from the work of Bob Ulanowicz and it tries to calculate the system's stability and maturity.

James Wilson
What does the fluctuation on the oscillation slide indicate?

Sheila Heymans
Every line is one functional group in the ecosystem model. The graph shows how these groups interact with primary production that has been forced by the North Atlantic oscillation Index. Some things will not be as influenced by primary production as others. I am assuming that the lines are affected by the oscillation.

Tony Pitcher
Yes, each biomass is relative to what it was in the beginning so fluctuations indicate a change.

Ecosystem models of past and present: Hong Kong.
Eny Buchary and William Cheung

Mary Gasalla
Did you say that conservation groups have closer relationships with fishermen?

William Cheung
We still lack communication between fishermen and conservation groups. This is an area that we still have to work on. We do lobbying, but do not always get the support of the fishermen. This is a crucial point and we want to build that as a major component into the future phase of Back to the Future in Hong Kong.

Nigel Haggan
This is largely based on William's M.Sc. work. He is currently working for the World Wide Fund in Hong Kong.

Tony Pitcher
At the moment you have a model of present day Hong Kong and of 1950, but for a full Back to the Future evaluation you should have more past models. What are your plans to get further with that?

Eny Buchary
In terms of archaeological information, Elizabeth Johnson at the UBC Museum of Anthropology did lots of archaeological work in Hong Kong.

William Cheung
I contacted historians in Hong Kong in the last few months and they said they have some information on marine ecosystems for the past that will further develop our research. I do not know how much information they have, but that is an option we can explore. When we hold workshops with the community in Hong Kong, we can invite these academics.

Tony Pitcher
When the English arrived in Hong Kong in the 1800s, there were only very small coastal fishing communities. These communities would have very different fisheries than those that existed in 1950.

William Cheung
The historian I talked to studies the history of marine science, and she found colonial records in England mentioning fisheries in the early 1900s.

Cyril Stephens
Before the war you had large fish on the rise. After the war, larger fish were depleted. You are seeing that as being overfished. Now you have a rise of smaller fish. How do you balance a fishery so you do not overfish the small fish so there will still be food for large fish?

Nigel Haggan
That is where Marine Protected Areas come in. They protect the breeding population. However, fishers tend to congregate on the borders of the Marine Protected Areas and do quite well.

Eny Buchary
There are two Fishing Protected Areas (equivalent to Marine Protected Areas) planned for Hong Kong. They have not been established yet because they are still waiting for the fisheries ordinance to be amended. However, they have established a pilot site where some artificial reefs were deployed. In this pilot site, scientists have also been monitoring fish attraction to the reefs and fish larvae dispersal. The progress of the program is encouraging because reef fishes are starting to be established, though the reefs are not large yet because they were started only 1 or 2 years ago. The latest news is that they are planning to introduce fry of two local species from local mariculture operations, *Lutjanus malabaricus* and *Epinephelus coiodes* into the pilot site to start rebuilding reef fish. They are planning to release the fry this October.

Nigel Haggan
If you want to see the future just look at the South China Sea where there are only small fish and invertebrates. Fishers are still making lots of money catching small fish to sell as feed for

chickens and aquaculture operations. That is where we are going.

Eny Buchary
Hong Kong is one of the best places to eat seafood, but the large fish that can be found in the restaurants are not from Hong Kong. There are no more large fish in the South China Sea, so those very expensive live fish that businessmen purchase for their banquets are from Indonesia or the Philippines and are fished using poison or cyanide because it is very difficult to catch these large fish using nets.

Quantifying qualitative information in a past ecosystem model of Hong Kong.
William Cheung

Robyn Forrest
Eny mentioned in her talk that prawns make a very valuable fishery. Are your estimates of prawn biomass driven by increase of catches due to increase of value?

William Cheung
Because of fishing down the food web and the increasing value of prawns in Hong Kong, lots of fishermen have changed from small-scale fisheries to prawn fisheries; so yes, there is a bias toward catching more prawns now.

Robyn Forrest
Can that be driven by the value of prawns rather than the structure of the ecosystem?

William Cheung
Yes, that is one of the biases from my interviews, but it can be negated with cross-references.

Nigel Haggan
The prawn fishermen and the trawlers will be the ones who will object most to our proposed changes. Also, there is a big prawn fishery in the East Coast of Canada, mainly because there are no more cod to eat them.

James Wilson
There is also a lucrative prawn fishery in Greenland, but there is still a lot of cod there.
Kim Wright
I was impressed with the detail you went into with your interviews with the fishermen and how you went into the communities. Did you find it productive?

William Cheung
Yes, it was very productive. I had no experience with this, so I had to explore alternative ways to get into contact with the fishermen. I found that going to fish ports and visiting boats was a very good way to get information. Also, if there were an arrangement with a fisher organisation, it helped because the organisation would select fishermen that were enthusiastic. The interviews take lots of time because they are semi-structured. We spent a lot of time talking to get small pieces of information.

Cyril Stephens
What is the size of the areas you went to? How far did you have to travel to do your interviews?

William Cheung
I did not have to do much travelling because Hong Kong is very small. It only takes half an hour by public transportation from one end to the other. I did make a point to go to both sides of the water because there are very different fisheries on either side. Fisheries on the West Coast near the Pearl River estuary are seasonal, whereas fisheries on the more oceanic East Coast concentrate on reef fishing.

Nigel Haggan
It would cost around $50 to visit all the fishing communities in Hong Kong. By comparison, it would cost around $5000 for one person to make one visit to all the Hecate Strait communities.

Back to the Future: Driving Models with Information About Past Climate.
Tony Pitcher and Robyn Forrest

Nigel Haggan
Can our climate data throw any light on the flip-flop with herring as opposed to sardines and anchovies which prefer warmer water?

Tony Pitcher
N0, although the flip could be forced in the model. At the moment, the model is not very good at dealing with populations when they get very low. This afternoon I will talk about local extinctions and offer suggestions on how to deal with local effects. Sheila talked about walruses yesterday. Because they are included in the model, their number can explode in time-series simulations.

Micro-level Historical Reconstruction of Newfoundland and Labrador Fisheries between 1891 – 2000: Findings and Issues.
Kara Rogers, Jeff Webb and Barb Neis

James Wilson
Did you try to get any sales or purchase lists?

Kara Rogers
I contacted the Department of Fisheries and Oceans, but I have been waiting for a month. We are asking for a lot of information, including gear type, species, and communities. There is information for Rocky Bay and Trout River, but we are just waiting for the information to be compiled.

James Wilson
For the historical information, looking back to the turn of the century, what about people who were buying fish that was landed? I assume most of the landed fish were exported to other regions and not consumed locally.

Kara Rogers
There were some merchant ships around that time, but most of that data is not available. The Newfoundland government took the data from these ships and compiled it in export data. The merchants used to just sail up the coast and collect fish, but those companies no longer exist; they were perhaps only in operation for 10 years or so. We can see if there were more of one species exported than another species, but it cannot be done on a micro level.

Nigel Haggan
I would like to suggest that either or both of you work with the modellers to make a paper for the report rather than ending up with 3 separate ones.

Tony Pitcher
This would be really powerful. Our ambition was to start at the 1900s and inch forward, tuning the model with the data that we have, and that could be helped immensely by your study. It can be used to tune the whole run of the ecosystem.

From Local Knowledge to Science and Back.
Erin Alcock

Nigel Haggan
This is quite exciting for me. This project is still in its infancy. At a typical conference, we usually only get a lot of papers. What you are seeing in this workshop are models and tools that can integrate multiple sources of information. Instead of just a report coming out of this, we will have people working on issues of scale and time. A model is a living thing that continues to grow.

Sheila Heymans
You said that you are only looking at area S3K1. Why are you limiting it to that area? It will not be comparable to other models at that scale.

Erin Alcock
There is no reason for me not to scale up to the same size as what you have been doing. I probably will scale up and do a model of the 1970s. The idea was to see how much I could use local ecological knowledge.

Tony Pitcher
I would encourage getting Barb and David to do the same. Your one or two time periods will be just right, and it would be great to just be able to slot your models into the last 100 years. That way, we will hit your snapshots as fixed anchor points. We are beginning to bridge a gap between the different philosophies in natural and social sciences. Usually the natural and social scientists stay in their respective caves. It is something we have to try to overcome. As natural scientists, we try to generalize. We make a model. The whole point of science is to generalize things that will apply everywhere with some uncertainties; whereas in social science, the tradition, especially in anthropology, is that you can only study this knowledge at this place and at this time – this knowledge has deep meaning, but you cannot use it to generalize. Those two ends of that polarity are really incompatible. What we have to do in Back to the Future is to bridge that gap. As scientists we have to say, “How do we take this information that is rooted in a specific place and make it apply to a general situation?” Your group is trying to piece together things to get a larger picture. We will want to push you more towards this. E.O. Wilson has written a book called *Consilience* that talks about the melding in social and natural sciences, especially in medicine, nowadays.

Erin Alcock
That is a very interesting point. Natural scientists are taught that the scientific method is to get a hypothesis that can be tested everywhere. I am taking a course in social sciences now and their methods are so foreign to me. It is a good thing to know that there are other ways of doing things other than using science.
Nigel Haggan
Agreed. In British Columbia, we have a treaty process and a history of First Nations resources being exploited. The First Nations have a healthy and well-founded mistrust of science and management.

Tony Pitcher
The next phase of *Coasts Under Stress* is to get to the spatial modelling part.

Stephanie Henri
That comfort level is hard to find. Working with different organizations, we tend to protect our knowledge of fishing grounds because we think of it as ours for traditional use. Some elders do not want to give up information on fishing hot spots. How did you handle that confidentiality? We have paid the price for speaking of them before, so we have the problem of sharing any more information. We hold tight to our maps.

Nigel Haggan
The counterpoint to that is that if we cannot find a way to harness our collective knowledge to understand the decline of salmon and eulachon, we will be in more trouble. The question is how do you protect the information at the same time as you work together with the information to protect the resources that are desperately in need of protection? Back to the Future seeks to involve all 'communities' in setting reconstruction goals for resources we all care deeply about.

Cyril Stephens
I come from the Nass River where we harvest eulachon. The reason why there is not too much information on it is that when information is given out, there is a chance that it might become commercialized. Once it is commercialized, the dollar sign kicks in and the depletion starts, like what happened for cod. Not sharing the information is one of the hidden protections we have. That is the reason why the First Nations do not want to give up information on where the hot spots are.

Erin Alcock
How to use that knowledge is a tough decision to take.

Copper River Subsistence Evaluation 2000 and Traditional Knowledge Project.
Bill Simeone

Nikki Shaw
It was nice to hear your presentation of such a heartfelt nature. We have had trouble with our fisheries and we have been trying for a long time to be heard. I want to acknowledge that we are on Musqueam territory. It is because of them that we are here now, when Mr Sparrow took our cases to court. I do not think this particular group in this meeting necessarily understands how long we have had to fight. Every presentation I have heard in this workshop began with the assumption that it is due to fisheries management that the fish have declined. I do not know if other factors like logging were taken into consideration in the models. I am glad Alaskans now forbid logging in the watersheds. I am also glad to hear that the Alaskans have such a unique management system where those who protect the resources are those who benefit from it. You are ahead of us on those things. I do not know where such a system came from. Was it from First Nations, or was it just wisdom on the part of the managers?

Bill Simeone
It is not from First Nations influence. Most of Alaska is federal land. In 1980, the federal government said that if the state of Alaska wants to manage the game and resources on federal land the State has to give rural priority. That is, if resources decline, then rural people get first shot at the resources. The state did not agree, so the federal government took it over with the notion that the First Nations get first crack if resources go down. There is a regional advisory council, consisting mainly of First Nations people, which makes decisions about the fish in the region. The decisions then go to the federal board, which consists of people from managing agencies, which usually follow the advice given. It is not perfect; Alaska has a lot of people who do not want the First Nations put as a priority. They believe that everyone should have equal access. Local information might finally make its way into management regimes. We are just lucky that it is being done before the fisheries in Copper River collapse.

Erin Alcock
The study of different worldviews, how you look at legends and how they are received, is very important. When scientists sit down with locals, it is easy to only use what traditional knowledge will fit into scientific models, but there are a lot of different worldviews out there which have nothing to do with science. I think local ecological knowledge is just as valid and true as other worldviews.

Bill Simeone
It goes back to what we were discussing about generalizations. I see myself as a cultural broker. Scientists and First Nations do not talk to each other. They either ignore each other or they shout at each other. I am trying to get into the middle and put the information in a systematic framework. I present to the scientists a legend entirely in the Ahnat language, and explain that this is where the Ahnat people's ideas come from, and see if it can be stuck into the management

scenario. This is self-management and this is where their ideas come from. The legend might be mythological, but a lot of the underlying themes make perfect sense, like taking care of the environment and the salmon. I am reinterpreting the legends but I do not want to be the speaker for them.

Nigel Haggan
Ecosystems are really useful as an integrative metaphor. Listening to my First Nations friends talk about the ecosystem as a whole including human, spiritual, biological and other elements which all have value and weighting, I am struck by the thought that this viewpoint is not dissimilar to the ecosystem justice that Rosemary Ommer talked about yesterday. What we are trying to do with this process is to develop a collective concept of the ecosystem. In this the First Nations have a great deal to teach us. What we are doing is mapping some of those connections the aboriginal people have understood on an intuitive level and which are difficult for the rest of us. The intention is there. We are trying to put the pieces back together to get a unified context.

Bill Simeone
To affect policy, you have to turn this into something that will be listened to. Policy makers will nicely listen to Ahnat elders and maybe change policy accordingly, but what gets to them is numbers to back it up. They have to be fair. The Ahnat elders have a cosmology that is valuable, but the sports fishers have a cosmology too. The policy makers need something that they can later comfortably justify.

Tony Pitcher
In terms of Back to the Future, if you can recapture what it was like in the 1860s, then you will have a policy objective. The much-hyped Copper River has actually lost species. It is important to look at that past with the local custodians of the river. You may then have a policy objective in quantitative terms, put forward with the consent of the peoples. I hope this project will open that dialogue. That is the objective.

The Community Workshop:
How we did it, and what we learnt.
Melanie Power

Cyril Stephens
I think the phrase 'team's choice' was a problem because the community consists mostly of gill-netters. When that fishery was left off the poster, the people of the community heard about it, so they figured Nigel was going to close down the community. That is why they nearly took his head off.

Melanie Power
I should point out that in the photos I presented, the boats shown were all gill-netters. With the word 'choice', it sounded like we were coming in with preconceived notions of what fishery should exist in the community.

Karin Mathias
The word 'choice' perpetuated the distrust that the locals have of the scientific community in general, even with universities. They step back and do not want to talk; and the choice of words just aggravated them.

Melanie Power
In July, we talked to someone who was skittish about talking with us. We assured them that we were just academics from the university and not with the Department of Fisheries and Oceans, but they said "You may not be from the Department of Fisheries and Oceans now, but you will be someday." It is important to remember that the things that are theoretical to us are real to the fishers. These things make up their lives. It is important to keep grounded and consider how the things we are doing in front of our computers are going to impact them, especially if this project is intending to have policy influence.

Cyril Stephens
That is their livelihood. For about a decade, the community of Prince Rupert has had mismanagement from the Department of Fisheries and Oceans on the fishing cycle, where a fisher has a season of 10 days. Then along come Nigel Haggan and his team, and the fishers wonder when this is going to stop, because of the way they have been treated. I strongly believe that this is a good project. The only obstacles to it getting off the ground are budget and its new ideas. When a project is new, you have to continuously sell it to people. When people see that it is a good project and once you have sold it, it will really get off the ground. This is the second workshop I have attended and I feel comfortable with this project because we do need it given the way fisheries have been managed until now.

Nigel Haggan
Even though our livelihoods aren't on the line, a lot of us 'academics' here have a lifetime commitment to fisheries and care deeply about what is happening to oceans. That is what pushed some of us into science to try and understand

what is happening.

Stephanie Henri
You only referred to what is happening from the north of Haida Gwaii to the north of Vancouver Island. Is the central coast built into your model? You have to concentrate on localization, especially where there are species at risk like the sockeye.

Nigel Haggan
I have been trying to get a central coast project for 4 or 5 years. I have invited many people from the central coast to this workshop, but you are the only ones who made it. I know the Department of Fisheries and Oceans has resources in the central coast, but our project only just touches on the central coast. We need a focused central coast project.

The Community Interviews: How we did them and what we learned from the LEK results.
Cameron Ainsworth

James Wilson
With your interviews, how did you weigh the ones regarding information from the 1950s? I have problems remembering what I did two years ago. How did you deal with that?

Cameron Ainsworth
That is a problem. An additional problem is that the further back you get, the less people are available to ask. There were maybe 30 people out of the 38 we interviewed fishing in 1970, and only 2 of them were fishing before 1950. As for them misremembering, we have to take their word on whatever they tell us. It is either our guess or their guess, and I was not even born in 1950. This is especially important for non-commercial species which the Department of Fisheries and Oceans does not keep records of.

Kara Rogers
In my own studies, I found that half the fishermen I interviewed could not even remember their children's birth dates. They do not remember by year, but they seem to remember what happened and what they caught when they associate it with the boat they were using at the time. It might help you if you try to ask them about the species they remember by boat. You might not get year-by-year information, but you could get information by 5-6 year intervals.

Sheila Heymans
If we could redo the interviews, we should ask what year they changed boats and what it was like during that time. That will likely work better.

Cyril Stephens
In comparing the graphs for 1950 to the ones for the present day, you have to remember that in the 1950s, they only had 10-14 foot boats with 20-foot gill netters that used linen nets. In the present day they have bow pickers that can cover an area from Prince Rupert to Port Hardy in 4 hours and catch a tide. Through modern technology, they can find a big run and go get it. How will your graphs correlate that? Take, for example, a community like the Heiltsuk Nation. If they owned a 10-14 foot boat in the 1950s, they hung around a certain area that is their catchment area. Nowadays, people can cover a lot of miles getting to fish. How will that affect the graph when you put it together?

Cameron Ainsworth
We did not ask for information by year, but rather by period. The question we asked of the fishers was whether the species increased or decreased during their career. If everyone said that one species increased, chances are it did. If half says it increased and half says it decreased, then maybe it stayed around the same level.

William Cheung
To address the issue of how to deal with people's memories of non-recent periods, you can ask fishermen about the big events in their lives. For example, you can ask them about the largest fish they saw in their lifetime and when it was, which reminds them of the time period when they caught the fish. Then you can ask about the situation in that time period, rather than just asking about the situation in the 1950s. There were also discrepancies in the correlation between interviews and government statistics. In your interviews, did you ask why they think there is an increasing or decreasing trend? That might give you a clue as to the reasons behind the discrepancy.

Cameron Ainsworth
We did not ask specifically for reasons. Sometimes the fishermen offer reasons, but the graphs just offer values of 1, 0, or –1. If everyone agrees that the abundance of a species went down, we can assume it went down.

Peter Johnson
Fishing in the 70s is different than fishing now. In the 70s, fishers could pull fish into their boat. This year, we have to dip net the fish into a holding box, sort them, and keep certain species alive. The procedure has changed so much.

Kim Wright

In terms of correlation between your data and data from the Department of Fisheries and Oceans, your interviews probably took place at a smaller scale, which might contribute to discrepancies. The Department of Fisheries and Oceans take data on a coastal level, whereas your interviews were at a local level. How do you correlate that?

Cameron Ainsworth
The more people we talk to, the better idea we get. We are just looking for relative abundance, not absolute abundance. We are not looking at hot spots.

Kim Wright
When you have a conference and invite people to come, the people who attend may be people who are worried about the stocks, so their tendency may be to report a decline. That would bias your interview data. You will get less bias if you go to a community.

What are the recreational catches from Northern BC?
Robyn Forrest

Tony Pitcher
I did not realise the anomaly between the two estimation methods [mailout/phone survey and creel census] was that big. They are done by two different DFO labs it seems.

Nigel Haggan
Is the catch really 14,000 tonnes of salmon? That is an awful lot of fish to catch by angling.

Tony Pitcher
That is about a quarter of the total catch. It is not insignificant, at any rate.

Robyn Forrest
That figure is based on my estimate of the average weight of fish. It might be less if I change the conversion factor.

Cameron Ainsworth
Did you find any information on discards? People in Prince Rupert were saying that the sports fishers may catch 20 fish for 1 that they keep.

Robyn Forrest
The catch and release figures were 43%.

Cameron Ainsworth
The sport fishery discards have nothing to do with catch and release - they get one fish, and if they find a bigger fish they throw the first one out. People were saying that it was significant enough.

Cyril Stephens
I am not quite sure if the numbers are right because in commercial fishing, they have counters that keep records of what is coming in. In sports fishing, there are no records at all. If I go down to Wesbrook, I do not see the Department of Fisheries and Oceans come in at 9:30 pm when sports fishers are returning to dock because the people from the Department of Fisheries and Oceans are done for the day. They only take in the information that comes in during the day. I do not think doing a survey like this will show numbers as they really are. The thing with sports fishing is that the cost to run it is so low compared to commercial fishing. The money is changing the rules for commercial fishing to favour sports fishing. There are no statistics or quota for sports fishing. We do not know the number of fish that die and are thrown away.

Robyn Forrest
Yes, it really is a very political issue. All I can say at the moment is that with the resources we have, we have to use the best available estimates, which are better than what we had before. It seems that the Department of Fisheries and Ocean are putting in more effort now into keeping track of recreational catches. They have realised that sports fishing is a big issue. I am hoping that we will have improved estimates in the future.

Karin Mathias
In your estimates, you adjusted the number of pieces of salmon two times. Do you have results from the mail-out surveys?

Robyn Forrest
The mail-out surveys report 2.4 million fish caught, 1.4 million kept.

Karin Mathias
Sports fishing is a hot topic now and the allocation issue between the sport and commercial sectors is really controversial. As it has been pointed out, there are a number of serious problems associated with it; for example, they cannot have observers on every boat.

Tony Pitcher
One would like to think a mail-out survey with 8000 respondents would get around the problem of fish coming late at night after the people from the Department of Fisheries and Oceans have gone to bed. However, in terms of anlers memories after the event, there is a classic case from British Columbia lakes where they stock the lake with trout every year. One year they forgot to

stock one lake with trout, so there were absolutely no trout. When they did a survey of anglers on that lake to ask how the fishing was, the anglers said things were OK and much the same as in previous years. So much for anglers' memories.

The Haida Fisheries Program does a census of sports fishers in the water and asks how much they've caught. Where does that information go?

Robyn Forrest
It is incorporated in the report.

Cyril Stephens
The problem with the Haida program is that the census takers have problems getting to the lodges.

The South Brazil Bight Revisited: "Digging" cruise charts and fisher's knowledge toward ecosystem modeling. Mary Gasalla

Tony Pitcher
How many interviews did you manage to do?

Mary Gasalla
81 so far.

Tony Pitcher
How did you turn the interviews into a flow chart?

Mary Gasalla
In each interview, we had a list of the resources, and we asked the fishermen to put the relationships (i.e. predators and prey lists) to each species of fish.

Tony Pitcher
Did the model balance after this?

Mary Gasalla
Not yet, but a new complete diet matrix has been generated.

Integrating migratory species into ecosystem models. Steve Martell and Stephen Watkinson

Stephanie Henri
I like the linking of the models because it is really hard just talking about salmon, when we are concerned about our eagles and grizzly bears as well, since they are disappearing.

Sheila Heymans
Would it be possible to have a terrestrial and marine link between the two and have them run together?

Steve Martell
Last summer we built two models in *Ecopath* which are independent and connected them to each other by diet matrix. One fishery went to one ecosystem then the other back and forth.

Tony Pitcher
How did you do the linkages between the models?

Steve Martell
It depends. We can build three separate models or build one *Ecopath* model. Otherwise, you can hire a programmer and get them to pass out the necessary information at each time step. In this example I showed here, the spawners get changed outside of *Ecopath* due to fishing or spawning, then get passed back in.

Tony Pitcher
Then how do you build in delays? For example, the sockeye have a 4-year cycle.

Steve Martell
Just use the delay pointers. It is a fairly standard procedure.

Problems in modelling rockfish in Northern BC. Erin Foulkes

Tony Pitcher
The problem of reconstructing the past in rockfish may not be as bad as you think because it was not heavily exploited. There were some First Nations catches, and offshore they were not really being caught at all. One stock assessment scientist from the United States, who gave a talk at the Fisheries Centre, talked about B_0 for one of the species. B_0 is a stock assessment concept that deals with pristine unfished biomass for that stock. I do not know if that is compatible, but it could be a starting point for an unexploited rockfish model. You will see some inconsistencies that you will have to adjust.

Nigel Haggan
Doug Hay mentioned studies for pristine areas in Alaska that can be used for British Columbia because of the similar ecosystem. There is an increasing body of study that says that almost all marine fish do come back to their place of origin, and that has serious implications for management.

Tony Pitcher
I also like idea of splitting up the rockfish group in the model. If we can get to a pre-contact model, there is interesting data from Quentin Mackie yesterday where he showed that the diet of the Haida included a vast number of species including rockfish. That means we can use the ancient diet of the Haida in the ancient fishery in the Hecate Strait model.

What was the structure of past ecosystems that had many top predators? Tony Pitcher

Nigel Haggan
If you have a lot of top predators and the amount of forage fish needed to feed them, is primary production not the primary constraint?

Tony Pitcher
No, in the bottom of the ecosystem there is a super abundance of those to drive all sorts of things above them. Primary production is not the problem. The problem is the middle layer.

Richard Stanford
Do you have evidence of predator diet shifting with prey abundance?

Tony Pitcher
That is a good question. We were very worried about that until three weeks ago. Diet ecology suggests that as abundance changes, diets will change. However, there is a paper by Lincoln Garret on Georges Banks that looks back to the 70s and shows that is not a problem. The proportion of diets reflects the abundance in the system, which is what *Ecosim* does.

Robyn Forrest
Did the herring boom after the cod collapse result from a fisheries shift to exploit the herring stock?

Sheila Heymans
No, the fisheries switched to crab and prawn, and they are still doing well.

William Cheung
There are a few papers studying freshwater ecosystems that suggest that increased biodiversity results in increased productivity of the ecosystem, which is a result of increased consumption facilitation and partition. Could this also be the case in the ocean where an increase in biodiversity helps increase production to provide food for the larger amount of predators in the past model?

Tony Pitcher
That could occur, but top predators themselves, by having a broader diet, might specialize within the species. There is a neat study on cod in the North Sea in the 70s where the diet of cod was very broad. Within the group, the scientists found certain groups of cod that specialized. Some cod would be able to suck hermit crab out of their shells. It was not revealed if they looked at the diet over the entire population. That diversity of diet could solve our problems.

Nigel Haggan
There is a number of species in Hecate Strait that could have been more abundant. There are several smelt species. Sandlance is a total mystery; no one knows anything about their abundance, although everything in the ecosystem eats sandlance.

Sheila Heymans
You assume that the percentages in diet were not the same pre-contact – it was broader. That is what I had to assume to balance the pre-contact model. The percentages of what they had to eat might not be the same. That is the easiest and most realistic thing to do to get mass balance. There is no evidence that is not the case. It is not reasonable to assume that the diet stayed exactly the same anyway.

The problem of local extinctions. Tony Pitcher

Sheila Heymans
Steve just reminded me that there is a way to emulate the presence of extinct species. You can have the biomass of 10^{-6} fixed in the model.

Tony Pitcher
We could do that and drive the forcing function by temperature. However, when they go into the model, you want them to be full actors.

Sheila Heymans
You can just have the biomass fixed at an extremely low amount for the time they were not there.

Nigel Haggan
In the case of Hecate Strait, you could go from pilchard to herring and back, according to the temperature.

Nikki Shaw
What is difference between local extinction and extirpation? If you have distinct populations of sockeye, they call it extirpation, but in reality it is

extinction because the genetic pool is lost.

Sheila Heymans
Does extirpation also imply human involvement?

Tony Pitcher
To me, The word 'extirpation' does imply an active process. I prefer to use 'local extinction'.

Do these models tell the truth?
Richard Stanford

Cameron Ainsworth
If your spike in plaice population were due to temperature rather than migration, you would expect to see a lag. If there are more of them with increased growth rather than moving in, then you can identify it with temperature and changes in environment. The population would not respond that year. If temperature goes in their favour, it would take a few years before the population spikes.

Richard Stanford
I agree with you in principle, but in practice a good year can make a strong year class.

Cameron Ainsworth
Yes, but that will not show up until later years, because the bulk of the biomass would consist of the 4-5 year classes rather than the juveniles.

Richard Stanford
The problem is that if fishing rate is increased and the stock becomes depleted, then the majority of the biomass will be the younger, smaller fish and the relationship between recruitment and overall biomass will become tighter.

Eny Buchary
Speaking of recruitment, did you separate juvenile and adult plaice in your model to see if there is a correlation?

Sheila Heymans
That will be helpful. The forcing function should be used on the juveniles, not the adults.

Tony Pitcher
It might be useful to drive the model with primary production and look at it again. If you still get a peak, then use your temperature forcing function. The switch between herring and sardines would be driven by temperature.

Nigel Haggan
There are always a few data points you are comfortable with. If you do something to force your line to fit one of them, you would be looking at several more to see if they correlate.

Richard Stanford
It is a question of whether that spike is real.

Nigel Haggan
Look at the degree of divergence from the points you are confident in when tuning your model.

Richard Stanford
I can set forcing functions specifically for plaice.

Tony Pitcher
Does that happen to other flatfish?

Richard Stanford
The other flatfish were not as important, so they were just grouped together. Therefore, their result is an average.

James Wilson
Were you comparing it to things that were happening in the North Sea and the south coast rather than just in the Channel? There is a lot of precise, localized data available. Are you validating your model for the Channel against bordering cases?

Richard Stanford
For some stocks, there is a channel stock, but for most of them, they have a bit of the North Sea stock and a bit of the North Atlantic stock in them, so we have a problem with the ICES data. The northeast Atlantic stock is probably increasing. The English Channel is not an ideal ecosystem to choose. It seemed like a good idea at the time!

Sheila Heymans
If you are only looking at one species, there are so many indirect effects that you are not taking into account. If you force only one species, you can throw everything else affected by that species out of sync. You might want to look at several species together.

Eny Buchary
Or you could look at a keystone species.

Building Consensus on Restoration Goals that are Ecologically Possible and Socially Acceptable.
Nigel Haggan

Nigel Haggan
We talked a great deal about goals that are ecologically possible; that is, what a system will

support in terms of climate and stock. However, the objective of Back to the Future as a policy agenda is to first of all establish an audit of what we have as opposed to what we had. Workshop participants chose four different ecosystems as policy goals in the workshop. That is indicative of the difficulty of finding plans that are socially acceptable. Do you have any thoughts on how we can reach a consensus of what we might find acceptable? The unusual thing about it is that what we ended up with is some variance of today's fishing fleet fishing a restored ecosystem, and that defies common sense. We agree that we have to fish it to make it socially and ecologically possible, but to take our current fishing system which is depleting the populations, and apply it to a restored ecosystem, does not make sense.

Tony Pitcher
When talking to a coastal community that has gone through so much pain and cutback, trying to look over and above the troubles to focus on a restoration agenda is really hard. What hits you in the face is one aspect or another of the allocation issue, which is huge. It is not our fault that there is an allocation issue, but it is there. That is why we are talking about a future restored ecosystem rather than how to get that, but it is hard for people to think about a future in 20 years when they are worried about today's problems. That is a real problem not just for the local people but for everybody. Immediately they ask how we would get to the restored ecosystem.

Robyn Forrest
A fisherman in Prince Rupert said that the problem is not the number of fishers, but the value of the fishery. Is it not better to value the fish and value the resource rather than put them in cans?

Nigel Haggan
That is what I thought we were doing when we asked how much of the species is available for harvest, but the valuation technique uses the prices from today's fisheries. Maybe we should not be doing that. How much money do salmon fishers get from Copper River?

Bill Simeone
They advertise Copper River salmon, so they have a high valuation for early fish. As fishers go further west, the prices drop because people are not interested in Bristol Bay sockeye; they want Copper River sockeye.

Nigel Haggan
So it is a marketing thing. It is a stunt that people did so that people in New York do not want anything else. We should also talk about the price for live fish, such as rockfish, rather than dead fish.

Cyril Stephens
It is not that the species itself does not turn red or looks nicer to cost more; the fish is always the same. It is what people put the price on. Everything goes hand in hand with it.

Bill Simeone
The other thing they have done is to create a limited resource. The Chinook and early sockeye are prime fish. The market opens from the 15th of May to the 15th of June, and then the price for salmon goes down. That is what they do with the wine market as well. It is not that the wine is better if there are only a limited number of bottles for a particular year. They fool people into thinking that this fish at this particular point in time tastes better than anything else.

Nigel Haggan
That is a marketing thing. I have noticed a great lack of creativity on the part of British Columbian fisheries. There are so many things to do with salmon other than just canning them or vacuum packing them in plastic wrap.

James Wilson
You are talking about niche markets. By definition, they are small markets, so you are talking about fetching a high price for a small portion of your catch. You have to be aware of the global market and the effect of aquaculture on fisheries in British Columbia.

On the wider issue of building restoration goals, it is difficult for anyone thinking of what they want realistically 10 years down the line, not to come up with an idealized version. How do you overcome that to make things doable?

Tony Pitcher
You need to have a policy goal and something to aim towards even if you never actually get there.

Bill Simeone
They are narrowing the number of fishers in Alaska by buying out licenses. Not everyone gets a high price for sockeye. They have to treat it correctly, get it to the beach, and then to the helicopter. If it spoils on the way to its destination, they do not get any money for it. Only a few people are getting the big money. One way to deal with that is to have Alaska buy up non-resident permits and getting rid of the people who are not getting the big money out of it.

Nigel Haggan
I was involved with the Stikine River fishery when people started putting fish directly onto totes with slush ice and running them downriver to Wrangell in Alaska. You have to work at it to have the salmon of high quality, but you can get a higher price for it. You do not have to can it all. I think you can create a demand. I think farmed salmon is going the way chicken went. It used to be that chicken was saved for special occasions, but now it is just junk food. There has to be a way to create a high-end market for wild salmon. Alaska has pulled a stunt by getting sustainable certification for their salmon fisheries from the Marine Stewardship Council. People are creating a demand for seafood from sustainable fisheries. If a salmon is ecologically certified and linked to the restoration efforts of the Oweekeno Nation, they will have a product identity and fetch a lot of money.

William Cheung
There is a new certification process with the World Wide Fund to have certification with the Marine Stewardship Council to further enhance ecosystem management.

Nigel Haggan
What we are saying in a way is that getting a higher price for a product is socially acceptable even if it is more difficult to obtain. People who grew up in an area with a long family history have gone from fishing many species all year round to owning huge boats where they can only fish a few days of the year. Is that what we want?

Robyn Forrest
What is the effect of aquaculture farms on salmon? Will it increase the demand for wild salmon?

James Wilson
They may collapse from a demand for wild salmon. Lately there has been a great number of farmed salmon available in the stores. The Chileans produced a lot of salmon last year and a large proportion of that ended up in North America.

Pablo Trujillo
That was deliberate. It was a market tactic to flood the salmon market to lower the price of salmon.

James Wilson
The idea of increasing the value of wild salmon is a great idea, but the demand for high value wild salmon is really limited. You will not be selling tens of thousands of tons because there is not a huge market for it. That will be taking it back to making salmon a rich man's meal as it was before. How much salmon was consumed in the 60s?

Nigel Haggan
I think that there is an opportunity to do it, and that might take the pressure off wild stocks, but it is not good for salmon fishermen. Then again, having someone making their livelihood on one species is unwise.

Sheila Heymans
Having a high value market is good when the economy is doing well, but the first thing that goes during a depression is the $20/kg salmon. Just like the climate, the world market is totally unpredictable. We have to take into consideration that we have no handle on it. Having First Nations dependent on one species is crazy.

Cyril Stephens
Sockeye is *the* fish, delicacy-wise. When putting a price on sockeye, think about the cost needed to get the fish. The costs include insuring a boat and running the gear; all that costs money. Salmon farming is sabotaging sockeye. Aquaculture costs really little compared to someone going out to get wild salmon, and that is dangerous in the eyes of the people, because farmed fish do not cost anything. There is not enough money from the government to enhance wild stocks. All the money is now going to salmon farms. This species of high quality is getting lost in the shuffle.

Tony Pitcher
In traditional times, you might notice that the breadth of human diet was extremely broad. They were harvesting right across the web from low trophic levels to high trophic levels. They were feeding and trading from a wide range of products. One thing that should be thought about in the future is to recapture the broad range of species and exploiting a balance of species. Maybe we can make an algorithm to determine what the balance should look like, something weighted by trophic level.

Barb Johnson
There is a high cost for wild salmon and we do not have that. The inlet has been shut down for some time, and people on the outside along the coast are saying that if they do not have boats they will not have a life. I do not remember when the last of our elders sold the last of their boats. There is no fish in our inlet now. Outside they are screaming about not being able to fish anymore, and we have had 40-50 years of no fishing. No fish, no money. We do not sell our fish. We

preserve it, we live on it. In the last five years, we have skimped and saved from one winter to another.

Nigel Haggan
I remember going fishing with Charles, Barb's husband, and getting 13 salmon from 5 minutes fishing with a net that was full of holes. When the Aboriginal Fisheries Strategy was imposed there was discussion of transferring sockeye to Oweekeno and other First Nations for economic and social development and re-investment in fisheries management. Next thing was that the fishing industry marched to Ottawa and succeeded in having an industrial solution imposed, so that First Nations like Oweekeno had to buy gillnetters and licenses to compete when they could have caught top grade sockeye in the river at no cost. That is the type of idiocy we had to deal with. People are too attached to the gears. Maybe they can look at area licensing so there is some ownership there so people can determine what they want in their area and then come up with a way to get it. Fishers are creative.

Modeling policy using individual gear types in Northern BC.
Cameron Ainsworth and Sheila Heymans

Cyril Stephens
When you give your presentations of the model outcomes, people will probably see where it went wrong. What is unique about this is that you learn from your experience and can then modify the model.

Nigel Haggan
That is the advantage of getting the community to look at the model and spot the absurdities. A lot of issues came up during the Prince Rupert workshop that would not have come up otherwise.

Barb Johnson
It would be good if you could show somewhere along the line that if this is what we do, then this is the result we are going to get. We can't do all of this. It is up to those ones up there to see what is going on. If they can't see what is happening on this side because of what is happening on the other side, then we are in trouble. We should find out where we are going if we keep on fishing with the current fleet.

Sheila Heymans
We did that in the beginning in the workshop in Prince Rupert but then the people shot us down because of the group policy choices. We will re-run the results with improvements.

Tony Pitcher
The point is not so much to show sustainability but to compare what would happen if we carried on with the present fleet and catch.

How to model the impacts of aquaculture.
Pablo Trujillo

Karin Mathias
Are you planning to address things like the impacts of the introduction of growth hormones and the use of antibiotics in your work?

Pablo Trujillo
In my thesis yes, but I don't think I can do that in the model.

Villy Christensen
You can do that using Ecotrace to model the flow of antibiotics from the pen into the environment.

Pablo Trujillo
I suppose I can do it as part of the nutrient flow. There is so much to do. We are very far away from having any sort of sustainable aquaculture in Canada. Hopefully, before there is an opening of the industry, we will have better regulations for control.

James Wilson
You are talking about finfish aquaculture?

Pablo Trujillo
Yes, I was generalizing again. When you talk about aquaculture here it generally refers to fishfarms, but the term is much broader.

James Wilson
In terms of modeling aquaculture historically, in France mollusk culture has been going on since the fourteen hundreds. That would be a good modeling exercise.

Nigel Haggan
With mussel aquaculture you are just increasing the amount of mussel habitat, not adding nutrients to the environment.

James Wilson
That is what I mean. It is extensive culture but you are encouraging growth as much as anything.

William Cheung
In your modeling will you also look at the effect of the introduction of alien species on the ecosystem?

Pablo Trujillo
Yes, I can do that. Atlantic salmon is one and Japanese oysters may be another. There may be other species that I would want to do that with. The advantage in modeling aquaculture is that it can be very site specific and thus localized, and can be a constant import to the ecosystem.

Karin Mathias
Are you planning to look at the various outcomes? In your talk you tried not to be polarized either way but what are you planning to model in your research?

Pablo Trujillo
I will do a comparative model using the data I have from Chile, which has many fish farms compared to BC. I can use the model to assess scenarios; for example, what happens in twenty years' time if we have an increase in fishfarming in BC.

Nigel Haggan
There is another impact that people in Prince Rupert talked about. Some intensive farms are on the pathway of migrating salmon smolts. It was suggested at the workshop that the farmed salmon eat the smolts that end up in their pens. If this is true, there is a potential impact of fish farms on recruitment of wild salmon.

Pablo Trujillo
In Chile, Atlantic salmon eat only pellets, as opposed to trout which are cannibalistic. If we are going to have salmon farms in BC as is likely to happen, my advice would be try control it beforehand. We can use local native species and ban the foreign ones, for example, or use aquaculture to restock wild populations. You can regulate aquaculture to be as benevolent as possible to the ecosystem.

Cyril Stephens
Is there a difference in texture when cooked between the farmed Atlantic salmon and the wild salmon?

Pablo Trujillo
It has been said that chefs prefer farmed Atlantic salmon because these fish have an evenly distributed fat and the filet maintains a better appearance when cooked!

Cyril Stephens
For those of you who have not tasted a wild salmon, like sockeye or chum, when you are so used to eating the wild stocks, there is no better food than that. If I catch a salmon up the creek and bake it in December, it is very mushy and very soft. Farmed salmon is not anything close. You don't know what you are missing if you haven't tasted a wild salmon.

Problems in modeling changes in habitat and MPAs using *Ecospace*.
Eny Buchary

Erin Alcock
Is the number of habitat cells on the map fixed, independent of the size of the area?

Eny Buchary
At the moment *Ecospace* can only accommodate up to eight habitats. But I think the program can be altered to increase the number of habitats when needed [*it has been, Ed*.]. Nevertheless, if you have more habitats in your model, it will get too complicated. For the Hong Kong map, there are 625 cells with 37 functional groups and four habitats. For that model I need ten minutes to run one simulation.

Tony Pitcher
This workshop is leading towards a *Coasts Under Stress* project evaluation in September and from now until then the team will be writing up what we have done so far. Using *Ecospace* to model Newfoundland and BC is an aspiration for the next phase.

Nigel Haggan
For some of the people here who are doing fine scale modeling, *Ecospace* may be ideal and the team here can give you a hand.

The DFO Hecate Strait Project.
Villy Christensen

Kelly Vodden
I have been speaking with Jeff Fargo (DFO) about incorporating the human and local traditional knowledge in this ecosystem approach and I know there is a move towards that. Has the team discussed it at this point?

Villy Christensen
Their interest is in fisheries and it will take years before they are ready for that. I have heard from the principle investigators in the project that they are interested in linking those concerns in the project. The Hecate Strait project is a hard-core search for numbers and that needs to be done in fisheries.

Nigel Haggan
We have a mandate to work with communities

from *Coasts Under Stress*, but our budget is low.

Tony Pitcher
Referring to the recruitment for the cod driven by environmental factors, would it be possible to build a forcing function for juvenile cod into Ecsoim to make it follow that time series?

Villy Christensen
Yes, it would.

Kevern Cochrane
You are looking for performance indicators, but these will be influenced by the objectives for utilizing that ecosystem. Are you looking at the policy and objectives or at what it is that people want?

Villy Christensen
I cannot speak for the Hecate Strait project because my model is technical. The SCOR ecosystem indicators working group that I lead includes people from all over the world working together. In that context we are working with four or five sub-working groups, one of which is led by Bill Costanza and deals explicitly with the social sciences. It is a component of the deliverables.

ANNEX: Programme of 2002 BTF/CUS Workshop at UBC

BACK TO THE FUTURE: METHODS & RESULTS

A Symposium on The Restoration of Past Ecosystems as Policy Goals for Fisheries

February 20-22, 2002, at the Graduate Student Centre, UBC

Coasts under Stress

PROGRAMME

Wednesday 20th Feb: Day 1

The aims and methodology of BTF

09.00-09.20 Welcome and Introduction to the workshop – Nigel Haggan
09.20-09.40 Introduction to BTF – Tony Pitcher and Eny Buchary
09.40-10.00 Constructing models of the Past – Sheila Heymans and Tony Pitcher

10.00-10.20 **Coffee**

10.20-10.40 *Coasts Under Stress* –knowledge of the past as the basis for future policy – Rosemary Ommer
10.40-11.00 Why we have to open the Lost Valley – Tony Pitcher
11.00-11.20 How can we value the restoration of the past? – Rashid Sumaila
11.20-11.40 Principles of Environmental Archaeology - Quentin Mackie and Trevor Orchard
11.40-12.00 **Discussion:** Can we actually change policy using BTF? - Nigel Haggan

12.00-13.20 **Lunch Break**

Clues that help us describe and model the past for BTF

13.20-13.40 Case Studies in Environmental Archaeology: Gwaii Haanas and the Aleutian Islands - Trevor Orchard and Quentin Mackie
13.40-14.00 Seaweed and the past – Nancy Turner
14.00-14.20 Making Sense of Ethnographic Research for Resource Managers and Fisheries Scientists: or, Why a fisherman takes three hours to answer a simple question – Charles R. Menzies
14.20-14.40 Filling in the Blanks - the Oral History of Haida Gwaii Herring – Russ Jones

14.40-15.00 **Coffee**

BTF project team papers

15.00-15.20 The Northern BC historical and interview database for BTF - Aftab Erfan
15.20-15.40 Ecosystem models of past and present: Northern BC - Cameron Ainsworth
15.40-16.00 Ecosystem models of past and present: Newfoundland – Sheila Heymans

16.00-17.00 **Round Table 1:** Discussion on Visualization and Presentation

- How can we represent complex models to local communities: what we have done and what we have learned? Examples of what we did (Melanie Power)
- How can we represent policy searches to local communities: what we have done and what we have learned. (Eny Buchary)

Thursday 21st Feb: Day 2

9.00-9.20 Ecosystem models of past and present: Hong Kong - Eny Buchary and William Cheung
9.20-9.40 Quantifying qualitative information in a past ecosystem model of Hong Kong - William Cheung
9.40-10.00 Micro-level reconstruction of the Bonne Bay, Newfoundland fisheries between 1891-2000 – Kara Rogers, Jeff Webb, Barb Neis

10.00-10.20 **Coffee**

10.20-10.40 Management Policies of Snow Crab and Herring Fisheries: From TEK to Science and Back / Decadal Change in Food Webs of the Newfoundland and Labrador Shelf - Erin Alcock
10.40-11.0 The Community Workshop: How we did it and what we learned from the results. – Melanie Power / Nigel Haggan
11.00-11.20 The Community Interviews: How we did them and what we learned from the LEK results. – Cameron Ainsworth
11.20-11.40 What are the sport fishery catches from Northern BC? – Robyn Forrest
11.40-12.00 Strictly for the Birds – Tony Pitcher (*for the Bill Montevecchi team, MUN)*

12.00-13.20 **Lunch Break**

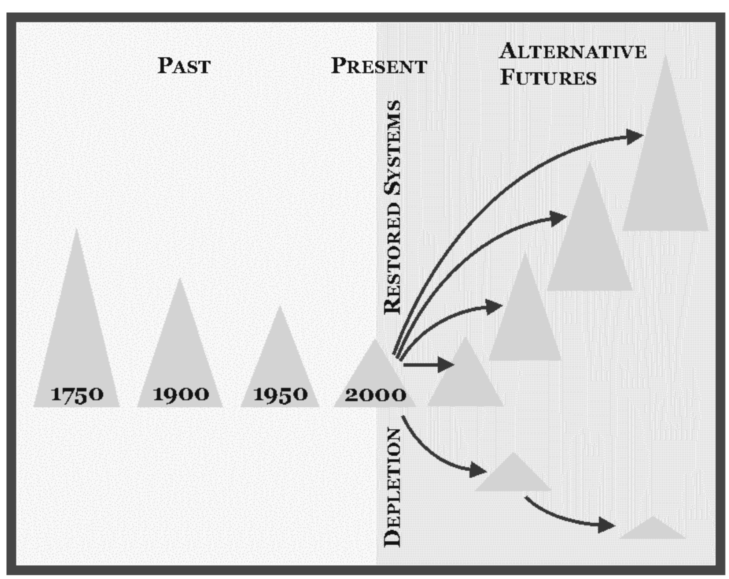
Issues in Modelling the Past and Forecasting the Future

13.20-13.40 Problems in Modelling rockfish in Northern BC – Erin Foulkes
13.40-14.00 Integrating migratory species into ecosystem models - Steve Martell and Stephen Watkinson
14.00-14.20 What was the structure of past ecosystems that had many top predators? – Tony Pitcher
14.20-14.40 Running ecosystem simulation models using information about past climate – Robyn Forrest and Tony Pitcher

14.40-15.00 **Coffee**

15.00-15.20 The problem of local extinctions - Tony Pitcher
15.20-15.40 Problems in 'tuning' ecosystem models to past data Richard Stanford
15.40-16.0 The DFO Hecate Strait project Villy Christensen

16.00-17.0 **Round Table 2:** Building consensus on restoration goals that are ecologically possible and socially acceptable. Nigel Haggan



Friday 22nd Feb: Day 3

Issues in Modelling the Past and Forecasting the Future – Continued

9.00-9.20 Modelling policy using individual gear types in Northern BC – Cameron Ainsworth and Sheila Heymans.
9.20-9.40 How to model the impacts of aquaculture – Pablo Trujillo
9.40-10.00 Problems in modelling changes in habitat and MPAs – Eny Buchary

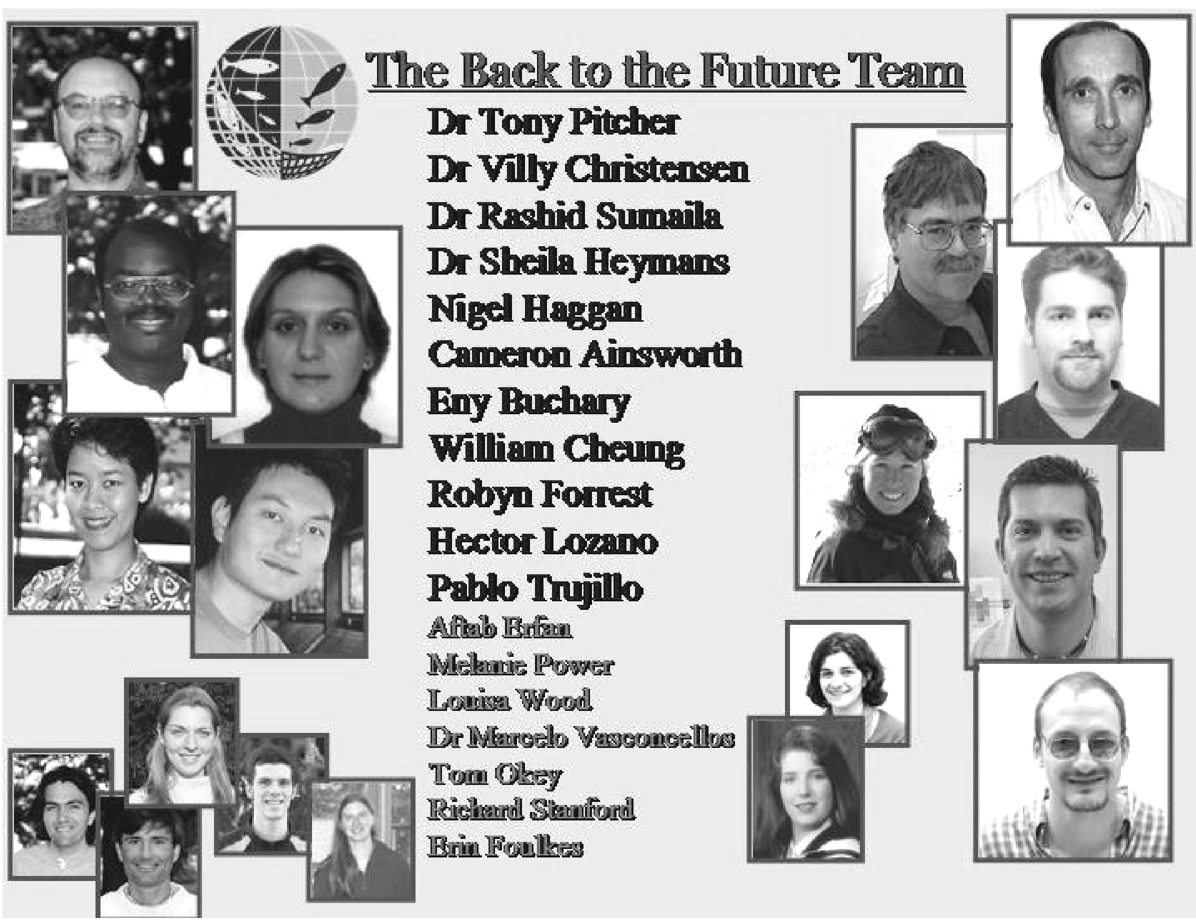
10.00-10.20 **Coffee**

Issues in valuing restored ecosystems

10.20-10.40 Aboriginal Values – Arnie Narcisse
10.40-11.00 How do we take aboriginal values into account? – Rashid Sumaila
11.00-11.20 A Great Leap Backward?? – Nigel Haggan

11.20-12.00 Final Discussion

12.00 Lunch and adjourn



The Back to the Future Research Team in mid-2003 (former members in smaller type)