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Back to the Future: Reconstructing the Strait of Georgia Ecosystem

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edited by

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Edited by
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Abstract

The contributions in this report jointly describe the ecosystem of the Strait of Georgia, British Columbia, Canada, as it presently is, and as it might have been one hundred years ago, before the massive expansion of commercial fisheries, and five hundred years ago, before contact of native Peoples with Europeans. The evidence reviewed includes ecological studies and analyses not only from all of the fish species, but also from all parts of the ecosystem, from whales, seabirds and salmon, to plankton, herring and clams. Essential information on the presence, location and abundance of living organisms is obtained from historical records and documents, linguistic studies, archaeological remains (including petroglyphs and pictographs), and the oral history and traditional environmental knowledge of the Aboriginal people who still live around the Strait of Georgia. All of the scientific and cultural information is used in the "Back to the Future" method.

This qualitative and quantitative evidence, gathered during a three-month pilot project, was reviewed at a multidisciplinary workshop held in November 1997 at the First Nations House of Learning, U.B.C. The data has been used to construct ECOPATH mass-balance models of the Strait of Georgia for the three time periods. The models comprise 25-27 functional groups. The epistomological, conceptual, and methodological issues raised by this interdisciplinary approach are discussed, as is the suitability of the ECOPATH method to serve as a template for ecosystem reconstructions of this type.

The work reported here represents a pilot phase in developing this new methodology. The "Back to the Future" process includes the model reconstruction of past and present ecosystems as a way of informing policy choices for fisheries. The evaluation of local benefits that may be extracted from alternative ecosystems, the design of practical management instruments, and the monitoring of the recovery of ecosystems and compliance, are all factors all that may endow the "Back to the Future" method with powerful support and consent among an unprecedented broad range of stakeholders. The next steps, both for improving the Strait of Georgia reconstructions and for the "Back to the Future" methodology, are discussed.

Pauly, D., T. J. Pitcher, and D. Preikshot, (Eds) 1998. Back To The Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Centre Research Reports 6(5).

Director's Foreword

The failure of fisheries science, paradoxically one of the most sophisticated mathematical fields within the discipline of applied ecology, is creating both trauma and denial among its practitioners.

Did I hear someone say "What failure"?

Conspicuously, that is in full view and knowledge of its licensed professional practitioners, fisheries science has failed to foresee major stock collapses (e.g. Newfoundland cod); to prevent collapses that were foreseen (e.g. Ecuadorean mackerel); to restrict the growth of fishing power and chronic overcapacity (globally); to attract support from fisheries stakeholders (anywhere they know themselves to exist); to avoid local extinctions of valuable species (e.g. Hong Kong); and to gain support from the moderate wing of the conservation community (Europe and North America), which is undoubtedly correct in its diagnosis of the need for change. These failures are chronic and well-documented and are commonly responded to by many of our colleagues in a range of voices that seek to deflect and deny.

To those of our colleagues in denial of these failures – we say examine the evidence! To those of our colleagues who blame environmental changes for fishery collapses, we say – remember that these supposedly delicate fishes have survived 100 million years of sweeping and cyclic environmental changes, including a global catastrophe that wiped out the dinosaurs and giant marine mammals! To those of our colleagues in denial of the need to change – help us extend the frontiers and try do at what we were formerly unable to do! To those of our colleagues tempted to sell out cynically to direct funding from the fishing industry, we say – think again about your freedom to state your findings about sustainable catches! To those of our colleagues who respond to our enthusiasm for a new and incomplete ecosystem science by claiming that we are acting merely as advocates, thereby committing the cardinal sin of science, we say – review and think carefully about the problems faced by new methods!

And rather than seek the impeachment of the fishing industry or the closure of all oceans to fishing, as suggested by the wilder species of conservationists, surely its better to look for ways of improving the scope of fishery science and at the same time seek a wider public support?

We at the Fisheries Centre believe that the "Back to the Future" process is capable of doing just that. This is an exciting new approach that challenges our science by requiring all kinds of ecological scientists to work together. The method prompts us to harness the work of economists, historians, archaeologists and linguists. "Back to the Future" has a direct use for the traditional environmental knowledge of indigenous peoples and experienced coastal fishing communities.

This report describes an exciting and innovative venture in interdisciplinary ecosystem analysis. "Back to the Future" is a technique that in its first year of life has attracted a remarkable wide range of support. Rather than snipe at its inadequacies, which is an easy target when directed at something which endeavours to describe the entire 500-year history of a complex aquatic ecological system, we invite our colleagues, by reading this report, to offer constructive criticism and help us to develop its analytical instruments.

Fisheries Centre Research Reports publishes results of research work carried out, or workshops held, at the UBC Fisheries Centre. The series focusses on multidisciplinary and innovate approaches to 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 workshop participants and project partners, and are reported in the Aquatic Sciences and Fisheries Abstracts (ASFA). A full list of previous reports appears on the Fisheries Centre's Web site, htpp://fisheries.com. Copies are available on request for a modest cost-recovery charge.

Tony Pitcher
Director, Fisheries Centre

Preface and Acknowledgements

This report documents the results from three months of research and a workshop devoted to ecosystem simulations of the Strait of Georgia, the sea inlet between Vancouver Island and the lower Mainland of British Columbia. The meeting was held on November 21-22, 1998 at the First Nations House of Learning, University of British Columbia.

Lots of workshops are conducted at UBC, and lots of workshops have been devoted to various features of the Strait of Georgia. Yet ours was not just another workshop. Its scope was different from that of previous attempts to understand the events affecting the Strait of Georgia, and the participants invited to that workshop were an unusual mix, not frequently encountered on the UBC campus.

The scope of the workshop presented in this report was the entire Strait of Georgia ecosystem, from its algae and shellfishes to its fish and fisheries, and the marine mammals to which it is a home, now and in the past. The temporal scope was broad as well: we attempted to reconstruct the Strait of Georgia ecosystem as it is now, and as it was 100 and 500 years ago, in order to provide a vision for rebuilding the Strait's once abundant resources. Thereby, we illustrated the "Back to the Future" approach, recently conceived, at the Fisheries Centre, UBC as an alternative to the ultimately selfish notions that fuel B.C's continuous, and acrimonious fish allocation debates.

The notion of rebuilding exploited populations resonates strongly with present First Nation communities, not least because they are heirs to a long tradition of sustainable exploitation of abundant resources. This is one reason - though not the only one - why this workshop was held in at First Nations House of Learning. Another reason was that First Nation partners were involved at all stages of the project which led to this report, another first. We thank them for the confidence this implies.

The project and workshop participants ranged from First Nation elders to commercial fishers and academics of vastly different disciplines, in both the Arts and the Sciences (see list of participants page 92). Our project and workshop bridged the gaps between our experiences and disciplines, clearly a characteristic of the "Back to the Future" approach. Indeed, we even saw University-based fisheries scientists agree with their colleagues from the Department of Fisheries and Oceans! We thank all these workshop partners for their patience with each other, and their constructive attitude. We hope they enjoy this report and are willing to return to this topic again.

Another important feature of the project which led to this report is the key role played by four UBC graduate students: Johanne Dalsgaard, S. Scott Wallace, Sylvia Salas and David Preikshot. Their tasks ranged from the 'usual' (i.e., doing the leg-work, the number-crunching and interviews) to the uncommon (writing up the key papers, and in the case of David Preikshot, acting as co-editor of the final report). We thank them wholeheartedly for their effort, and for the enthusiasm with which they ran this project.

This has been pioneering and exciting work and we are really most grateful to our partners among the fishing and aboriginal communities, especially to Ross Lodge, Duncan Stacey and Robert Kreutziger from the BC Community Fisheries Development Centre, and Dr Jo-Ann Archibald, Director of the First Nations House of Learning on UBC campus, for providing invaluable assistance in locating, sifting and evaluating historical, archival and cultural material.

Finally, we acknowledge financial support from the Peter Wall Institute for Advanced Studies, UBC, whose support, although modest, has made this pilot work possible.

The Editors
December 1998

Part 1: Conceptual and Methodological Framework for Ecosystem Reconstruction

"Back To The Future": a Novel Methodology and Policy Goal in Fisheries

Tony J. Pitcher
Fisheries Centre, UBC

Abstract

The key characteristics of the Back to the Future methodology are presented. These are: (1) construction of a mass-balance model of the ecosystem of interest; (2) the involvement of local and, if any, aboriginal community representatives and the use of historic and archaeological data in identifying qualitative features of the ecosystem at an early period; (3) the incorporation of the features identified in (2) to construct a mass-balance model of past ecosystems; and (4) the formulation of policy objectives based on a 'rebuilding' plan derived from the architecture of past ecosystems.

Introduction

The rebuilding of resources, rather than sustainability, represents a new policy goal for fisheries management (Pitcher & Pauly 1998). Such a policy likely represents the only hope for the future for fisheries targetting wild living resources, which have been progressively and seriously depleted (e.g. Pauly et al. 1998). This approach attempts to reverse the ratchet-like-

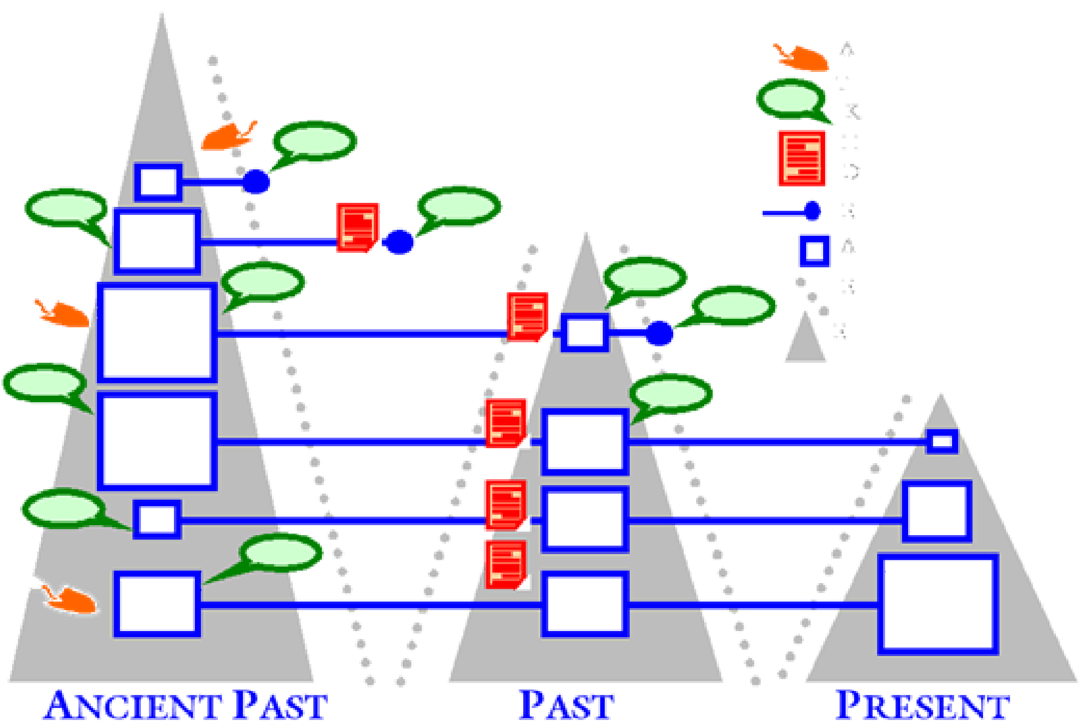

Figure 1. Diagram illustrating the 'Back to the Future' methodology for the evaluation of past ecosystems. Triangles represent three Ecopath models, constructed at appropriate past times, where vertex angle and height is inversely related to biodiversity and internal connectance. Timing of models depends on the locality, the dawn of quantitative documentary evidence and major shifts in resource history; a fourth model might be drawn up for a pre-modern human, late Pleistocene era. Broken lines next to triangles represent limits to Ecosim simulation modelling of 'what if?' scenarios based on the Ecopath models. Time lines of some representative species in the models are indicated, where the sizes of boxes indicate relative abundance. Sources of information for constructing and tuning the Ecopath models are illustrated by the symbols for historical documents, archaeological data and the traditional environmental knowledge of indigenous Peoples. For further details, see text.

ecological processes caused by human fishing, which have been largely ignored by a fisheries science primarily concerned with single species population dynamics (Pitcher 1999).

In the 'Back to the Future' (BTF) approach, scientific tools are used to construct and evaluate present and past ecosystems. The policy objective for management becomes the rebuilding of the past system that would, if restored, maximise economic benefit to society. The approach is fundamentally different from a policy goal of sustainability, which may seek only to sustain present misery.

Ecosystem modelling techniques have recently been harnessed to this new multidisciplinary methodology for the model reconstruction of past systems and for the evaluation of their present economic value (Pitcher et al. 1999). These methods, termed '*BACK TO THE FUTURE*' (BTF), employ Traditional or Local Environmental Knowledge (TEK or LEK), historical documentation and archaeology (including ancient DNA or molecular archaeology), to validate ecological modelling of species now much depleted or lost. Past and present ecosystems, from plankton through fish, marine mammals and seabirds, are modelled using the Ecopath and Ecosim techniques, including simulations to answer 'what if' questions, such as changes in fishing practices and the closure of areas (Pitcher 1998a). Evaluation of a series of such reconstructed ecosystems since ancient times can illustrate dramatically how past marine harvests have progressively foreclosed our future economic options (Pitcher and Pauly 1998).
The *Back To The Future* methodology supplies a practical direct use for the knowledge of maritime historians, archaeologists, ecological economists, fisheries ecologists, and the TEK of indigenous peoples. (See related contributions in this volume.) It gives all these participants an exciting common goal. Interestingly, TEK, if not denied a voice is strengthened in the BTF process by a cross-validation with ecological science, and may thus be endowed with a real and valuable role in shaping future fisheries policy.

TEK and the Back to the Future Process

Because it is generally not structured in the same way as ecological science, at first sight it appears difficult to entrain TEK to the '*Back To The Future*' process. But through use of carefully designed questionnaires and interviews, it is possible to break complex matters down into simple choices, for example: of presence and absence, place and time. Abundance can be scored relative to other times, or relative to other organisms in the ecosystem. Thus this

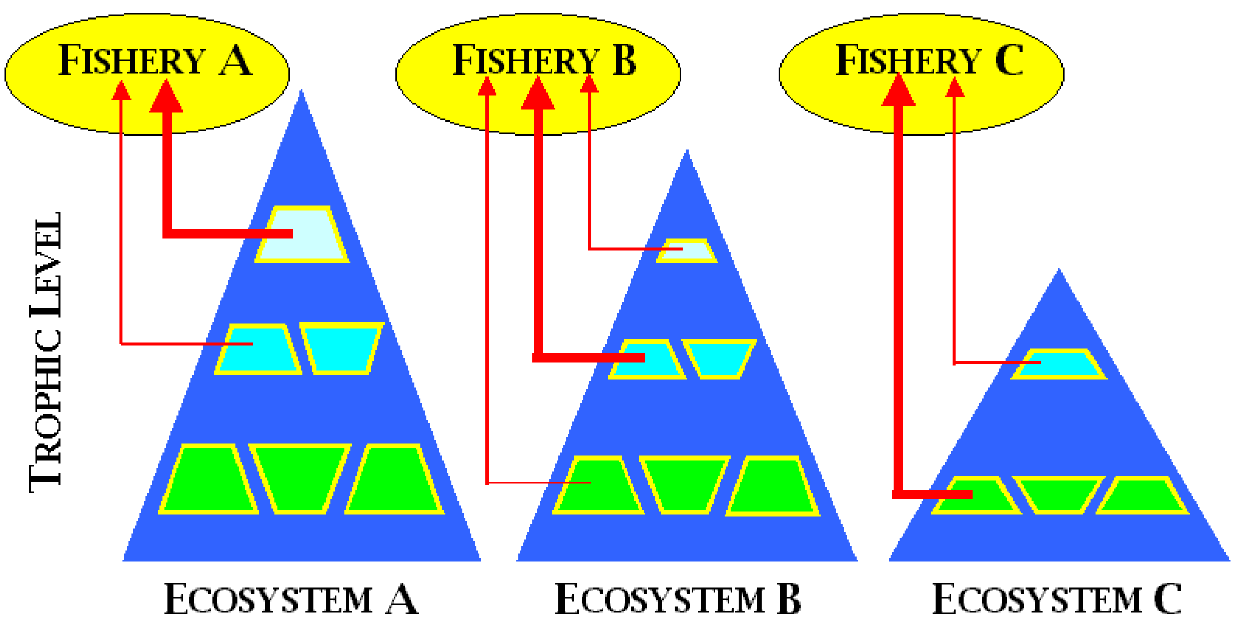

Figure 2. A schematic illustrating the ECOVAL a comparative policy evaluation process. The triangles represent ECOPATH models, which are drawn up for the current ecosystem and its fishery alongside several alternative ecosystems with different fishing regimes. The vertical axis of the pyramid represents the trophic level of resources that might be exploited. Schematic resources are illustrated at three trophic levels. Vertical arrows leading to ovals at the top represent fishery catches. The table below the diagram summarises suggested evaluation criteria, including costs of implementation. For further details, see text.

partnership between TEK and Ecopath can provide a powerful description of past ecosystems (see Haggan 1998).

Figure 1 is a diagrammatic representation illustrating the model construction part of the BTF method. The triangles represent Ecopath models, which are drawn up for the present day and a for a series of specified past times. Triangles are used because the Ecopath model is conventionally represented in this way, where the vertex angle and height of the triangle are scaled to overall transfer efficiency which is related to biodiversity and internal connectance (Dalsgaard et al, this vol.). The dotted lines represent limits to Ecosim 'what if' simulations employing species present at each stage only. The boxes represent species, and the size of boxes, the relative abundance. Note that boxes could equally well represent genetically distinct lineages within a species. Arrows between boxes show the time line of species, ending when local extinction occurs. (see Pitcher, this vol., for a sea cow example). Information about what species were present comes from archaeology, traditional knowledge or documents represented by the respective symbols. Abundance estimates may be given as trial input to the Ecopath model which can then be used to adjust the values to be compatible with the trophic web.

Figure 2 illustrates this second part of the BTF method; the comparative evaluation of alternative ecosystems. The triangles represent Ecopath models, which are drawn up for the current ecosystem and its fishery alongside several alternative ecosystems with different fishing regimes. One model, for example, might represent an unfished ecosystem.

Applying the Back to the Future Approach

The historical times at which it may be appropriate to draw up Ecopath models will vary among sites. For example, in the Strait of Georgia, British Columbia, Ecopath models have been constructed for the present day; for 100 years BP before the huge modern expansion of fisheries; and 500 years BP before contact of native peoples with European settlers and the expansion of the fur trade (Dalsgaard et al. this vol.). In other localities, different snapshot timings will be appropriate and more or less than the three snapshots we have used here will be required.

The essential feature of the BTF process is to evaluate the benefits that might be gained by restoring all, or elements of, former ecosystems (Pitcher et al. 1999). Local extinctions caused by fishing (Pitcher 1998b) constrain what maybe possible, although a range of restoration and reintroduction options may be contemplated for valuable species (for discussion of these options see Pitcher 1999). Policy decisions would be based upon choosing the ecosystem that maximises the benefits, economic and social, to society. In human-made environments, such as lakes, policy options may be compared using a range of alternative ecosystems (e.g. Pitcher 1999b for Lake Nasser, Egypt). In nearly all cases, past ecosystems provide more valuable policy goals than present or future ones, future ecosystem being envisaged as what will happen as we continue to alter the nature of marine ecosystems by fishing down the food web (Pauly et al. 1998). Unfortunately, continuing depletion by effort expansion of catching power and overcapacity in fisheries means that the status quo is not really an option.

In summary the BTF procedure consists of seven stages:

1. Ecopath model construction of present and alternative ecosystems;
2. Ecosim and Ecospace exploration of the limits to fishing, sector by sector, for each alternate;
3. Evaluation of economic and social benefits for each system;
4. Choice of policy goal as the ecosystem that maximizes benefits to society;
5. Design of instruments to achieve this policy goal;
6. Evaluation of costs of these management measures;
7. Adaptive implementation and monitoring of management measures.

The various contributions in this report document the wide range of linkages established in the course of the project leading to our three models of the Strait of Georgia. Application of the BTF approach to other areas will require a similar range of linkages that are much wider, incidentally, than required for standard 'fisheries stock assessments'. We look forward to the gradual emergence, among fisheries scientists and their disciplinary neighbours, of a sense that such wide ranges of linkages is a 'normal' requirement of their work. This, by itself, would make the BTF approach a success.

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Knowledge Gains Power When Shared

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Abstract

Three researchers from very different backgrounds describe their experience with Ecopath as a way to integrate different traditions of knowledge, represented by the voices of First Nation Elders, the academic tradition of the University of British Columbia, and commercial and sport fishers. The role of human nature and thought in our present ability to catch all the fish in the sea is discussed. Two challenges are posed: how to reverse the course of human thought about fisheries and how different traditions of knowledge and branches of science can learn to communicate and work together with dignity and respect. The paper explores the role of UBC as a neutral forum and facilitator, and the potential of ecosystem modelling to focus discussion and integrate information from disparate sources. It introduces, and is focussed upon, the Sto:Lo Nation insight that "Knowledge Gains Power When it is Shared."

Introduction

People have been fishing since the dawn of time. No one knows how it all began. Maybe from watching other creatures catch fish and eat them. Herons spear them. Bears flip them up on the bank. Eagles seize them in their talons. Maybe traps were invented after watching fish stranded by the ebb tide or caught in a basket left in a stream. 85,000 years ago, people in Africa carved fish spears out of deer antlers (Yellen et al. 1995). Fishing skills evolved and spread very fast. People watch, learn and adapt. They communicate with each other. They learn from people they meet in their travels and pass on their own skills in return. If they are fishers, they brag and compete.

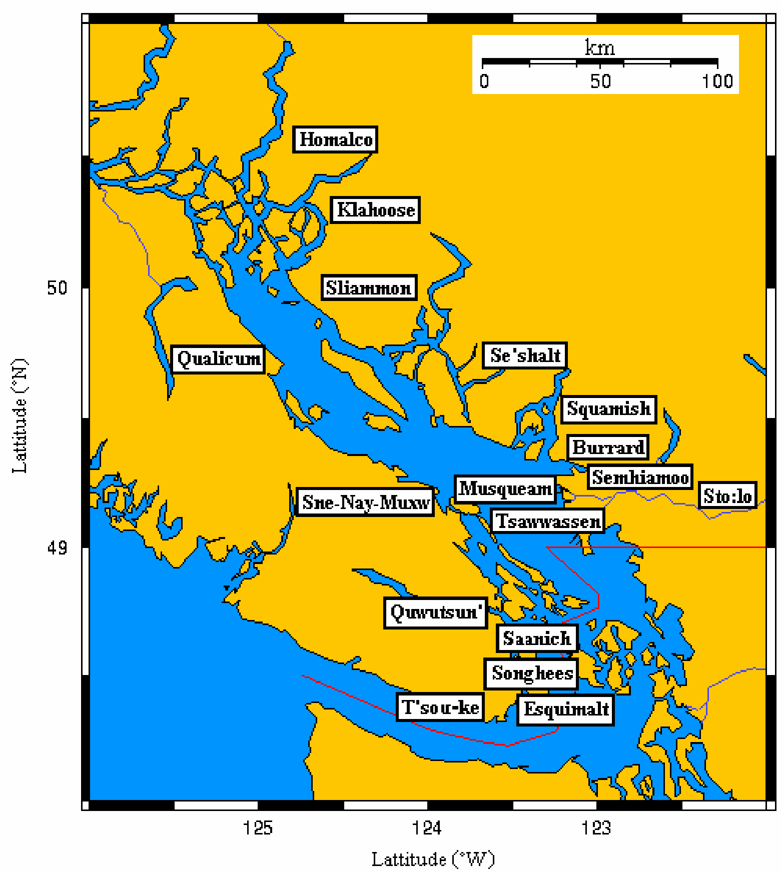

Figure 1. First Nations language groups around the Strait of Georgia (Prepared by Dave Preikshot based on data from the UBC Museum of Anthropology web page; www.moa.ubc.ca).

They lie awake at night trying to think of better ways to catch fish. Above all, they pass knowledge from one generation to another.

In the years since people invented fishing technology, we have learned to catch virtually all the fish in the sea. The food needs of a growing world population, expanding seafood markets and excess catching power threaten fish stocks with extinction. Humankind is now faced with a challenge of mythic proportions: how to halt the decline in major fisheries and re-direct human ingenuity to rebuilding aquatic ecosystems (Pitcher and Pauly, 1998).

The consequences of failure are ecologically, economically and culturally devastating. The collapse of the east coast cod was a disaster (Walters 1996; Walters and Maguire 1996; Ommer 1994). Mitigating community impact has cost Canada $3 billion to date (Anon. 1997). The social and cultural loss to outport communities is incalculable. The grief felt at this loss is well understood by BC First Nations who had earlier lost access to the salmon and other resources forming the economic, cultural and spiritual basis of their societies (Brown, 1993).

Another deep issue is the reversal of the fragmentation of knowledge. The Christian Bible tells of a nation who set out to build a tower so high that it would reach up to Heaven. God was not amused and punished them for their arrogance by causing them to speak in different languages. They had to give up on the tower because they couldn't work together anymore. The story of the Tower of Babel parallels the development of science. In the 19th Century, it was possible for one, well educated person to grasp the elements of all branches of science. As inquiry progressed, scientists had to content themselves with narrow fields of enquiry. Each field acquired its own language and rules.

And yet, questions such as what really goes on under the surface of the ocean fascinate fishers, scientists and other people alike. Fish seem to have a powerful hold on the human mind. There are few people who won't stop and look into a body of water. Fewer who won't smile with quiet satisfaction if they see a fish. Clean water and healthy fish are a metaphor for the health of the social and physical environment. Similarly, the message sent by science about the disappearance of fish from the world's oceans is deeply upsetting, as reflected, for example, in the strong media response to the paper of Pauly et al. (1998).

Nigel Haggan spent 12 years working with First Nations on the design and implementation of cooperative management programs and policy. His thinking was profoundly influenced by two early experiences as a Technical Advisor to the Oweekeno Nation on the central coast of BC. First was an April night when an Oweekeno Nation member took his three young children to the lakeshore and shone a Coleman lantern in the shallows so that they could see the sockeye salmon fry emerging from the gravel. The second was the same man going to all resource users in the territory, loggers, commercial fishermen and sportfishing lodge operators to seek funds and in-kind contributions for a salmon hatchery. This example of First Nations, other resource users and government joining forces to restore depleted fish stocks formed the basis for 12 years work with the Oweekeno and other First Nations in planning and implementing fisheries programs and policy development.

Over this time it became clear that the divisive influence of allocation disputes was much stronger than the pressure for First Nations, government and industry to work together in the interest of conservation and good management. 'Fish wars' between Canada and the US, allocation disputes between commercial gear types, a growing sportfishing industry, the re-emergence of First Nations' fishing rights and an increasingly effective environmentalist movement contributed to a climate of polarization. Evidently a new type of forum was needed. Something with no baggage or alignment to any one sector. The one possibility seemed to be a university such as UBC. Within UBC, the Fisheries Centre and the First Nations House of Learning joined forces to explore ways to integrate different traditions of knowledge.

The First Nations Longhouse was the site for the November 21-22, 1997 workshop with various community representatives. The Longhouse serves as a 'home away from home' for the First Nations students who study at UBC and a gathering place where people can share their knowledge and culture with others. The building blends traditional architecture with the modern and reminds us to be respectful and responsible as we seek to combine various kinds of knowledge. While the Fisheries Centre is anchored in the European academic tradition (Cahill, 1995), the FNHL longhouse reminds us that the university itself is located on land occupied by the Musqueam Nation, whose culture was founded and sustained for thousands of years by the fisheries of Georgia Strait and the Fraser River (ref).

Two traditions of knowledge and thought come together in the present study. The Traditional Environmental Knowledge (TEK) of Aboriginal communities (Hunn 1993, Inglis 1993) combines with science carried out by government laboratories and universities (Preikshot, this vol.). TEK involves sources such as:

- Myths and stories illustrating the relationship between people and the rest of creation (see Williams, this vol.);
- Information from First Nations Elders see Archibald et al., this vol);
- Information from commercial fishers;
- Information from sport fishers;
- Fish remains and human artefacts in the archaeological records;
- Archival sources and popular literature (see Wallace, this vol.);
- Information on past, present and future trends in climate.

Integration of Traditional Knowledge

There has not been a great deal of crossover between TEK and formal scientific knowledge. TEK is primarily concerned with relationships and connections within the ecosystem. Fisheries science, at least heretofore, has focused on one or two commercially important species.

TEK illuminates the whole stage, while fisheries science spotlights key performers. From this perspective, at first sight, the myths and stories that characterize TEK shed little light on the dynamics of fisheries. But previous analyses of TEK have provided helpful insights in terrestrial ecosystem management (e.g. Bomford & Caughley 1996). Moreover, TEK has been cross-validated with ecology in tropical marine ecosystems (Ruddle & Johannes 1985, Johannes 1981, 1978). The scope of TEK in Canada is reviewed by Kuhn & Duerden (1996). There have been several descriptive attempts to show how TEK might be used to help sustainable management in Canada (Richardson 1992, Freeman & Carbyn 1988), Australia (Williams & Hunn 1982) and for aquatic resources in British Columbia (Weinstein 1994, Kew & Griggs 1992). Back to the Future goes beyond this description, however.

Many First Nations have a story about the importance of returning salmon bones to the river. If this is not done, the salmon will not come back. Fisheries scientists have known for a long time that the productivity of lakes and streams is related to the amount of nutrients which salmon bring back from the ocean and contribute to the waters when they die. Indeed, salmon carcasses have been identified as a major contributor to the forest ecosystem. When you think about it, rain leaches nutrients from the land. Water runs from the mountains of BC like rain off an iron roof. Returning salmon bring nutrients back. Bears, eagles and other agents spread them over the forest.

Science is precise. It expresses itself in defined terms, it feeds on numbers and expresses them in figures, tables and graphs. TEK is much less precise. Names may link fish species, weather or other factors. Similarly, names of time of year or months may relate to important fish runs. Numbers where they exist, range from none at all, to some to lots.

Ecopath offers a way to link scientific data with TEK. Both Ecopath and TEK are concerned with the relationships, ratios and connections within the ecosystem than with achieving an absolute understanding of individual elements. In their own way, both Ecopath and TEK are comprehensive, just as local fishers consider an entire constellation of factors along with the target species, prey, associated species, weather, current, tide, phase of the moon, to name but a few. They will also compare and balance their observations on any particular fishing day with previous years and with the information which has been handed down to them.

The mathematical side of Ecopath uses the scientific data available for as many species as possible to build a mass-balance or 'Eat or be Eaten' model of an ecosystem. Where data is lacking on the abundance of a species known to be present, Ecopath generates a number that is reasonable in terms of the food available for it and of how it contributes to the diet of other species. More precisely, Ecopath generates a range of values for that species.

This 'intuitive' ability of Ecopath stems from precisely the kind of ecosystem relationship that forms the basis of TEK. Practitioners can look at the range generated by Ecopath and compare it with their knowledge, where information on presence or absence are of key importance. Knowledgeable people from the First Nations, commercial fishing, sport fishing, scientific and other communities thus have a common basis for discussion. Where their knowledge indicates different values, they can be entered in the Ecopath model. The model will then adjust other elements of the ecosystem to accommodate the new values. In turn, scientists and TEK practitioners can compare the new values with their experience.

The value of Ecopath in integrating TEK is that the whole ecosystem approach strikes an immediate chord at the local community level. This is where the opportunity lies to connect the two. Ecopath sheds light on relationships poorly understood or unknown before. The project documented in this report is the first attempt to incorporate TEK into an ecosystem model.

Respect, Responsibility, Reciprocity and the Power of Knowledge

Jo-ann Archibald points out that, in Sty-Wet-Tan Hall of the First Nations Longhouse, carved doors depict the life cycle of the salmon, within a circular shape, and two human figures are situated on both sides. The artist, Bradley Hunt of the Heiltsuk people of the Northwest Coast, noted that the human figures are dependent upon the salmon for sustenance and we humans are reminded about maintaining respectful relationships with the salmon.

The principles of respect and responsibility were critical for the 'Back to the Future' project. The First Nations House of Learning informed First Nations community members about the project and sought participation from individuals who have traditional ecological knowledge. Dr. Archibald also piloted the interview questions developed by the other project team members. The three Elders interviewed were Chief /Dr. Simon Baker of the Squamish Nation, Dr. Vincent Stogan of the Musqueam Nation, and Elder Bob George of the Tsleil-Waututh Nation. All three Elders are respected for their particular types of traditional cultural knowledge. Each carries out a teaching role and is asked by numerous educational and community groups to share and teach their knowledge to First Nations and others alike. Dr. Archibald, Who learned from each for at least five years, had also asked a woman Elder to participate. She would have liked to, but was not in good health. However, in an earlier work with Coast Salish Elder woman, Ellen White, conducted in 1992, Jo-ann gained an appreciation about the power of words and how cultural knowledge gets power:

> *"I have heard and come across many speakers' messages about the power of words: power to heal and the power to hurt. The message they give is, 'think carefully about the words you say, choose them wisely; and let silence help.' Not too long ago, I spoke to a group of first-year university students about the power of words. I talked about it as the notion of knowledge as power, as words from knowledge. One student asked whether the knowledge of the speaker or storyteller didn't give them power over the learners? I explained that our [Sto:Lo] people believe that the power contained in the knowledge and words of the speaker, storyteller or teacher had to be 'given back,'. This giving back, though, is to others who need the knowledge, the power, the teachings; thereby ensuring the perpetuation of cultural teachings, values, and beliefs that contribute to the cultural strength and understanding of the people."*

The movement of power is not hierarchical, as from the teacher at the top down to the student at the bottom. The movement of power may be pictured as flowing between concentric circles. The inner circle may represent the words, knowledge itself that expands and moves as it is taught to and shared with others. The other circles may represent the individuals, family, community, nature, nation, and spiritual realm that are influenced and in turn influence this power. This may be called knowledge-as-power and it must be based on cultural reciprocity and grounded in respect and responsibility.

Going to the Elders

Jo-ann and Silvia visited two of the Elders at their homes and one came to the First Nations House of Learning. Each talk/interview lasted between one and two hours. Silvia and Jo-ann took notes. For the first interview, the Elder asked if we had a tape-recorder. He is accustomed to using one and seemed disappointed that we didn't have one. For the other two interviews, Silvia brought a tape recorder but we didn't use it. As we started talking with the Elders, it seemed inappropriate to bring out the tape-recorder. It felt like the flow of the talk would be disrupted. It was important to pilot the questions and process before going to other First Nations people along the Strait of Georgia. Because the Elders knew Jo-ann and knew that the work of the First Nations House of Learning is centered in quality education guided by community involvement, they readily agreed to participate.

Remembering ... long ago

During the sessions, it turned out that each Elder had vivid memories of a life style centered on sea life. Each one recalled what it was like in their childhood, before attending residential school, and also in their early adult lives. Each one said that the food from the sea was "abundant." One of the interviews took place on the porch, on a warm sunny November morning. The interviewee remembered his people going down to the beach to gather shellfish and that the bay, nearby rivers and streams teemed with fish. That lifestyle no longer existed for this Elder, and all we could do was share his memories and look out to a beautiful but 'empty' bay.

Because each interviewee was remembering the greatest abundance during childhood, they could not identify quantities of food or numbers of people using it. The usefulness of an interdisciplinary approach becomes evident in this situation. Piecing together qualitative and quantitative information from different sources is critical to the accuracy of the reconstructed ecosystem. The need to go back to the same individual and also to other individuals in the same community to verify and build upon the ecosystem information was also reinforced from the interview experience.

Further Reflections of the process

In disciplines which study natural resources, there is a tendency to concentrate on understanding these resources, often ignoring those who make use of them. These people, in permanent contact with their resources have accumulated knowledge that can be of great value in the process of understanding those ecosystems. However, incorporating qualitative information has been difficult for academics, particularly in the natural sciences.

The integration of traditional knowledge in rebuilding ecosystems however is not an easy task. It is not as easy as going to the archives (which by the way is not easy work either; see Wallace, this vol.) and opening a book that will provide the information. It is not simply a matter of selecting a group of people who will become our source of information. It is a long process of work and interaction with people who, in the first place, have the right to deny or accept participation in the process.

In this project, the process of interaction with First Nations people was initiated by Jo-Ann. The participation of interviewer and interviewee in the interviews was open and confident. They knew Silvia was an outsider, but she was brought there by Jo-Ann, thus Silvia must be a reliable person. That made Silvia feel very committed to the work she was involved in, and determined to deal the best she could with the information they gave her.

The results we have obtained so far are encouraging, not only in compilation of information, but also in finding that interaction among researches from other disciplines and Native people is possible. The integration of their knowledge in the process of understanding ecosystems and the possibility of extending this type of work as a potential to explore ways to rebuild ecosystems is exciting. It is important to note that research interaction among people with diverse experiences and understandings can be very rich. But respect for the views of people with whom we conduct our research is necessary, to ensure the possibility of maintaining this interaction and open more channels of communication, otherwise this potential can be lost.

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Using Interdisciplinary Data in Fisheries Science

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Abstract

An important element in the construction of a model of the Strait of Georgia as it was 100 years ago, was the use of information from sources such as historic archives and traditional environmental knowledge (TEK). This direct use of interdisciplinary information is one of the first in fisheries science. We hope it will lead to a general trend in fisheries research to tap into new pools of information and to find new ways of answering traditional fisheries science questions more efficiently and cheaply. A similar exploration of the use of interdisciplinary information is being attempted in the realm of fisheries management. The potential of research and decision-making applications of such interdisciplinary information is discussed.

Introduction

One of the hot-button issues that has come to the fore in discussions on the future of fisheries science is the potential role of interdisciplinary information. As with other so-called 'paradigm shifts' we should take a deep breath and assess the meaning of what may actually have been gained, and why it is 'worth it' to try. Fisheries science has been subjected to critiques, both internal and external, over its inability to predict fish stock collapses, thus destabilizing economies and ecosystems (Hutchings et al., 1997, Pauly 1997). An instructive lesson on the appalling state of most fisheries in the world can be found in Newton and Garcia (1997). This 'failure' by traditional biology-based fisheries science has led to calls for new approaches. A more sophisticated analysis of this history, however, suggests that fisheries science has not failed in the narrow sense of addressing the questions posed to it, but rather, in the broad sense that advice generated from fisheries scientists' work has often been misused, misunderstood, and misrepresented. Policansky (1998) presents, for example, an informative discussion on the difference between fisheries science questions and fisheries policy questions and how these two influence the perception of whether a fishery is 'successful'. This implies that the 'failure' was in the lack of communication between scientists, policy makers and the public. Interdisciplinary studies, then, can provide two potential services to fisheries science in the future. The first and most important would be to serve as a bridge between biologically-trained fisheries scientists, social scientists, and economists, allowing a cross fertilization of ideas to find answers to traditional biological fisheries science questions. Implicit in this would be a communication with other people who hold knowledge, especially sources such as the traditional environmental knowledge (TEK) of First Nations People (see Haggan et al., this vol.; and Archibald et al., this vol.).

A fundamental goal of such research should be the combination of different disciplines to examine issues in fisheries science. This type of combination work assumes a functional equality of the information arising from other sources with that from biology (see Robinson 1996). The second use of interdisciplinary studies in fisheries would be in aiding the application of its answers, that is, management. This implies that scientists communicate their findings to a wider range of people than was the case in the past. It also seems that many governments will be granting more control and ownership of fisheries resources directly to the user groups through Individual Transferable Quotas (ITQ's) in the developed world, and Territorial Use Rights in Fisheries (TURFS) in the developing world (Fairlie et al. 1995). If this is so, fisheries scientists will have to deal with user-groups in a more open way than through the centralized systems that typified most past fishery management.

Direct biological applications

The so-called failure of traditional fisheries science is not a failure of science in particular. It is all too often the case that the resources needed by fisheries science are simply unattainable given available funds. For example Hilborn and Walters (1992) note that:

> *Tagging of individual fish is very commonly used in fisheries. Tagging programs can be enormous in size ...[and]... can also be very expensive; a program designed to mark yellowfin tuna (Thunnus albacares) in the western Pacific ... by the South Pacific Commission estimated that it would cost $5,000 for every yellowfin tag ... returned ...*

Further, these authors

> *"simply do not recommend tagging studies as a*

way of estimating abundance ... unless it is practical to mark a very large percentage (25% or more) of the total population"

Given the low probability for fisheries scientists to access the kind of money necessary to work at such a level, it is no wonder that there have been difficulties in obtaining highly precise estimates of fish population parameters.

In the narrow sense of answering traditional fisheries science questions, using interdisciplinary information may be fruitful to the extent that it enables fisheries researchers to make more efficient use of available funds. To address the question of how fisheries scientists can use non biological information, we should first examine th few examples of such work drawing upon interdisciplinary knowledge. Following this, we can speculate on the potential use of such work.

One notable case has been the use of piston cores in anoxic ocean basins to examine historical population trends of sardine and anchovy off California. This work has reconstructed past abundances for these species and led to speculation that a regime shift which occurred earlier this century was driven by natural phenomena, and that changes in the relative abundance of these two species may thus be due as well to natural causes as to overfishing (Baumgartner et al. 1992). Using scale deposition rates calibrated from correlations with modern day population surveys Baumgartner et al. (1992) created an index of variability in sardine and anchovy stocks and found nine collapse recovery events for the sardine population through the last 1 700 years. They conclude the collapse recovery cycle of this century was similar to these in duration and magnitude.

Another effort to incorporate non-biological information can be seen in the application of climatology to fisheries science. Indeed, this work has become one end of a spectrum of opinion in the fisheries science of the Pacific Northwest regarding the cause of population changes of salmon. Sources such as Beamish and Bouillon (1993) and Henderson et al. (1995) attempted to correlate historical pressure and temperature regimes with salmonid abundances. Beamish et al. (1993) showed that the historical catch trends from Canada, the United States, Japan, and Russia of pink, chum, and sockeye salmon were similar. This suggested the influence of a large scale phenomenon. They stated that the "long-term pattern of the Aleutian Low pressure system corresponded to the trends in salmon catch ... indicating that climate and the marine environment may play an important role in salmon production." Henderson et al. (1995) demonstrated the influence of temperature on the survival of salmon fry in the Fraser River. They found that fry had lower survival when reared in relatively higher temperatures. They warned therefore of the potential catastrophic influence of increased Fraser River temperatures in a world affected by greenhouse gas warming.

Such interdisciplinary work however, has been between natural scientists. Despite the contentiousness that may arise whether it is climate or fishing which is the driving force behind fish population dynamics, the different disciplines still speak in the language of mathematics and of testing formal hypotheses. Examples involving disciplines closer to the social sciences and the humanities are rarer still. One of the few cases has been the work of archaeologists studying middens. Chatters et al. (1995) took advantage of archaeological data to hindcast abundances of salmonids in the Columbia River. Archaeological evidence, gathered from remains of consumed fish in middens, showed that decreases and increases in salmon abundance were correlated with environmental warming or cooling respectively. The determination of relative cooling or warming in the river habitat was derived from growth marks on the bivalve *Margaritifera falcata* whose structure is strongly correlated to temperature (Chatters et al. 1995).

One of the few cases I am familiar with of actual historical, archival and traditional knowledge being applied to fisheries science is Dalsgaard et al. (this vol) and is based on the project documented in this report. Information from a wide variety of sources was incorporated to help 'tune' known biological parameters to build a possible model of the Strait of Georgia ecosystem before the introduction of wide scale industrialised fishing. One of the most interesting aspects of the work was that the model used, Ecopath, can only generate possible results in terms of mass balance energetics. The model indicated that many of the species now commercially harvested could also exist at abundances at an order of magnitude greater than today (Dalsgaard et al. this vol). Such abundances, when reported in historical literature and First Nations oral history, had often been held by scientific researchers to be clouded by time, or just simple exaggeration. The cross validation generated by Ecopath of what the ecosystem could energetically support, indicates that such sources of information may have a greater service for fisheries science if 'translated' correctly (see, for example, Danko this vol.). The term 'translation' is used because the general type of information collected by natural scientists or others has often been the same. The specific type of information has been where the difference lay. In the case of fish populations, for example, scientists have asked *quantitative* questions about population, abundances, body, sizes and instantaneous mortality rates. Non-scientists have often been equally keen in their observations but focused on *qualitative* information such as the species of fish found in certain places or their relative abundance compared to the past. These types of knowledge are not exclusive, as showed by the historic Ecopath model of the Strait of Georgia. For example, they have much overlap and complementarity, and thus augment the ability of science to answer questions of fisheries biology (see e.g. 'Boxes' by Beattie, Newlands, and Power, in Dalsgaard et al. this vol.)

Another fascinating development occurred at the historical ecosystem modelling of the Strait of Georgia workshop at the First Nations House of Learning. On the afternoon of day one, participants were split into two groups to examine abundance estimates for the various species groups that had been identified in preliminary modelling work. Each group drew upon the expertise of its constituent members (both groups were highly interdisciplinary, and also included non-academic participants) to debate the estimated abundances and decide whether and what changes were necessary. There were no major disagreements in the recommendations of the two groups (Wallace et al. this vol). This illustrates the point that it is possible to assimilate interdisciplinary information and that this information also has a coherence that has not previously been appreciated.

Management applications

Interdisciplinary work has indicated that as well as helping answer questions of a biological nature it also leads to new sets of questions. This set of questions is still unclear though economists, with varying degrees of success, and sociologists, often with even less success, have begun to give fisheries managers different ways to think about their work. This is not to imply that the previous paradigm of most management was framed in terms of a policy separate from science. Rather, science and management worked together in a relationship that developed a standard set of procedures as to what were the appropriate types of questions to ask, what appropriate policy goals were, and how the two jointly functioned. Social scientists, economists and people with traditional environmental knowledge can help the management process by introducing new world views. These perspectives can offer new approaches to established biological issues. Furthermore, these novel vantage points can lead to entirely new management goals. In turn, these goals require new questions and approaches. Yet, with the application of interdisciplinary information to fisheries science, we must realise that the success of new approaches to management is not guaranteed. The measure of the usefulness of interdisciplinary approaches will be their ability to ease the management process. If the application of new information requires a vast expansion of resources and time for the management process while returning no improvement in biological, economic, or social well being, then no justification could be reasonably argued for abandoning current practices.

A debate over the goals of management should foster the involvement of new groups in policy making. For good reason, First Nations communities in Canada were long suspicious of fisheries scientists and managers. Even when traditional knowledge was used it was perceived by Native people as having been 'stolen'. This is because information flowed to the researcher and rarely came back to the community. There is a strong parallel here between the commercial 'drain' perspective of resource use and the commercially driven resource science it appears to have fostered. The First Nations view of the ecosystem as a web, therefore, is just as applicable to the way management must approach aboriginal people – that is, as a web-like system of information sharing between equal partners. This approach was fundamental to the nature of the research done by the Strait of Georgia team, in terms of helping to frame what management issues could and should be addressed by combining TEK and traditional fisheries science.

Pitcher (this vol.) discusses the concept of rebuilding ecosystems. This is a management goal that would likely have been inconceivable before the cross validation of the TEK and Ecopath model, since the focus of previous management in the Strait of Georgia, in terms of species abundance and diversity, has been 'sustainable development'. Since traditional fisheries science had only begun to analyse the ecosystem *after* the commercial fishery had depleted most valuable species, there was no impetus to ask the question of what the ecosystem had been like *before* the commercial fishery. Most scientific information gathered so far rests on data collected for or via the commercial fishery.

Conclusion

Interdisciplinary information does appear to have a role to play in fisheries science. As the discipline lies at the interface between human activity and natural phenomena, it is surprising such applications have only recently begun to be explored. Projects such as the Ecopath model of the Strait of Georgia one hundred years ago show that science can use qualitative information from other disciplines to refocus its approaches and refine its work. Although historical ecosystems seem to be obvious candidates for an interdisciplinary approach, the work of economists and sociologists, among others, intimates of new assessment and forecasting applications that can be developed by fisheries scientists. There is a caveat, however. Fisheries science, regardless of the method it deploys, remains a discipline that has as its end the description and understanding of populations of fish and other aquatic organisms. The success or failure of fisheries science remains in its ability to answer questions about fish, not people. The introduction of interdisciplinary information may modify that goal or cause it not to be achieved. Interdisciplinary information is no panacea which is going to solve the biological questions posed within the discipline. It is, however, a potentially valuable new tool which may help scientists better explain the world they are asked to define by an increasingly diverse and sophisticated public.

The potential service of interdisciplinary information to fisheries management is no different. There is a definite trend in countries such as Canada for greater 'stakeholder' participation in management and decision making process. Most of these early efforts, however are mainly consultative with managers appearing to listen then imposing decisions previously made. Nevertheless, as the Canadian government, among others, begins to downsize and privatize, non-governmental groups which are assuming more research costs will demand participation in the decision-making process, because of this new financial responsibility. Thus fisheries managers will also have to have a sophisticated knowledge of the communities of fishers and environmental groups with which they will be dealing. Of this the Food and Agriculture agency (FAO) of the United Nations is well aware. Much of its work in the analysis of fisheries of the developing world includes social, historic, and economic surveys with biological data as a basis of describing, understanding, and making recommendations. This implies that fisheries managers will have to grasp the opportunity provided of taking an interdisciplinary approach. Hopefully, this potential boon does not simply become another factor complicating the decision making process or providing ammunition for those who seek to obfuscate rather than enlighten.

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Sources of Information Used to Create Past and Present Ecosystem Models of the Strait of Georgia

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Abstract

A number of information sources were used to estimate parameters for the Ecopath models of the Strait of Georgia ecosystem (B.C. Canada) at present and one hundred years ago. The present day model was developed using primarily quantitative data from published sources. The data used to create the model of the ecosystem as it might have been one hundred years ago required a variety of sources which provided both quantitative and qualitative information. This paper critically reviews the sources used to construct the models.

Introduction

While the construction and validation of an Ecopath model representing the present Strait of Georgia ecosystem can rely entirely on published sources, construction of a model representing that same ecosystem as it might have been one hundred years ago requires access to what may be called non standard sources, at least by fisheries scientists. Indeed, information gathered from such sources are often seen as 'anecdotes' not pertinent to fisheries research, despite their importance for the establishment of baselines (Pauly 1995). The sources tapped for the reconstruction of the Strait of Georgia ecosystem are listed below, with short commentaries on th type of data they included.

Discussion

Catch Statistics

The *Annual Reports of the Department of Marine and Fisheries* were the most valuable source of historical catch information (see also Wallace et al., this vol.). These reports were written by the British Columbia Inspector of Fisheries and published in the annual *Canada Sessional Papers*. These documents contain the amount of fish caught in marketed form (e.g. barrels of salted salmon), the district in which the fish were caught and a written summary of that year's most noteworthy events. These reports were published on an annual basis between 1875 to 1944. From these sources we were able to estimate human harvest and, in some cases, estimate the biomass of targeted species. A number of species reviews were also available which provided historical estimates of catch. Present day catches were provided primarily from the Department of Fisheries and Oceans (DFO) catch statistics (Table 1).

Species	Fishery	Model	Source and remarks
Salmon	Commercial	Past	Anon. (1887-1900)
	Aboriginal	"	Argue et al. (1990), Hewes (1973)
		Present	Nagy, (1997)
	Recreational	"	Nagy, (1996)
Herring	Commercial	Past	Anon. (1887-1900)
Dogfish	Commercial	"	Ketchen (1986)
Lingcod	Commercial	"	Cass et al. (1990)
Halibut	Commercial	"	Anon. (1887-1900), Carrothers, (1941)
	Aboriginal	"	Carrothers, (1941) average
Sturgeon	Commercial	"	Anon. (1887-1900)
	Aboriginal	"	Carrothers, (1941) estimate
Smelt	Commercial	"	Hart and McHugh (1944)
Eulachon	Commercial	"	Hart and McHugh (1944)
Whales	Commercial	"	Merilees (1985)

Table 1: Sources of data for commercial, recreational, and aboriginal fisheries in British Columbia from 1873-1996. Commercial landings for the present day model (1990-96) are from DFO catch statistics. The 'past' model refers mainly to the years 1870-1900.

Historical Accounts

Accounts of the early explorers of the coast provided interesting information on species distribution and abundance. For example in 'The Naturalist in British Columbia' (Lord, 1866), one finds a description of a First Nation's eulachon fishery and the estimate that "seven hundred weight [of oil] will be made by one small tribe". This type of information can be used to obtain rough estimates of aboriginal catches.

Archaeological Literature

Most of what is know about historical aboriginal diet comes from middens studied by archaeologists. From this literature it was shown that salmon and shellfish were the most important seafood caught (Mitchell 1988).

Anthropological Literature

Stories passed down from generation to generation provide information on historical abundance and distributions of species (see Salas et al. this vol). For example, the Sechelt Nation describes porpoise as an important component of their diet (Peterson 1990). However, porpoise are a rare occurrence in their area today.

Newspapers and Magazines

Newspapers from the latter part of the 1800s were great sources of fisheries information. In particular, whaling exploits were regularly reported. An estimate of the Strait of Georgia whale population was obtained from these.

Photographs

Historical photographs confirm the presence and absence of certain species in an area. As well, some photographs, if accompanied by a written description can provide other information. For example, we found a photo of a pile of rockfish with the caption, “450 lbs of cod, two rods, two hours”. This information represents an estimate of catch per unit effort providing an indication of past abundance.

Maps and Charts

Maps often have places with animal names which can provide interesting information. For example, in the Strait there is ‘Ballenas Channel’ named by the Spaniards after the whales that once occured there. Other examples include Halibut and Sturgeon Bank named by fishers who fished for those species. Now, both species are commercially extinct in the Strait.

Interviews

Interviews with First Nations peoples were conducted to gain insight into resources used historically by aboriginal people (see Salas et al. this vol.).

Expert and Workshop Opinions

Experts were invaluable in providing estimates of historical abundance. This was done on an individual basis, and at the workshop (see Wallace et al., this volume). For example, the workshop allowed for an expert (Professor Carl Walters, UB.C. Fisheries Centre) to present an estimate of historical salmon abundance which was then discussed among workshop participants.

Cross Validation of Sources

Having access to a number of sources allowed for cross validation of information. This was true for several model inputs. For example, porpoise was found to be an important component of aboriginal peoples diet; moreover, the *Sessional Papers* indicate that porpoise was caught and combined with dogfish landings. Also, the bay at the end of Sechelt Inlet was once called Porpoise Bay. We can therefore deduce that porpoise abundance in the Strait of Georgia was greater than presently. Although much of the historical data was qualitative, cross-validation is an effective method for making quantitative references of this sort.

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PART 2: CULTURAL INPUTS TO THE STRAIT OF GEORGIA ECOSYSTEM RECONSTRUCTION

Aboriginal Knowledge and Ecosystem Reconstruction

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Abstract

The 'Back To The Future' (BTF) project uses ecosystem modelling and other information sources to visualize how the Strait of Georgia ecosystem might have been in the past. This paper explores the potential of integrating traditional environmental knowledge (TEK) of aboriginal people in ecosystem modeling. Methods include archival research and interviews with First Nation Elders from different regions of the Strait of Georgia. We describe the interview process from initial contact, facilitation, questionnaires and recording information for accreditation after review of written reports with interview subjects. Use of the resources, community arrangements and trading activities of aboriginal communities in the past in the corresponding areas are also presented. Strengths and weaknesses in the approach are discussed.

Introduction

Aboriginal people have their own ways of knowing and understanding their environment. From generation to generation, people have described and explained the origin of the land, its inhabitants and their relationship with animals. Fladmark (1986) stated that when one uses aboriginal oral history and modern archeology, the cultural perception of the flow of time and classification of natural phenomena agree and complement each other in important ways.

Thus, the TEK of aboriginal people could also be used to tune and validate models of reconstructed past ecosystems. In the BTF project an attempt was made to combine ecosystem modeling with to describe natural ecosystems as they might have been in the past.

The ecosystem reconstruction proffered by the BTF project was based on archival research and interviews with Elders from Aboriginal communities. The main purpose of the interviews was to frame a picture of how the ecosystem might have been in the past, based on traditional knowledge of resource use by aboriginal people. This information was expected to validate and complement archival information was also describing the state of past natural system.

Methods

The BTF project involved the reconstruction of present and past ecosystems in the Strait of Georgia (SoG), based on a model constructed at a workshop held in November 1995 at the Fisheries Centre, the University of British Columbia, Canada (Pauly and Christensen, 1996). Different sources of information (see Wallace, this vol.) were used to tune and update that model. Reconstruction of the system as it might have been 100 ago was based on archival records, historic documents and written testimonies, as well as interviews carried out in three First Nations communities. Interviews with Elders from the Squamish, Musqueam and Burrard bands were carried out in November 1997. Contact with the Elders was arranged by the first author who also assisted with the interviews. The questionnaire is presented in Box 1. The present and past models of the SoG based on this work are presented in Dalsgaard *et al.* (this volume).

Our ability to cover the large area of SG was constrained by available funding and time. As a result, informants in only three communities were interviewed face to face (Squamish, Musqueam, and Burrard). Two of these, Squamish and Musqueam, were located near to inlet-river areas. The fourth case was based on written testimony from Saanich people, a sea-oriented people (see also Danko, this vol.). See figure 1 for the locations of the sites.

Box 1. Questionnaire used in the interviews.

1. What were the main resources present in the area? Did you catch or hunt them? If so, how were they caught and preserved and what type of gear used? Please give details for:
    - . Salmon;
    - . Eulachons;
    - . Herring;
    - . Shellfish;
    - . Birds;
    - . Sturgeon;
    - . Marine mammals (including the possibility of presence of Sea otters and Sea cow)
    - . Other fishes: halibut, ling cod, rockfish.

2. If commercial fishing was in place, how much did you catch compared with local consumption?

3. Did you have community arrangements or rules to maintain a management system? Any kind of regulations like area, season or gear?

4. Did your ancestors belong to a fishing trading network?

5. How many people lived in the area and how many participated in fishing?

6. How was the local consumption in the area of sea life?

7. Have you observed decline in resources abundance and if so since when did this happen?

8. What do you think contributed to the loss of resources?

Information obtained as a result from the interviews is defined as: use of the resources, community arrangement and trading activities of aboriginal people. (Box 1).

Results

There was overlap between information on the archival records published, oral histories and interviews, with few inconsistencies. Aboriginal people took advantage of the access to the resources depending upon the geographical location of the community and the climatic and seasonal conditions. Also, a wide range of resources was tapped (Table 1).

All the Elders interviewed confirmed that they always took only enough fish for food use, as was commonly done among all the tribes. They had ceremonies to thank the river and fish for what they got and they supplemented their seafood diet by hunting and plant gathering.

The Elders also confirmed that, long ago, people could move from one place to another following the salmon run. There was no competition among communities because there was plenty of salmon. At that time, permits were not needed to move from one area to another.

One informant (Simon) reported that:

> "*People used to go to Chamainus, Galiano Island, Pender Island, Main Islands and they stay there for some time fishing*".

Another (Vincent) said:

> *In the olden days, the water was pure, there was abundance of seafood, people were healthier. My grandmother lived over 100 years. There were no divisions in areas to fish or gather sea-life, people used nets to fish salmon, they shared the whole beach. There were no power boats at that time They also used to hunt in the mountains for mountain sheep, Elk and deer.*

The other statements we gathered are incorporated in our text or cited in italics and grouped by **resource type** and by informants in the different Nations. The first name of the informant immediately follows explicit quotations.

Salmon

The salmon caught in the three river-inlet communities were: dog salmon (chum), spring salmon (chinook), humpback (pink salmon), sockeye and coho. Some communities, eg. the Squamish people, had direct access to the runs; in other cases, e.g. the Burrard people, had to travel and set up camps to stay during the run.

Group/Species	Squamish	Musqueum	Burrard	Saanich
Finfish				
Salmon	Yes	Yes	Yes	Yes
Herring	Yes (eggs)	No	No info	Yes (fish &eggs)
Halibut	No info	No info	No	Yes
Sturgeon	Present but not caught	Yes (soup)	No info	No info
Eulachons	Yes (smoked)	Yes (smoked)	No info	No
Trout	No info	No info	Yes	No
Rock fish	No info	No info	Yes	No info
Ling cod	No info	No info	Yes	Yes
Shellfish				
Clams				Yes
Crabs	Yes	Yes	Yes	Yes
Sea Urchin	No	No info	Yes	No info
Oyster	Yes	Yes	No info	Yes
Mussels	Yes	No info	No info	Yes
Seaweed	No info	No info	No info	Yes
Marine mammals				
Sea otters	Present but not caught	Present but not caught	No info	Yes
Whales	Present but not caught	Present but not caught	No	Yes
Black fish	No info	No info	Present but not caught	Yes
Seals	Present but not caught	Present but not caught	No info	Yes
Sea cow	No	No	No info	No
Birds				
Seagulls	Yes (eggs)	No info	No info	Yes (eggs)
Black duck	Yes	Yes	No info	Yes

Table 1. Historic presence (yes) and use, or absence (no) of resources in the Strait of Georgia.

All the native people from B.C., Washington, Oregon, Montana lived on salmon (Simon).

Traps and nets were the main methods used to catch salmon in the river. Spears and hooks were also common. People relied on drying and smoking the fish to preserve it and have a good supply for winter (Stewart 1982). First Nations people have a ritual consisting of throwing the salmon bones back into the river so that the salmon would return. (Ham 1982).

Squamish Nation

During spring Chum salmon came to the Fraser and Squamish rivers to spawn. They were more abundant than nowadays, throughout the Strait of Georgia and Johnson Strait channels. Pink, Coho, and Sockeye were also more abundant in the past (Simon).

Chum was plentiful during the fall and still is now. They used to spawn near Stanley park and Beaver lake. Sockeye used to come back every four years. At that time, about 100 people fished for salmon (Simon).

In the olden days we could see salmon from Jerico to Sand bars coming into False creek and over area around the PNE. In 1934 we set a net and got 1,000 fish, they even jumped into the boat (Columbia river boat). People could work 16 hr a day and get about 6000 humpbacks (Simon)

Musqueam

Sockeye were caught in the middle of June, using a winter spring gear, smaller than the average used this days (10-12 lb). March and April were the hardest months for people. During that time salmon was caught only for ceremonial purposes. One or two boats, mainly canoes, would go out fishing for food because there were few power boats. We only caught what we needed. In one set we could take millions of fishes. It was abundant at the mouth of the Fraser. Sometimes people went across Vancouver Island to fish and up North for the early run (Vincent).

People used to can and smoke salmon to save it for winter. Salmon could lose about half of its weight when smoked. After smoking, salmon was preserved into holes in the ground, and covered with soil which kept it cool. Smoked fish could be maintained in there even for a full year.

The holes or cool-bins were maintained by my

> *grandmother for the winter* (Vincent).

Burrard

> *People used to catch salmon at the head of the Inlet, using nets. There was a village with a dozen houses each with a smokehouse behind the main house. People would live there during the fishing season* (Bob).

Saanich

> *Saanich people used to catch salmon in the sea on the main route of Sockeye salmon migration during the early summer. They used to catch it using reef nets throughout San Juan Islands up around Boundary Bay and the other Islands* (Poth 1984).

Spring salmon was fished when it came along with the herring. Humpback arrived towards the mid-summer. This was the most plentiful of all salmon (thousands of fish in a school). Coho arrived in September and dog salmon arrived in early winter But people did not wait for this run; it was time to go back to their main camp (Poth 1984).

Herring

Squamish people did not fish for herring, only the eggs were collected. Sometimes people would go to Vancouver Island to fish. The Musqueum people neither caught herring nor collected the eggs.

When the herring season was over Squamish people used to hang young cedar branches in the water to collect herring spawn. Afterwards they were dried, according to Mr. Stogan. In Bella Bella kelp was collected and hung in the water to collect herring spawn.

The Saanich people knew the tides so well that they could tell at what time the herring would arrive. They used the eggs and the fish. The eggs were collected on branches in the same way the Squamish people did. Herring was preserved by smoking in three different ways: whole, gutted and, boneless (Poth 1984)

Eulachon

Eulachon has been a very important resource for aboriginal communities, not only for food, but for other uses (Drake and Wilson 1991, see also Hay, this vol.). It was also called 'candle fish' or 'salvation fish' since the dried body can supposedly be used as a candle, and its arrival at the end of the winter provided aboriginal people with food (Stewart 1982). They were caught in the Fraser river using nets, and methods varied from different parts of the coast (Stewart, 1982).

> *We use to go as far as New Westminster and Mission to fish because Eulachon move down there. Musqueam people used drift nets about 50 fathoms (6 ft to 1 fathom). Modern Eulachon nets are shorter now (15 fathoms) than in the olden days* (Vincent).

Squamish and Musqueam people preserved Eulachons by smoking But they did not make grease even though the run started in the Musqueum area, when the fish had a higher concentration of body fat. Eulachons were mainly gathered for food and were a very important food item in the Musqueam Potlatch.

Sturgeon

Although sturgeon were plentiful in the Fraser river, they were not used much by First Nations people. Sturgeon seemed to have an spiritual meaning for some tribes. Sto:lo sturgeon fishers said people who fell from their canoes and those whose bodies were never found became or lived among sturgeons. Among the Scowlitz band, old people consider themselves under the care of the spirit of the sturgeon (Glavin, 1994)

Sturgeon was considered 'evil' by the Squamish people They did not like it because it reminded them of snake (for the type of skin) and because it was hard to cut and cook. However, the Musqueam people liked to make sturgeon soup. Mr. Stogan recalls that the biggest fish on record caught at Ft. Langley weighed about 700 lb. Sturgeon was also traded with Chinese people who preferred sizes of around four to five feet.

Other Finfish

King-fish, or white croaker (*Genyonemus lineatus*), was caught by the Musqueam people, but is not present anymore in the area. Flounder sole was common in Squamish area, but not Halibut (See Table 1). Halibut was important in the diet of Saanich people, as well as cod. They were caught in the time called PENAWEN, 'the harvest time' (Poth 1984). Lingcod, flounder, rock fish, bullhead were exploited by nets in the Burrard area. These species were also caught by Saanich people (Poth 1984):

> *When the tides were high people caught the fishes. There was no halibut in here, but Rainbow trout*

was found around the creek. Also Lingcod, Flounder, Rock fish and Bullhead were around the area. Rainbow trout used to be big, now there is not any (Bob).

Shellfish

Butter and other clams (littleneck cockle), oysters and mussels were the more common shellfish used by the three communities interviewed and also for Saanich people. Mr. Stogan mentioned that Vancouver Island was the area were more shellfish could be found. Clams were boiled for local consumption by Musqueaum and Saanich people and dried by Burrard people.

> *The Burrard people used to build fires on the beach and dry the clams and put them on cedar strings, which were taken by men when going hunting. On spring tides, people could dig every night for the whole week to get clams, but they never dragged* (Bob).

The Squamish people used to sell clams to a cannery in Sidney for two cents per pound:

> *In winter we got butter clams (big clams). We used to dig and got one sack per night (20 lb.). In Capilano, when tides came people could get between three and four sacks per night* (Simon).

Crabs were abundant in the Saanich Peninsula and Capilano (Poth 1984), but not much in Burrard:

> *Crabs were not plentiful in Burrard inlet, only some apple crab were found at low tide. Also in the olden days sea-urchin was eaten by some persons (Bob)*

Marine mammals

Marine mammals were not an important component of the diet of the Musqueam, Squamish and Burrard communities. The Musquaum and Squamish people saw some otters in the area, but they did not hunt them:

> *During the Fall close to Stanley park we saw Otters sometimes. One or two were shot but they did not usually take them. There are still some out there* (Simon)

However we cannot tell if these otters were sea or river otters. Inlets such as Saanich Inlet were used as nurseries for females to have their young. They would stay for several weeks before leaving (Poth 1984). Sea otters are not reported in the area by Poth (1994). Barnett (1955) stated that sea otters were extremely rare along the Salish coast (but see Pitcher, this vol.). Seals were also seen but not hunted because people did not like the excessive fat of these animals. Mr. Stogan mentioned that Nisga'a people ate seals.

Our informant had never heard about the Steller's Sea-cow. Humpback whale were caught along the West coast to Alaska but they did not get into Squamish region; blackfish (killer whales) were hunted (Poth 1984):

> *Some whales were sighted near Burrard Inlet sometimes in groups of three or four, some other time alone, usually in the main channel in the deeper area* (Simon)

> *Blackfish came there sometimes. People believe they bring 'signs' to the family. My grandfather saw three of them and said to his wife 'a great chief is going to die', and next day he died* (Bob).

Marine mammals were hunted by Saanich people and some Halkomelem also took seals in the lower river and in Pitt Lake (Ham 1982; Poth 1984). Harpoons, nets and clubs were used for seals which were caught by two to three man crew in canoes at night during the mid-summer. Porpoises were hunted during the day, as was sea lion and killer whale (Poth 1984).

Birds

Ducks were abundant in all the zones and seem to be a very important component in the diet of many First Nations communities (Ham 1982, Poth 1984). Black duck was one of the favorite dishes for many communities and were commonly served at Musqueam ceremonies. The Elders said that before people could hunt the ducks freely but that now they need a permit. Eggs were also collected.

> *Half a dozen different types of ducks were present in the Burrard area: whistler, butterball, Mallard, long neck diver, black duck (delicious and hard to get it). People used to eat them all* (Bob).

> *My mother used to gather seagull's eggs. She used to paddle to Squamish to sell them. Ducks were also abundant in the area. We used to shoot over 100 black ducks in Dead-man Island* (Simon).

Saanich people collected seagull eggs in spring. They would not take all the eggs in one nest; they have to leave at least one. The maximum number of eggs per nest was usually four. Geese and swans could be found on the mud flats and marsh beaches (Poth 1984).

Discussion

The information collected suggested seasonal use of the resources. The main seasons when resources from the Strait of Georgia were used by aboriginal people were late winter- spring and late summer-autumn. The latter catches were preserved for the winter.

Ham (1982) reports the species abundance and availability to which aboriginal people had access. The seasons agree with the information obtained from Musqueam community. The respect that people show to nature and the knowledge about this resources (cycles, patterns of behavior) is evident from all communities. They had defined their own rules to protect resources that were both source of food and of inspiration. There was a general concern about the reduction of abundance of some of these resources:

> *In the last 10 years we have noticed a drastic drop in salmon. Nowadays there is limited period for fishing, it can go from 12 to 36 hours per season* (Simon).

Trading was a common activity among aboriginal people. For example, the Burrard people used to trade salmon with the inland Squamish people. The Musqueam traded with people from the Okanagan:

> *People traded mainly salmon, but could sell other things gathered or hunted. My grandmother used to go to the West End and sold berries, clams, eggs, mats, baskets and get clothes or money as a trade* (Simon).

> *Between 1940 and 1945 Musqueaum people would fish from 8:00 A.M. to 6:00 P.M from Monday to Friday. Saturdays and Sundays were used to fix and prepare nets for the following week. Some people went up North for early running of salmon* (Vincent)

However, much of this changed with the advent of industrialisation. Around 1929-30 commercial fishing started for canneries, using sail boats mainly. Power boats were introduced in the 1950s (Vincent). Fish was processed by canneries, many owned by the B.C. Packers Company which supplied the nets. Most cannery workers were aboriginal people, or of Japanese ancestry.

Conclusions

The foregoing illustrates that First Nation people of B.C. have a rich heritage and their knowledge has much to offer. Their TEK can be incorporated into environmental and ecosystem analysis. The other contributions in this report should be consulted in order to see how this was achieved. The use of this approach in the BTF project and the results obtained so far are encouraging.

However, it is important to remember that people should not be viewed only as providers of information. Also their perspectives, questions and suggestions on approaches to the problem being addressed by the researchers should also be considered. This shows respect for their knowledge and makes them feel part of the project. The growing involvement of aboriginal people will then tend to expand the interdisciplinary perspective.

TEK leads not only to the development of management strategies to rebuild ecosystems, but also to understand the users of the resources (how do people operate and under what conditions). TEK also fosters understanding of the changes occurring through time. Information about the use of the natural resources used by aboriginal people and information about their community arrangements are important elements in the development of management strategies.

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Building a Reliable Database from a Native Oral Tradition using Fish-related Terms from the Saanich Language

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Abstract

A list of fish names and fishing related terms was extracted from T. Montler's '*Saanich, North Straits Salish Classified Word List*' of 1991. These terms were tested for their ichthyological and ecological accuracy so that could be employed in the Back to the Future model reconstructions. This list testifies to the close association between the Saanich people and the coastal resources of the San Juan Islands in the Strait of Georgia. It also illustrates the need for cross validation by natural scientists of word lists such as Montler's.

Introduction

The Saanich people belong to the Salishan language family. The linguistic division of the Saanich is Coast Salish, and Saanich is one of the six different dialects in the Straits Salish language group. Culturally, the distinguishing characteristic of the Saanich people is their reliance on salmon as a resource, despite their lack of access to a river. Their range covered the Saanich Peninsula, to Mount Douglas and Goldstream in the south of Vancouver Island (see Fig. 1 in Haggan et al., this vol.). The Saanich people also spread out east through the San Juan Islands and across the Strait of Georgia to Boundary Bay (Elliot, 1983); see also Figure 1 in Haggan et al. (this vol.).

Records of languages such as Saanich can provide scientists with insight into animal behaviour, seasonal cycles, and a chronology of the biological evolution of a geographic region. For this, however, the language must be translated into a reliable ethnobiological database. Production of this this type of database is complicated because its source is based on an oral tradition, susceptible to discontinuity because words and/or their meaning may change, the perspective of a culture may change, or the environment may change without written record. Montler (1991) compiled a word list for the Saanich language with the help of two Saanich-speaking informants, Mr. Claxton and Mr. Pelky. Both had previous experience working with David Elliot Sr., a Saanich elder, in his development of a writing system for the Saanich people. Such word lists help to preserve language and make the information that language contains accessible to more people.

However, these word lists may not always be a reliable source of scientific data, because the matching between the Saanich and scientific names for species are neither certain nor one-to-one. This is not due to any lack of ability on the part of Montler, nor to the inadequacies of the oral tradition. It is a reminder of how complex Native languages are and of the inherent difficulties associated with recording any one language in the context of another. This contribution, which analyzes that part of Montler's list dealing with fish and fishing, gives examples of the potential unreliability of word lists and suggests ways to increasing their reliability when used as evidence of past occurrence and abundance in the Back to the Future ecosystem reconstruction work. In a very tangible way, this supports the idea that the knowledge they contain is precious (Berlin 1992).

Conceptual issues

The first problem involved with the production of a reliable ethnobiological database is the fact that both languages involved here, Saanich and English, have, to some extent, inexact vocabularies. For example, the Saanich people did not have distinct names for all fish species. While they identify five different types of salmon, they have one collective word for other salmonids, colloquially known as 'trout'. This problem is the same within most fish families which have more than one representative within the geographic range of the Saanich people. *Sebastes* spp. may be grouped collectively under the word, *?eyethithen*[1], the Saanich name for 'rock cod', but this is unclea, as Montler has also listed names for 'grey cod', 'blue cod', and 'any cod'. In this case, the Saanich have a simple and useful classification system that suits their own needs, but Montler's list fails to relate exactly how these fish were classified by the Saanich people. Thus, in some cases fish species which were important enough to the Saanich to earn a unique name were linked to generic names, a phenomenon discussed in Berlin (1992). The goal here is not to identify a name for each species of fish but to learn exactly how, with

1 Editorial note: The question mark represents a glottal stop (see Pullum and Ladusaw 1986).

as little error as possible, the Saanich described the fish that were important to them.

Perspectives of the language being studied and the language of the recording culture always differ to some degree. Contemporary society has a calendar which dictates months and seasons of specific lengths even though the meteorological and biological events that correspond to the season may vary between years. Instead, the Saanich people traditionally relied on meteorological and biological events to determine the length of their seasons. The meteorological patterns of summer do not always coincide with the duration put aside by contemporary calendars nor do salmon begin to spawn on the same day every year. It is reasonable to assume that the Saanich were able to and did adapt the timing and length of their 'seasons' accordingly. Unfortunately, contemporary perspectives placed Saanich words for months in a specific order in Montler's (1991) list, and this order is inconsistent with Elliot's (1983) order. According to Elliot, the word *sxwan'ehl* , meaning 'bullhead' a fish, is also the word used to describe the time of the year we know as April. Montler uses *sxwan'ehl* to represent May. The brown bullhead spawns in February approximately (Carl, 1971; Hart, 1973), and during this time the fish is present in large numbers. It seems more likely that the contemporary notion of April is a more appropriate word pairing. This is not an attempt to question Montler's work. Rather, it illustrates the many different ways of interpreting a Native calendar; it shows that any attempt to shoe-horn a culture's vocabulary into a model of another may lead to incompatibility and error.

Results and Discussion

The following is an annotated word list of Saanich fish names adapted from Montler (1991), with orthography simplified using phonetic equivalents in Pullman and Ladusan (1986). The list is ordered by word list number and presented in the following sequence:

saanich name / common English name / word list number / comments.

schaanexw / any salmon / 244 / The Saanich people sometimes use specific species names, such as 'salmon', to refer to periods of their seasonal cycle. Many of the Saanich 'months' or periods are named according to the fish species being caught at the time.
k'wolexw / salmon after spawning / 245
siná?ech / big salmon going up stream / 245.1
st'thokwi? / spring salmon / 246 / Followed the herring into the Saanich area. This period was wexes, March. The Saanich people have no access to river-run salmon i.e. they fish strictly in marine waters. A reef-net was used to take these fish off-shore.
thaw'en / coho salmon / 247 / Fished during the moon chen'thaw'en, or "time of the coho" September. Named for the abundance of coho. Saanich people gaffed coho at Goldstream and also used reef-nets (word list # 809) to access this fishery.
thekey' / sockeye salmon / 248 / Fished during the moon chen'thekey', or "time of the sockeye", July. Named for the abundance of sockeye. These are the first salmon of the year to be caught by the Saanich. The sockeye were fished using the reef-net.
xwselawe / sockeye (one you are poor with) / 248.1
henen' / humpback salmon / 251 / Fished during chen'henen or "time of the humpback", August. Humpbacks were also fished using reef-net.
k'wol'exw / chum salmon / 259.6 / Fished last in the season when the time of year is called, pek'elanexw, October. The season word does not correspond to the Saanich word for chum. The chum were gaffed at Goldstream, where men and sometimes women waited on the edge of the water for the passing salmon.
st'thkway' / grilse / 271.3
sxew'k'em / steelhead / 253
k'wsech / any trout / 252 / Ambiguous word which may refer to any Salmonidae species, depending on interpretation by the Saanich people.
lheyek' / shiner / 255
wachi / perch / 259.5
k'toyethen / sturgeon / 256
lélethen / eel (gunnel) / 258 / It is hard to establish how this word was applied to the local fish fauna. There are many eel-like fish is the Saanich area. Considering how much time was spent in the intertidal zone, the Pholidae seem most likely to bear this name.
sxwan'ehl / little bullhead / 259 / 1906 is indicated as the year of introduction of *Ictalurus nebulosus* (Carl et al., 1971). The species represented by this word must have been present before this date. It is hard to imagine that the Saanich renamed an entire season based on a recently introduced fish. The Saanich are a marine oriented fishing group and would not have had access to *I. nebulosus* which is a freshwater fish. *Leptocottus armatus* would be the logical choice to correspond with this Saanich word. However, staghorn sculpins spawn in February (Hart, 1973), whereas the sxwen'el are closely associated with April in Saanich seasonal cycles (fish and month share the same word). This word may be reference to any of a number of cottid fish.
skwen'axw / big bullhead / 259.1 / As 259 above.
tekwtekw / red snapper / 259.2
kweles / smelts / 259.3
skwome? / ratfish / 259.4
lhémek'we? / sole / 260
p'ewi? / flounder / 261
thotx / halibut / 262
slhong'et / herring / 263
slhele?lhong'et / jack herring / 263.1 / David Elliot Sr. (1983) describes juvenile herring entering spawning grounds first and being followed by the adults two to three days later. The term 'jack' may be applied here, as it is with certain *Oncorhynchus* species, to those individuals that return to spawn early.
swiw'e / eulachon, candlefish / 264
?eyethithen / rock cod / 265 / Common names are very site specific for these species. Where possible a conclusion is made. Elsewhere, options are given that are most likely.
pk'iken / kelp cod / 266 /As 265 above.
?ayet / lingcod / 268 / As 265 above.
skim'eth / gray cod / 267 / As 265 above.
?ayet / gray cod / 267 / As 265 above.
t'thémekwe? / blue cod / 268.1 / As 265 above.
sheyehl / any cod / 268.2 / As 265 above.
sk'ey'ek'shen / dog fish / 269
k'wet'thenéchte? / shark / 270
k'ak'ew' / ray, skate / 271

t'thextolelhche / giant skate / 271.1
monoletche / deep sea bass / 271.2
lhol'es / anchovies / 271.4
moneches / hake / 271.5 / A nearby native culture also uses this word, but for a different fish altogether (Brian Compton, pers. comm. 1996). Therefore no specific species is given and the family referred to is speculative.
pish / any fish / 271.6

There may have been various reasons for Montler's choice of scientific names for Saanich terms, but the user of the database is left unaware of possible alternatives, because the interpretative process is not documented within the word list. The word list used by Montler is organized according to the Classified Northwest word list used in the Royal British Columbia Museum (Montler, 1991). This includes both species names (the above list) and terms related to fishing (listed below). Although new words can be added when appropriate, this organizational scheme can easily fail to include all relevant terminology from one or both languages involved. There may be cases where one word is not sufficient to provide a full meaning. The example of seasons, from above, illustrates this case well. One way to overcome this problem is to employ a malleable and unique word list for each and every different language studied. A second solution is to record the process of interpretation so that those who employ the word list in future will be at liberty to make subtle yet important changes in the application of a language to an event. Interpretation of word pairings, on the part of both language groups, must incorporate many opinions to avoid bias. If a record of opinions, disagreements and problem-solving were included in the word list, a user would be better able to employ the Saanich language in the way it was intended. Another example is the omission of the word 'gaff' from Montler's word list. Saanich people fished for coho and chum salmon using a gaff (Elliot, 1983). Montler (1991) does not include this word in his list, but he does include words such as 'fish spear', 'harpoon', and 'salmon trap'. His interpretation of the word 'gaff' may be implicit in the list but without documentation of the interpretive process, the application of the word 'gaff' to Saanich culture is unclear.

Ambiguity may be avoided if the ecology of the region being studied is reviewed before assumptions are made during the compilation of a word list. Some activities may no longer be practiced by the culture being studied, and some plant and/or animal species may no longer be present in the geographical range of a people. A language of oral tradition has three ways to respond in these cases: it may use the same name for the new species or activity, it may use a new name yet retain stories and vocabulary from the old species or activity, or it may use a new name and new vocabulary completely displacing the old from memory. In order to build a reliable ethnobiological database these facts must be clear. Unfortunately, it is often difficult to determine which scenario has occurred as is evident in the next example. 'Little bullhead', the contemporary common name used in Montler's word list and paired with the Saanich *sxwan'ehl*, usually refers to a species of freshwater catfish, *Ictalurus nebulosus* (with possible exception due to inconsistencies in colloquial fish terminology).

'The Saanich People' (Anon. 1978) has a stylized drawing of *I. nebulosus* below a description of the '*sxwan'ehl*.' This creates a serious problem because the Saanich people were 'Saltwater people'. They had no river to fish. According to Elliot (1983) all their fishing was marine oriented. A Saanich elder, he described the method of fishing for the 'sxwan'ehl', wherein the women would walk out at low tide and find the *sxwan'ehl* under rocks. Since *I. nebulosus* is a freshwater fish it should not be found in the intertidal zone (Hart, 1973). To further confound the issue, *I. nebulosus* was not introduced to Vancouver Island until 1906 (Carl, 1971), strengthening the argument that bullhead is an erroneous interpretation of the Saanich word *sxwan'ehl* (see list above). Depending on which scenario is at work in this case, the knowledge contained in the Saanich language has failed to surface due to incorrect or incomplete review of the geographical range inhabited by the Saanich people. If the ecology of the bullhead had been reviewed at the time of compilation, questions surrounding its inclusion could have been tabled immediately so that suggested alternate solutions would have resulted in a better record of the Saanich people and their environment.

The following annotated list of Saanich words related to fishing terms, activities and products was adapted from Montler, (1991), with orthography simplified and using phonetic equivalents in Pullman and Ladusan (1986). The list is ordered in the same manner as the fish word list.

TERMS

thi?thehl ?e tse snganet / top of mountain / 37
xwsko?th / river mouth / 42.2
xwengaleken / swift water / 59.1
t'the?kweng kwo? / water (fresh) / 77
sto?lew' / river / 79
p'ep'o?eng / river rising / 79.1
hik'weng / river rising from rain / 79.2
stotelew' / creek / 80
xoche? / lake / 84
tlh'achelh ?e tse kwo? / bottom of water / 88
xw?ey'eng kwo? / clear water / 89

xwkeleng kwo? / muddy water / 90
pkwechen / sand / 97
t'thxit / pebbles / 98
?i? schelhikw / sea close to shore / 140
tlhlalhse / saltwater / 143
temeng / good fishing tide / 157.8
tkap / saltwater fish-trap / 800.1
shxatlh / fish-trap, river trap / 800.2
ngal'ngal' / fish bait / 801
skeche? / catch, harvest / 801.1
sk'wewyekwalo / tackle box / 801.2
swelten / fishing net / 805
?ek'wiin / dip net / 806
shxwechiteng / scoop net / 807
kselay'en' / gill net / 808
sxwole? / reef net / 809 / The sxwole? is one of the most important Saanich tools. The net is made from the inner bark of the willow tree. The word for the net is shared with the willow tree. The leads were the first lines set and were anchored by lashing large rocks to them. Other lines were used to form sides and bottom creating a large channel. These secondary lines had sea grasses between their braids to mimic the sea floor. This channel gradually sloped up and was placed into the current. Fish swimming with the current would enter the channel and could not turn around because of the fish behind them. The rise in slope of the channel allowed people to see how many fish were entering the net and then decide when to pull it up. Salmon would dive into the large hanging net trying to reach the saftey of the depth. The net would swell with fish and the two canoes which anchored the net portion would come together to haul up the net. The canoes are reported to be forty feet, or twelve meters in length. If the catch was too large the crews from the two canoes would enter one boat and use the other to transport the fish.
?o?xwiyen / seine net / 809.1
tkap / salmon trap / 810
tchosen / fish spear, short cod spear / 811
t'thxengen / long cod spear / 811.1
skwak'ep / lure for cod fish / 811.2
shmot'esten / harpoon / 812
shmot'esen / harpoon / 812
k'wewyekw / fish hook / 813
themon'e / halibut hook / 814
k'wikwál'sen / fishing line / 815
cheshi?en / line with halibut hooks / 815.1
paach'en / fishing rod / 816
k'wokwesten / salmon club / 817
snganet / sinker / 818
shetháleken / sinker / 818
shat / sinker / 818
shp'ekwten; / float on fishing line or net / 819
sp'ekwtan / float on fishing line or net / 819
lhét'emen' / herring rake / 820
slhéngi? / herring stick / 820.1
t'a?ech'en / salmon stretcher / 821
k'wechten / salmon knife / 822
shk'wiw'et'th / salmon knife / 822

ACTIVITIES

t'eyemt / bait a line for fish / 1172
k'wek'wemal's / casting, fishing near shore / 1231.1
not'theng / catching fish / 1235.2
wake'em / dive (fish) / 1295.1
k'wewyekw / fish in general / 1332
chenanxw / fish for salmon / 1332.1
lhet'em / fish for herring / 1332.2
chenanxw / fish with a net / 1333
k'wewyekw / fish with a line / 1334
?el'xew'a? / fish with torch (pit-lamp) / 1335
slhengtal's / jigging deep / 1408.3
wak'em / jump (of fish) / 1413
sheteng; / swim (a fish) / 1687.1
mexwoseng / swim (a fish) / 1687.1
tkap / trap fish / 1713

PRODUCTS

sk'wel'eng's schaanexw / barbecued salmon / 868
lek'weng / raw fish / 868.1
pek'wing'ehl; xacheng / smoke (salmon)-verb / 1619
spak'ws schaanexw / smoked salmon-food / 869
shmexwalsh / smoked salmon soup / 869.1
k'wit'thet / sliced salmon / 870
shamet skelex / prepared salmon eggs / 871
slhop' schaanexw / salmon stew / 872
k'weleng / barbecue fish / 1177
k'weleng / roast fish / 1555

The final example serves to illustrate the problems presented in this paper. The language of a culture, rich in oral tradition, inherently contains chronological information about the culture's environment, and this can be useful to both Science and future generations of First Nations. When a story exists about a place and an animal or plant, the story supplies information about the distribution of species. As names and stories fall in and out of use in the culture over a period of time, the relative abundance of the pertinent species may be estimated. Extracting this information correctly and reliably can be valuable, and therefore must be performed while wholly aware of the pitfalls involved with recording another language. The language of the recipient culture is subject to differences in perspective from that of the language being studied. These differences may be overcome by using a dynamic word list that does not compromise perspectives of one culture for that of another. Interpretation of such a dynamic and unique word list requires a record of the process that was followed to arrive at the solution presented. This interpretation must include a review of the known ecology of the region through time. Finally, all interpretations must attempt to identify reliably as many different scientific names of biological species as possible, individually or as specific groups (see list of fish names). With these precautions, science may gain valuable records of the past.

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Reading Rocks: On the Possibilities of the Use of Northwest Coast Petroglyph and Pictograph Complexes as Source Material for Ecological Modelling of Prehistoric Sites

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Abstract

It is proposed that the petroglyphs and pictographs abundant along the coast of British Columbia, Canada, may be used to infer the occurrence and relative importance of aquatic animals to the First Nations who lived in the area, and hence may be used in the reconstruction of past ecosystems.

Introduction

I propose that pre-contact data on bird, animal and fish populations on the Northwest Coast of B.C. may exist within native petroglyphs and pictographs. Petroglyphs are images of objects, creatures and abstract forms incised, pecked and cut into stone. Pictographs are images, visual narratives, records of spirit encounters, or tally marks, painted on stone. Some tribes favour one form over the other but both occur throughout British Columbia. At Petroglyph Park, south of Nanaimo, the entire hill is covered with petroglyphs which were, and still are, painted to renew their power. Rock images were made for various reasons, in specific sites, and were manifestations of a variety of events only some of which are known. A number are the record of a young person's encounter with a spirit guide, some are tools to facilitate a tribe's interaction with natural forces and some mark territorial boundaries. There are rock image complexes that record important conflicts, natural events, migrations, or provide a record of capture and conservation methods employed. The complexes tell not just which animals and aquatic creatures were encountered, petitioned, emulated, and consumed by Northwest Coast people but indicate what larger role these creatures performed within the cosmology.

Justification for the use of this material by the *Back To The Future* project is the crisis status of the ocean and its inhabitants. While preserving the sanctity of rock sites it is, I am sure, our collective duty to use these ancient records to focus on not just preservation of individual species but also to promote the reestablishment of productive environments for the long haul. It is my suggestion that petroglyph sites, and to a lesser extent pictograph sites,[2] on the Northwest coast can be used to provide a record of human interaction with native animal and fish species over a wide range of time. The objective of *Back To The Future* (BTF), to model the Strait of Georgia as far back as 1500 AD, is not possible without use of native records (see Pitcher this vol.). While Northwest native history was oral, any student of art history knows that visual record, historical information and cultural usage are all embedded within any decorated object or image. Rock imagery is the oldest local record we have aside from small bone pendants, combs, pestles and stone tools. The difficulty is to learn the visual language and to interpret it.

Reading petroglyphs and pictographs

To date, rock writing, with a few notable exceptions, has been presented as singular pictures of mostly imaginary things and interpreted from the viewer's cultural perspective. There has been little attempt to approach complete sites as manifestations of cultural concepts. Little thought has been given to consideration of the sequence of images as a coherent visual language, a code that could be broken. Yet, York (1993) 'reads' hundreds of rock panels in ways that indicate she at least possessed the key to a language we barely admit existed. York is also the repository for a secret language of Chiefs that enabled them to converse with those speaking another native language. Martineau (1973) proposed that Indian sign language, which was used from Alaska to the far Southwest, provided a clue to breaking the code of rock images. Images on rocks that resemble sign language have enabled him to read entire

[2] Pictographs, unlike petroglyphs, are generally thought to be recent due to their faster weathering. This attitude might change if it is accepted that the process of absorption of the paint into the rock is a kind of frescoing procedure that fixes the image quite permanently should the overhang be sufficient. In *The Cave Of The Animals* in Shoal Harbour all the animals on the coast are depicted in paintings well out of the elements and may be ancient. A pictograph image in Homfray Channel is dated to 350 years ago due to its subject.

complexes. He was also convinced that quadruped images and their elaborated horns are sometimes signs about direction and content. One must then be cautious in assuming that a recognizable goat is simply a picture of a goat. It may be a symbol instead.

Petroglyphs and pictographs exist world wide and are positioned strategically along the North American coast from Alaska south. Similar images can be found in Siberia and on the coast of China and the coherence of the imagery indicates that it is meaningful both locally and to neighbouring tribes.

An useful example of a petroglyph complex exists at Dogfish Bay, east of Francisco Point, on the Southeast tip of Quadra Island, B.C., Canada. Here, at highest tide level, is a large altar-like stone engraved on its sea side with a hook-nosed creature sporting a head and back fin, exposed ribs, a lower lip labret or tongue and a upcurving tail within which is a salmon-tailed creature. Local native people refer to it as the Seawolf. Within the trans-polar native mythology, wolves and whales are the same thing. Literally. If the footprints of wolves are seen on the shore, whales, which are thought to be the same wolves transformed, will appear. Coastwise mutability, transformation from animal to human and animal to another animal, or occasionally animal/human to stone, is the big cosmological game.

The Seawolf's rock is covered with pecked and smoothed indentations thought to be evidence of drumming that occurred as the shaman performed ceremonials. There is a face carved on the land side of the stone and grooves on the top which would allow any liquid substance placed there to run into the Seawolf's mouth. 15 feet seaward is a 20 inch diameter, finely surfaced stone bowl now overturned by the waves. To the left of this bowl is a series of three shallow ponds. Archeological evidence indicates that the boulders surrounding and demarcating these ponds have been moved there. Similar ponds were owned by specific families for their exclusive use.

East of the ponds is a canoe slide formed by clearing rocks. Petroglyph heads mark its land exit. Directly above is a large flat midden, indicating extensive occupation. There is also a year round spring. Wolves were considered guardians of fresh springs. Local native elders say that this point was frequented by *all* the species of salmon at various times and that the passage from Cape Mudge Village to Campbell River, with its strong tidal current reaching up to tremendous rapids, might be filled shore to shore with fish.

Joy Inglis, who has worked with the Letwiltok people at Cape Mudge for many years, contends that Dogfish Bay is the site of a first salmon ceremony. The first salmon caught were cut up, cooked and all members of the tribe partook. The bones of these salmon 'chiefs' were then returned, if possible by twins, to the sea and they, impressed by the good will of the tribe, would return to their salmon people and send them forth to be caught. Twin humans were thought to be salmon and given salmon names (Inglis, pers. comm.).

This site provides us with a hybrid image of whale/wolf, a great hunter with the desired prey, a salmon, in its tail. Images of humans or guardian spirits and birds are to be found where the canoes land. The stone bowl might have been the cooking vessel, the water heated with stones, and the ponds used for trapping various species of fish. Drumming stones, that is stones with sequences of carefully pecked indentations, occur at Grief Point below Powell River in conjunction with visible fish traps.

A second dense complex occurs inland at Petroglyph Park in what appears to be a shaman's grove. There is a good view down to the Strait. The surrounding area has many sets of elaborate engravings, most at some distance from the sea. In the Park are images of many kinds of birds and flat fish mixed with wolf jawed sea creatures. Thochwan, the shaman delineated here, is accompanied by his hybrid familiar. The decoding of this site presents an intriguing problem. Are we to assume that some images are factual and others spirit animals and that the two are intermixed? Or are we to accept native information that there once was a sea creature, deadly to encounter, but the possession of the tiniest portion of which meant wealth and power. Images of 'sea monsters' occur within every tribal territory. Could these images provide us with evidence of lost species that would help define the ecology of the ancient coast? Coordinating rock writing with fossil evidence might answer questions about their factual validity.

Conclusion

In conclusion, I put forward nine points to take into account when attempting to decode rock writing:

1. Petroglyph images are often used by people in our culture as receptacles for projection. Because the weathered image resembles something familiar it is then labelled as that.

Coastal iconography was, and is, highly codified. Knowledge of that code is necessary for complete identification. The stylistic changes the iconography underwent can be a key to dating and tribal affiliation.

2. To obtain information useful for the BTF project, some form of dating must be devised. According to a dig at Namu in the Queen Charlotte Islands, B.C., conducted by Simon Fraser University archaeologists, the earliest dated image of a rockfish is about 3 500 years old, although people have lived at that site for approximately 9 700 years. Many petroglyphs are intertidal and weathering is a significant factor. Factoring in the kind of stone used and tidal action Doris Lundy (pers. comm.) estimates that known petroglyphs on this coast are from 3 000 to 300 years old. Stylistically small portable objects, dated to 2 500 to 1 500 years ago, show a startling relation to birds and canines depicted in petroglyphs.

3. The oldest dated rock art in the Pacific Northwest is a deeply carved petroglyph panel partially buried by ash from the explosion of Mt. Mazama which formed Oregon's Crater Lake some 6 700 years ago. In B.C. a petroglyph, on Protection Island off Nanaimo on Vancouver Island, has been dated by radio carbon dating charcoal from stratified midden material partially overlaying the image of a killer whale. It had been pecked into sandstone which forms the upper portion of a seaward bank. Researcher Ann McMurdo reported that a date of approximately 345 years (plus or minus 40 years) or 1605 A.D. was secured (Inglis, pers. comm.).

4. It is likely that stylistic analysis, lichen growth, rock patination and soil or debris over burden are our only forms of dating. Over burden on the extensive complex of figures at Nanaimo River is roughly estimated at 1000 years. Much of the area has not been uncovered and more petroglyphs might still be found and accurately dated.

5. The combination of clearly identifiable birds, flatfish and creatures no longer recognisable should be approached with caution. Petroglyphs *do* include spirit animals such as dragons and shaman's familiars. However, these creatures are usually, if not always, made up of known animals.

6. We cannot assume that we are in possession of any complete knowledge of the meaning of rock image sites. So little information has been recorded that most written evidence is guesswork. Knowledgeable native people maintain that certain images release the spirit of that place or creature, or are doors to another world which it may not be healthy to open unprepared. Until we are better informed it is best to assume that all petroglyph sites are sacred and all should be approached with reverence and respect. The wishes of native people of the region are to be respected. Sites should not be approached casually, treated as tourist stops, photo opportunities or be used commercially. Rubbing should be kept to a minimum. No attempt to move petroglyphs or rocks can be supported since the complex in which they are found is as informative as the image itself.

7. The range and universality of rock imagery is startling. This should not be surprising. A unique personal expression is available to its creator and close acquaintances, but if a tribal neighbour at one or two removes is to read your sign its iconography must be available to them. A shared set of signs, as in sign language, is essential. The Seawolf, readable in widely separated territories around the North Pole, speaks of animals, fish and method throughout that region.

8. Modern petroglyphs and pictographs have often been ignored because of the inclusion of non-native iconography. But their very modernity means they can be read and validated by historical events. The readable imagery helps us enter the code of the older visual language. If X means Y in this case, perhaps a like usage can be found in an older panel. If, at Kingcome Inlet, native *coppers* are shown with cows in a panel dated 1927, another panel nearby with *coppers* and a deer might prove a similar depiction of a potlatch and perhaps some other form of dating can be located.

9. It is important to state that in order to interpret rock writing we must both get our minds inside the culture that produced them and find native people who can read the imagery. Imaginative guesses, projection, or comparisons based on one's own culture will never provide complete answers. But the sites themselves do help decode sets of images. In essence, no petroglyphs or pictographs should be analyzed separated from its site. Images should be described in context and

actual sites visited. Rock writing is site-specific, and it is that specificity that could prove helpful to scientists desiring to catalogue area populations prior to non-native records.

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Part 3: Biology and Exploitation of Animals and Plants in the Strait of Georgia

Past and Present Features of Macrobenthos in the Strait of Georgia

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Abstract

A brief review of knowledge on macrobenthos distribution in the Strait of Georgia is presented, with emphasis on depth and substrate type. Inferences are drawn on past biomass based on inferred past consumption by humans and the catches they imply. The resulting biomasses and related parameters (P/B, Q/B, etc) are proposed as inputs to an Ecopath model of the Strait of Georgia one hundred years ago.

Introduction

The Strait of Georgia, on the west coast of Canada, is 200 km long with a mean width of 30 km, a total area of 8 600 km^2, and a mean depth of 156 m. Rocky and sandy shores predominate, accounting for about 90% of the shoreline in the Strait and contiguous inlets. Benthic communities vary through the Strait with geology, substrate type, wave energy and depth. Soft bottom environments typically support burrowing organisms, whereas rocky environments (which do not occur in deeper parts of the Strait) support many organisms adapted to attaching to or moving across rocky surfaces.

Guénette (1996) estimated the Ecopath inputs for macrobenthos in the Strait of Georgia, i.e.. tentative estimates of biomass, P/B, Q/B, P/Q and EE for two macrobenthos groups of the Strait of Georgia. In this contribution, parameters of three exploited benthic groups, bivalves, abalone and *Octopus* and two other groups, miscellaneous large macrobenthos (MLM) and small macrobenthos are estimated for the same location one hundred years ago.

Identification of benthic groups

The bivalve group comprises intertidal clams, oysters and geoducks, these jointly constitute 98% of the exploited bivalves. Octopus and the abalone *Haliotis kamthsatkana* are considered separately, because they are important species for human consumption, with highly specific feeding habitats. Estimates were obtained using catch data from Bourne (1987) and following Hewes (1973), who suggested that the total biomass of a exploited population one hundred year ago would be 15% of present commercial catches. Density of bivalves was estimated taking account of the soft bottom area (after Levings et al. 1983), and density of *Octopus* and abalone were estimated considering that they occur on hard substrate. It is assumed that there was no exploitation of subtidal species in 1897 beyond a depth of 20 m.

Ducks can be important predators of marine bivalves. Bourne (1984) estimated that a flock of 200 scoters could consume between 5.3 and 16 t of littleneck and/or manila clams in a six month period. The intertidal flats at the mouth of the Fraser River and Boundary Bay are recognised as particularly significant feeding areas characterised by soft sediments (Levings 1989).

Miscellaneous large macrobenthos (MLM)is also important. Ellis (1969) used data from the Strait of Georgia to identify infaunal species of great ecological significance, i.e., which occur in a high percentage of samples from collecting stations, or in high densities or biomasses. From 19 species that occurred in every one of 45 replicates, he identified nine as ecologically significant: errant polychaete (*Lumbrineris* and *Nephtys*); the sedentary polychaetes, (*Maldane glebifex*, *Sternaspis fossor*, and *Prionospio*); the bivalves, (*Compsomyax subdiaphana*, *Macoma elimata*, and *Yoldia ensifera*); and brittle star, (*Ophiura sarsi*). For modelling purposes these nine species were grouped together. The figures in Table 1 are computed from data presented by Ellis (1968), grouped by depth stratum. In a later review, Ellis (1971) stated that the benthic macrofauna is a stable community with a high (dry weight) biomass of about 60 $g \cdot m^{-2}$. The biomass decreases with depth and has values of about 14 $g \cdot m^{-2}$ organic matter. This community feeds largely on deposited material, a flux of 3 000g·m-2/·yr-1 with a carbon content of 7.5% (Stephens et al. 1967).

Depth stratum (m)	0 – 20	20 - 50	50 – 100	100 – 200	200 - 300	>300
Area (km^2)	1245	800	1560	2130	1570	1330
Bivalves	71-92	7.9-10.2	-----	-----	-----	-----
Abalone	0.62 - 0.85	0.07 - 0.09	-----	-----	-----	-----
Octopus	0.37 - 0.78	0.04 - 0.09	-----	-----	-----	-----
MLM	48.08 – 72.12	378- 567	407- 610	111 – 166	343 - 515	150 – 225
Small Macrobenthos	12-18	95- 142	102 – 152	28 – 42	86 - 129	38– 56

Table 1. Estimated biomass ranges of different macrobenthic groups (t-km^{-2}) per depth stratum in the Strait of Georgia, one hundred years ago.

Groups	Catch (t·km^{-2})	Biomass (t·km^{-2})	P/B (year^{-1})	Q/B (year^{-1})	EE	GE (P/Q)
Bivalves	0.082	90.7	0.7	5.0	0.80	0.140
Abalone	0.067	0.812	0.0	20	0.80	0.029
Octopus	0.033	0.634	1.0	9.0	0.77	0.111
MLB	-	295	3.0	36	0.90	0.083
Small Macrobenthos	-	88.5	8.4	30	0.68	0.280

Table 2. Suggested values for Strait of Georgia Ecopath model one hundred years ago.

	Predators				
Prey	**Small Macrobenthos**	**Birds**	**Miscellaneous Macrobenthos**	**Abalone**	**Octopus**
Detritus	0.85	0.8	0.1	0.04	0.01
Phytoplankton	0.1	0.15	0.2	0.01	0.01
Benthic algae	0.04	0.01	0.2	0.95	0.05
Zooplankton	0.01	0.04	0.3	-	0.08
Small Macrobenthos	-	-	0.2	-	0.3
Bivalves	-	-	-	-	0.2
Misc. Large Macrobenthos	-	-	-	-	0.35
Abalone	-	-	-	-	-
Octopus	-	-	-	-	-

Table 3. Assumed diet composition of macrobenthic groups in the Strait of Georgia.

Small Macrobenthos (SM) and Their Substrate

This group comprises starfish, urchins, anemones, chitons, polychaetes, crabs, isopods and many other invertebrates. Many of these species provide food for other species, notably the giant octopus which feeds on a variety of crustaceans and bivalves (Lambert 1994).

Intertidal mudflats support burrowing organisms such as clams and nereid polychaete worms. Both manila and soft-shelled clams are exotic species, introduced from Japan and the Atlantic Ocean, respectively, in the last century (Harding et al. 1994). Subtidal soft-bottom communities support burrowing invertebrates such as polychaetes, sea cucumbers, clams, heart urchins and bristle stars (Harding et al. 1994). Sandy subtidal areas in the Strait support communities intermediate between those found in rocky and muddy areas. Sandy intertidal areas do not provide stable habitats and support few species. Deep subtidal habitats in the Strait (i.e., > 200 m) do not support diverse invertebrate communities or productive fish communities and are not heavily fished (Ketchen et al. 1983).

Results and Discussion

Ecopath inputs values were estimated following Pauly et al. (1993). Suggested input values for catch, biomass, P/B, Q/B, EE and GE are presented in Table 2. There are no records of catches before 1880. Nevertheless, there are evidences that First Nations seafood consumption was very high (Hewes 1973; Fladmark 1986). Assuming that per capita consumption was as high as double the present Canadian consumption (23 kg; Anon. 1996), and that it consisted of 25% bivalves, 10% Abalone, 5% *Octopus* and 60% other species, the catches were estimated for an assumed population of 6 000 inhabitants in the Strait of Georgia region. (Table 2) As stated above, this is based on the assumption that there was no catch below 20 m depth, and that 67% of the area was soft bottom (Levings et al. 1983).

The biomass of the exploited groups is the weighted mean of the values presented in Table 1. For the

miscelaneous large macrobenthos and the small macrobenthos groups the

biomass is the weigthed mean of the biomasses (wet weight) in each depth stratum, assuming that 100 years ago it was 15% more abundant than today. Abalone natural mortality (P/B) was estimated after Breen (1980); octopus natural mortality was estimated from longevity (t_{max}, in years) using Hoenig (1983) empirical equation: $\ln(Z) = 1.44 - 0.984\ln(t_{max})$, knowing that the life span is about 5 years (Bourne 1989). Other values of P/B, Q/E and EE come from Palomares et al. (1993) and Chavez et al. (1993). The group's diet composition (Table 3) was estimated after Harding et al (1994) for the small macrobenthos, after Bourne (1989) for abalone and bivalves, and after Lambert (1994) for octopus.

Based on commercial catch data, stock abundance for shrimp, clam, geoduck, green and red sea urchins is low to average; of these, stocks of clam, geoduck, green and red sea urchin appear to be declining. The abalone fishery is now closed due to low abundance (Levy et al., 1996). This is similar to trends in other species groups in the Strait of Georgia (see e.g. Martel and Wallace this vol., Winship this vol.) This implies that current management practice aimed at sustainability may not be the most adequate, since there is strong evidence that several stock are well below historic levels, leading to reduced catches.

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Historic Changes in Capelin and Eulachon Populations in the Strait of Georgia

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Abstract

A brief review of the biology of two small pelagic species of the Strait of Georgia, capelin (*Mallotus villosus*) and eulachon (*Thaleichthys pacificus*) is given, with emphasis on distribution and historic change in abundance. The conclusion is drawn that the abundance of these two species one hundred years ago may not have been higher than today.

Introduction

Capelin (*Mallotus villosus*) is an important source of food to a number of piscivores in the Strait of Georgia, as is eulachon (*Thaleichthys pacificus*). Eulachon was also of great nutritive and cultural importance to the First Nations around the Strait of Georgia. This contribution reviews the biology of these two species with emphasis on their distribution and relative abundance through time.

Capelin (*Mallotus villosus*)

Capelin are small pelagic fish of the family *Osmereidae* (smelts) that is widely distributed over the northern Atlantic and Pacific Oceans. The Strait of Georgia is the southern edge of their distribution. Hart and McHugh (1944) reported that Ladysmith (about 49° N on the east coast of Vancouver Island) was the southernmost spawning location for which documentation was available. There has been, since, a record of spawning capelin taken once at Sequim Harbour, Washington, approximately 48°05′N off the Strait of Juan de Fuca at the extreme southern end of the Strait of Georgia. There are some intermittent records of occurrences in areas outside the Strait of Georgia, notably off the east and north coast of the Queen Charlotte Islands and in the Prince Rupert area (Hart and McHugh 1944).

In the 1930s capelin spawned regularly at night in intertidal areas on certain sandy beaches in the Strait of Georgia. Spawning usually occurred in the fall (late September and October) during full moons (or spring tides). In other parts of their range such as the Bering Sea in Alaska and Siberian coasts, capelin are Spring spawners, so the Fall spawning habit of the Strait of Georgia capelin may have been unique.

Small recreational fisheries usually occurred at the main spawning sites, including Denam Island, Departure Bay Nanaimo, and some nearby beaches at Hammond Bay, the north shore of Burrard Inlet and areas near Ladner on the Lower Mainland. Hart and McHugh (1944) reported captures from 1930, 1932, 1934, 1936, 1939 and 1940 in Departure Bay. These records indicate that capelin spawned quite regularly in Departure Bay, probably every year. Other areas have also been used for spawning, but have not been documented. It seems that these fall-spawning capelin disappeared, in approximately the mid-1970s. From the few accounts from participants in the recreational fishery, abundances appeared to decline for several years and so people lost interest. In the Denman Island area, people observed dogfish (*Squalus acanthias*) pursuing capelin into the shallow waters of their spawning beaches (Mike Morrell, pers. comm.). During the last two decades the Pacific Biological Station (DFO), Nanaimo, received numerous calls from people asking about capelin, and where they are spawning. Often these calls indicate that people have looked for capelin in areas where they once occurred, but they were unsuccessful in finding capelin. These accounts, plus the apparent absence of capelin from other sources (such as incidental catches in research samples) has led me to conclude that the Fall spawning capelin, present from the 1930s (or earlier) to the mid-1970s, has disappeared from the Strait of Georgia.

In the last few years (1995 and 1996) capelin have 'reappeared' at the heads of Bute and Knight Inlets, which open into the north end of the Strait of Georgia. These 'new' capelin were captured in March. Some fish were sexually mature and others were spent, indicating that they were captured during spawning. These capelin were captured accidentally during routine purse seine catches conducted by staff of the Department of Fisheries and Oceans to monitor herring in these areas. Similar small-scale fishing efforts have been conducted in previous years, so it is probable that if capelin had been resident in these areas in previous years (in the 1970s and 1980s) some would have been captured - but we have no reports of them. Therefore, these observations suggest that capelin have now returned to the

Strait of Georgia, although these new 'Spring spawning' capelin may not be the same as the previous 'Fall spawning' capelin. Also, they still are not reported from any areas in the Central Strait.

The significance and implications of these observations are uncertain and many of the following comments are speculative, but some may be relevant to debates about changes in the Strait of Georgia ecosystem. My first key point is that capelin probably were not a large component of the Strait of Georgia ecosystem, either as a predator of zooplankton or as a prey species. At nearly all times there, abundance has probably been low and, in British Columbia, they are not reported as being a primary food source for predators. In contrast, capelin are extremely abundant and important in northern areas (Vilhjalmsson, 1994) as a prey species for fish, birds and marine mammals.

My second key point is that there was no commercial fishery for capelin so the disappearance of the fall spawning capelin does not appear to be associated with any commercial fisheries directed at capelin. The recreational fisheries were very small and irregular. In each of the three areas where direct observations are recorded the fisheries were irregular events, and the catches were small.

My third key point is that there were no major spawning habitat changes associated with the disappearance of capelin. Most of the beaches were capelin spawned are basically the same now as they were in the mid-1970s, before the capelin disappeared.

At worst, the Fall spawning capelin was a unique, reproductively isolated population(s) that inhabited the Strait of Georgia since the post-glacial period of 10-15,000 years. On the other hand, this Fall-spawning capelin may have been part of a much larger 'North Pacific' population that has periodic influxes to areas like the Strait of Georgia, or other areas. If so, the recent observation of the smaller, Spring-spawning capelin may be part of the same biological process of geographical expansion and contraction of the population over time. In time, these recent capelin colonizers may evolve into the Fall-spawning populations.

Therefore, although we do know the biological significance of the 'lost' capelin, or the reasons for their disappearance, it is possible, and perhaps probable, that the disappearance was not caused by direct anthropogenic effects such as fishing for capelin or spawning habitat destruction. However, we cannot rule out other indirect effects- such as subtle changes in the pelagic ecosystem of habitat caused by fishing or environmental change or degradation.

Moreover, we do not know that change in ocean climate may be important in determining the distribution and range of capelin**.** Even small changes in ocean temperature might impact capelin, which are in the Strait of Georgia at the southern edge of their range. Within the Strait of Georgia there has been a pronounced rise in sea-surface temperatures since the mid-1970s, about the same time that capelin disappeared. Vilhjalmsson (1994) indicated that both spawning migrations and spawning location of Icelandic capelin are influenced by temperature. Temperature variation is reported to influence timing of migrations of the shad *Alosa sapidissima* (Leggett and Whitney 1972) but not necessarily other species such as the Atlantic smelt or alewife (Chadwick and Claytor 1989). Therefore sea-surface temperatures, or other climate-related variables, could be important in the determination of capelin distribution and abundance in the Strait of Georgia Still, some uncertainty remains. This suggestion (i.e., hypothesis) will be demonstrated to be incorrect if sea-surface temperatures remain high, and capelin still return to spawn in the fall at locations known as spawning areas from the 1930s to the 1970s. On the the hand, if the disappearance of capelin was related to temperature or climate change, then we should not expect a re-establishment of capelin if temperatures remain high or continue increasing. If so, for capelin in the Strait of Georgia, there is no way '*Back To The Future*'.

Eulachon (*Thaleichthys pacificus*)

Since 1994, there has been a sharp decline in abundance of the anadromous eulachon, both in the Columbia and Fraser Rivers and elsewhere in southern British Columbia. The explanations for these declines are uncertain and may be related to changes in spawning habitat, changes in ocean climate and other factors - but the biological mechanisms are not clear. Eulachon, however, is migratory, and spends relatively little of its life in the Strait of Georgia. There are very few records of adult eulachon capture in the Strait of Georgia, whereas there are numerous accounts of eulachons on the west coast of Vancouver Island and other areas of northern British Columbia. Therefore the Strait of Georgia does not seem to be important to eulachons, other than as a passageway from the river to the coastal feeding areas, and later, from the coastal feeding areas to the riverine spawning areas. If the Strait of Georgia was not important to eulachons, the reverse may not be correct; eulachons might be (or have been) important to the Strait. For instance, the Fraser River eulachon population may have once consisted of many thousands of tons of spawning fish. We do not know the spawning biomass but we might use the Columbia River as a reference point, although the Fraser River is somewhat smaller than the Columbia. Until recently, the Columbia River has sustained an eulachon catch of several thousand tonnes and still had an abundant spawning biomass. Presumably, the Fraser eulachon run was once large and may also have consisted of thousands of tonnes. In most eulachon bearing rivers, the eulachon spawning run attracts many predatory species of marine mammals and birds. Presumably many predatory fish also follow eulachons. Therefore, the present diminished run of eulachons in the Fraser probably attracts a much smaller group of predators--so eulachons would have had a short-term effect on predator distribution in the Strait. Eulachons die after spawning (Hart and McHugh 1944) and the input of several thousand tonnes of dead eulachons could have had large impacts on the scavenger community, both within the river and in the estuary, where many of the dead, spawned out eulachons would collect. In particular, it is known that the sturgeon (*Acipsenser transmontanus*) feeds on eulachons during the spawning run (M. Baillie, pers. comm.). These effects notwithstanding, the impact of eulachons on the Strait of Georgia ecosystem (or vice versa) probably was not large relative to that of other, more abundant species that are resident in the Strait for longer periods.

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Estimating Historical Lingcod Biomass in the Strait of Georgia

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Abstract
Using historical removals, length frequency of catch and fecundity at age information, we reconstructed historic biomasses of lingcod (*Ophiodon elongatus*) in the Strait of Georgia, B.C., Canada, using an age synthesis model. The lingcod biomass has been reduced by over 95% between 1951 and 1991. Based on the historical removal data, the biomass 100 years ago is greater than or equal to the biomass in 1951.

Introduction

Once lingcod (*Ophiodon elongatus*) reach maturity, they become a top predator in rocky reef areas throughout their range from Baja California to the Shumagin Islands, Alaska (Cass et al. 1990). Although lingcod populations are genetically similar throughout most of their range, significant differences have been detected in populations in the Puget Sound/Georgia Basin area (Jagielo et al. 1996). The removal by fishing of this top predator over the last century has undoubtedly changed the ecosystem structure of the Strait of Georgia. Furthermore, this stock, being non-migratory is vulnerable to overfishing. In this paper we use catch data from the commercial fishery and sports fishery, and an age synthesis model to reconstruct past lingcod biomass in the Strait of Georgia from 1951 to 1993. The model was then fit to length-frequency data collected from creel surveys using a maximum likelihood function.

The lingcod fishery in the Strait of Georgia started in the 1860s and continued until 1990 when the fishery was no longer economically viable. Records of lingcod landings started in the early 1889; however, these data sets included all species of ground fish (Cass et al., 1990). More extensive data sets on total landings and effort started in 1951. The lingcod fishery in the Strait peaked in the mid 1950s, and since then has declined from ~1000 t per year to < 5 t per year. There are indications that the fishery may have been larger in the 1940s, but single species data are unavailable to verify this (Beamish et al. 1994). After the closure of the commercial lingcod fishery in the Strait of Georgia, a voluntary size limit of 58 cm for the sports fishery was adopted. Over the next two years, with no signs of the stock recovering, the sports fishery was subjected to further restrictions: a mandatory size limit of 65 cm, and bag limits of 1 fish per day and 10 fish per year. At present, lingcod abundance in the Strait of Georgia is being estimated from creel survey data.

Reconstructing the Population

The biomass was reconstructed using an age synthesis model, with different growth rates for males and females (Smith and McFarlane, 1995). Natural mortality ($M = 0.22$ ◇ year $^{-1}$) was assumed to be the same for both males and females. The fecundity of females was a constant 26 eggs◇g $^{-1}$ of female.

Parameter (unit)	**Female**	**Male**
L_∞ (cm)	104	82.9
K (year^{-1})	0.18	0.25
t_0 (year)	-1.11	-1.19
b	4.67	3.35
q	0.179	0.079

Table 1. Growth parameters estimated from a lingcod tagging study conducted in the Strait of Georgia (Smith and McFarlane 1995).

The reconstructed biomass was initialized using the number of recruits observed under equilibrium conditions. It was assumed that the sex ratio of the recruits is 1:1. Each cohort was propagated through time using the following function:

$$N_{i+1,t+1} = N_{i,t} > S > (1 - U_t > V_i) \quad ...1)$$

where $N_{i,t}$ is the umber of individuals age *i* in year *t*, $U_t = C_t / B_t$ and V_i is the vulnerability at age. The exploitation rate (U_t) is calculated by dividing the catch (C_t) by the predicted biomass (B_t) from the age synthesis model. The vulnerabilities at age schedules (V_i) are allowed to vary in the first 5 years for both males and females, while lingcod greater than 6 years old are assumed to be fully recruited to the fishery.

Recruitment in the next year is calculated using the Beverton-Holt stock recruitment function:

$$R_t = \frac{\alpha > E_{t-1}}{1 + \beta > E_{t-1}} \quad ...2)$$

The number of eggs (E_t) was calculated by taking the sum of the mature female biomass in the previous year multiplied by the fecundity. Alpha and beta are constants that are estimated assuming an unexploited steady-state population.

The length frequency data from the creel survey were converted to catch at age data using the von Bertalanffy growth equation and the growth parameters in Table 1. The difference between the proportions at age in the model and the observed catch at age data is minimized by allowing the vulnerabilities at ages 1-5 to vary, allowing for recruitment anomalies, and allowing the initial biomass to vary. A maximum likelihood function was used to calculate the optimal biomass in 1950:

$$L=\Sigma[\Pi\rho_{i,t}\ Observed\ ☜\ (\ Ln\rho_{i,t}\ Expected)] \qquad ...3)$$

where $\rho_{i,t}$ refers to the proportion at age i observed in year t.

Estimating Lingcod Biomass in the Strait of Georgia 100 Years Ago

In the absence of lingcod catch data prior to 1951, we were unable to provide an estimate of the pristine biomass of lingcod in the Strait of Georgia. The maximum exploitable biomass observed was 10 642 t in 1951, and the biomass continued to decline up to 1991 (Figure 1). The minimum exploitable biomass observed was 276.2 t in 1991, a mere 2.6% of the biomass observed in 1951. In 1993 an estimated 336.2 t of lingcod was thought to exist in the Strait of Georgia. If we assume the surface area of Strait of Georgia is roughly 6 900 km^2, then the density of lingcod in 1993 was 49 kg☜km^{-2}. The density of lingcod in 1951 is estimated to be 1 542 kg☜km^{-2}. For the purpose of the 100 year Ecopath model, the assumption can be made that in the 1890s, when the fishery was beginning, the biomass would be similar or greater than the 1951 estimate. We recommend the 1951 biomass as a conservative input to the model.

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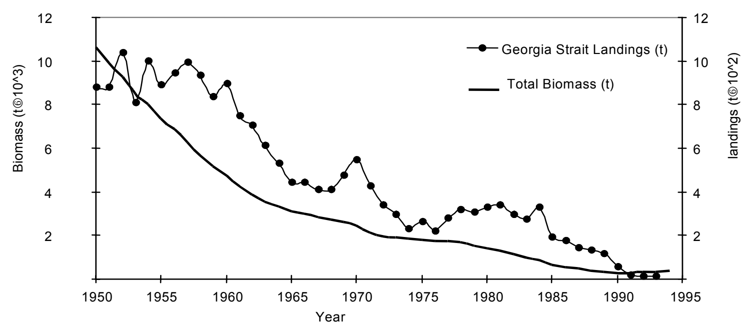

Figure 1. Reconstructed biomass, and landings (commercial and sport) of lingcod in the Strait of Georgia, 1950 to 1994.

Pleistocene Pastures: Steller's Sea Cow and Sea Otters in the Strait of Georgia

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Abstract

A review of the biology and ecology of Steller's sea cow *Hydrodamalis gigas* is presented, along with a history of its exploitation and ultimate extinction. It is argued that the sea cow functioned as a keystone species of North Pacific kelp ecosystem and that their extinction lead to major structural changes in these ecosystems. Thus models of pleistocene North Pacific coastal ecosystems should include Steller's sea cow. The sea otter, which may also act as a keystone species by foraging on kelp-eating invertebrates, has likely been absent from the Strait for over a hundred years, but was likely present 500 years ago and in more ancient time.

Introduction

One of the limitations of the Ecopath mass balance model, even in its ECOSIM formulation, is that it cannot predict major shifts in the structure of ecosystems because, in large part, such changes are not trophic in nature. For example, these models cannot mimic the effects of keystone species, which, despite embodying relatively minor numerical, biomass and energy flow quantities, can nevertheless shift the nature of ecosystems in major ways, usually by altering habitat structure. Keystone species can establish refugia habitats for adults and juveniles, alter breeding grounds, augment primary productivity, maintain a higher diversity of food niches, and generally establish a dynamic balance of structure and trophic links that characterise an ecosystem. A classic example is the African elephant which maintains a balance between open gallery forest and savannah in East Africa. The ecosystem reconstruction method which is integral to the *BACK TO THE FUTURE* approach is one practical way of comparing the presence and absence of keystone species in ecosystem models.

Two species of sea mammals in particular may have acted as keystone species in past Strait of Georgia ecosystems: the sea cow feeding on kelp, and the sea otter feeding on kelp forest invertebrates. Sea otters, where they have been re-established in northern California and in Alaska act as keystone species in their local habitats today. Were these two keystone species in the Strait of Georgia 100 and 500 years ago? If so, our past ecosystem models for the Straight will likely exhibit major discontinuities compared to the system obtaining today. This paper aims to examine these issues.

Steller's Sea Cow

Soon after the human colonisation of North America (Hoffecker *et al.* 1993), Steller's Sea cow, *Hydrodamalis gigas*, described by naturalist George Steller (1751) as gentle, trusting and unable to submerge, vanishes from the fossil record around the North Pacific (Domning 1978). A population of about 1500-5000 sea cows survived only in the uninhabited Komandorskiye Islands in the Aleutian chain, but was wiped by the 1760s through use as a 'living larder' for fur traders (Steineger, 1886).

For terrestrial mammalian megafauna, such as the mammoth, and the associated specialised carnivores and scavengers, it has become increasingly apparent that a 'blitzkrieg' of late Pleistocene extinctions throughout the world coincides with the advent of cooperative hunting behaviour and technology as modern humans spread around the globe (Martin 1967, 1984; Stringer and McKie 1997). In the past 100,000 years North America has lost 73%, South America 79%, and Australia 86% (Flannery 1990) of endemic genera of terrestrial megafauna. Few large mammals survived: some proboscids, red kangaroos, and others with life histories that could in some way withstand human hunting or lived in remote habitats hostile to humans. The horse, aurochs, and both new and old world camels survived being hunted by humans only after domestication, while both horse and camel appear to have been exterminated in North America (Martin 1984). It is surprising that a recent keynote volume reviewing the determinants of extinction rates (Lawton and May 1995) regards the extinction of the Pleistocene megafauna as a side issue (Erlich 1995, page 220-221), as though these eminent bird, insect and plant ecologists had never heard of keystone species. With the exception of asteroid impact on Earth, anthropogenic influences overwhelm the natural ecological processes of extinction: they are four orders of magnitude greater than that seen in the fossil record according to May *et al.* (1995). Cooperative hunting by humans decimated large mammal biodiversity which in turn affected dependent species and habitat. Later in human history, early attempts at agriculture seem to have helped to create many of the world's deserts. Our species has 'terraformed' the land areas of the planet through species loss and habitat change and it is now realised that we have subjected the oceans to a similar depletion (Pitcher 1998, Pitcher and Pauly 1998, Pauly *et al.* 1998).

Fossils show that sea cows were distributed around the northern Pacific from northern California to Kamchatka some 8-10,000 years BP (Domning 1978), but there are no records from this wide range more recently. Mitochondrial DNA analysis suggests that the present coastal peoples of the Pacific Northwest arrived 5000 - 8000 years BP (Morell 1997), and this may explain their lack of a cultural memory of sea cows. The first peoples in North America arrived much earlier than this (at least 15,000 BP; Hoffecker *et al.* 1993) and, as the Clovis people, soon left evidence of active hunting of large mammals, causing the Pleistocene extinctions of large mammals noted above (see Diamond 1997). It is possible that sea cows were eliminated from most of their range along the Pacific coast by these first North American peoples (Downing 1978). But, because of sea level and coastline changes (Josenhans *et al.* 1997), direct evidence of such ancient human predation, such as butchering marks on bones, will be rare.

On the other hand, Savinetskij (1992) suggested that changes in abundance of sea cows in the Late Holocene can be associated with climatic changes, their abundance increasing during warm and decreasing during cold periods. Cold conditions may have conspired with human activity at the time of extinction. The conflict between anthropogenic and climatic causes of major changes in abundance is a familiar one and has generated active controversy over Australian (see Flood 1995), North American and Eurasian large mammal extinctions (see Diamond 1997). But given current archeological evidence, it seems reasonable to suspect a human hand in the fate of large mammals that become extinct, or in the case of the sea cow, nearly so, just after the arrival of human hunters.

Andersen (1995) has suggested that the demise of the seacow may have been accelerated by a complex feedback relationship among sea urchins, sea otters, kelp species and sea cows. Steller's sea cow, unlike its tropical relatives the dugongs and the manatees, evolved a large liver to detoxify algae (and consequently a large body size), but was confined to grazing the less-toxic kelps of shallow waters. When sea urchins graze heavily, kelp species shift in favour of those with more toxic phenols as an anti-grazing defence. Sea otter predation reduces urchin numbers, thereby reducing diet toxicity for sea cows. Conversely, if otter numbers are reduced, sea cow diet toxicity will rise. Sea cow extinction may therefore have been accelerated by sea otter hunting, and moreover the loss of sea otters from a habitat might preclude the return of sea cows. This process could have occurred as Clovis hunters took sea otters for fur and sea cows for meat and resulted in a series of local extinctions of sea cows along the Pacific coast. The last local extinction of the sea cow was the global one recorded in historical times when the 'living larder' was raided by hungry fur traders.

In conclusion, Steller's sea cow was likely not present in the Strait of Georgia 500 years ago, but would have to be included in a 10,000 BP Pleistocene model. With sea cows grazing large amounts of kelp, otter and grazer dynamics in the Straight would have been very different, probably with much higher turnover rates. Sea cow predators would have been mainly killer whales. Available eco-physiological parameters for dugongs (about 3 metres in length) would need to be modified to reflect slower turnover and larger body size (7.5 metres long) for incorporation into such an Ecopath model, but a starting value for sea cow biomass might come from the estimated 1500–5000 population in the area around the Komandorskiye islands.

Sea Otters

Prompted by Steller's reports of their amazing dense fur in 1751, in less than a hundred years, sea otters, *Enhydra lutris,* known today to be keystone species of Pacific Northwest coastal kelp forests, were rendered almost extinct throughout the North Pacific. Local extinctions by hunting were rapid. For example, at the Komandorskiye Islands, the site of sea otter and sea cow discovery on Vitus Bering's voyage of discovery, sea otters were already rare only 10 years later (Domning 1978).

There appear to be no specific references to sea otters in Captain George Vancouver's travel log from 1792 when he named the Strait (or Gulf) of Georgia in honour of the British King George 3rd. However, fifteen years before that, the fur trade was already being persued by native peoples for sale to Europeans. The fur trade started very soon after Admiral Vincente Tofino in 1774 and

Captain James Cook in 1778 visited the Pacific west coast of Vancouver Island. Although these navigators did not enter the Strait, it is not hard to imagine that word of the foreigners' delivery of great wealth, in the form of metal tools in exchange for furs, would have spread very rapidly among people living in the area. Native peoples all over the world are documented as adopting useful technology rapidly after first contact (Diamond 1997). Cook's account encouraged a British base for the fur trade and was the principal initiative that lead to Goerge Vancouver's voyage only four years later. After Alexander Mackenzie reached the coast overland at Bella Coola in 1793, and Simon Fraser reached the Strait of Georgia in 1808 by navigating the Fraser river, the fur trade expanded rapidly and fixed trading posts were established. It is not hard to imagine that sea otters would have became endangered species along the B.C. coast during this early period.

Forty years later, after Vancouver Island was made a colony of the British Crown in 1849, the fur trade remained the primary concern of Governor Sir James Douglas when appointed in 1851, and later when he became the first Governor of the new colony of British Columbia in 1858. Notably, in 1855 there were only 755 registered European inhabitants, almost all of them engaged in the fur trade. But for the first eighty years after European contact (1774-1854), documentation, especially for things like the exact geographical origin of sea otter furs traded by local peoples, was very poor. It is therefore not so surprising that, as yet, no one has discovered written records of sea otters in the Strait. It would be helpful if historians could look in these older archives for more direct evidence. Sea otters in the Strait of Georgia could easily have been wiped out during this period. In fact, local extinction of the sea otter in its enclosed calm waters and islands could have been rapid.

Unfortunately, in present accounts by First Nations people, it is difficult to separate river otters, which have declined in numbers in living memory but are still present in the Strait, with sea otters, which could not have been present in significant numbers in the past 150 years. Otherwise they would have been documented by the first fully organised colonial administrations in the 1860s. Moreover, a cultural memory of sea otters would have to have survived the huge reduction in the native population by the epidemics of the mid to late 1800s, and the consequent disruption and relocation of many native communities (Ray 1990, 1997). This demographic and social catastrophe appears to have been more severe in the Strait of Georgia than areas further north and remote from Europeans, where nations such as the Haida, Toltan, Haisla and Heiltsuk, though much reduced, kept much of their culture intact through this difficult period. It would be very helpful if there was another attempt to examine the cultural memories of elders of native peoples along the Strait of Georgia,.

It is said (Jane Watson, pers. comm.) that the type of kelp beds within the Strait of Georgia is not suitable sea otter habitat. However, Andersen (1995) suggested that algal communities are labile and respond to the presence and absence of grazers (see also Riedman and Estes 1990), so that the kelps in the Strait could have been quite different with sea otters present. Giant sea otters (*Enhydra macrodonta*) existed in the North Pacific in the Pleistocene era Kilmer 1972) and may also have succumbed to ancient human hunting, thereby also changing kelp communities.

As broadly similar sea inlets to the north and south of the Strait of Georgia undoubtedly held sea otters, and in Alaska still do, it is stretching credulity to suppose that they were absent from the ancient Strait of Georgia. Rather than assuming that no evidence signifies absence from the ecosystem, I consider that sea otters should be entered in the 500 year BP model, and in any model to be constructed for more ancient times.

Conclusions

Pleistocene aquatic pastures with the sea cow and sea otter present would have looked very different to today's Strait of Georgia, but with sea cows gone, even a 500 BP system, with sea otter predation on urchins and abalone, may have had significant differences compared to today. As they act as keystone species, information about these two sea mammals is critical to the *BACK TO THE FUTURE* procedure in the Strait of Georgia.

To learn more about their likely impacts on ecosystem structure, the next step would be to construct and compare the following models with and without Steller's Sea Cow and sea otters, as follows:

Species	Present	100 BP	500 BP	8000 BP
Steller's Sea Cow	Absent	Absent	Absent	Present
Sea otter	Absent	Absent ?	Present	Present

The present exercise, as might be seen in Dalsgaard et al. (this vol.) covers the first three of these combinations, but a model of the Strait of Georgia including both sea otter and Steller's sea cow, as might have been found in the mid Pleistocene, is still to be constructed and examined.

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Pinnipeds and Cetaceans in the Strait of Georgia

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Abstract

Biomass, annual consumption and diet composition of marine mammals in the Strait of Georgia, British Columbia, Canada, (now and 100 years ago) were estimated for later incorporation into Ecopath mass balance models of the Strait of Georgia ecosystem. Ranges of biomass were provided, rather than discrete numbers. This allows the data to be used with the routine of Ecopath thus allowing explicit consideration of uncertainty.

Introduction

The marine mammal species that currently use the Strait of Georgia year round are the transient killer whale (*Orcinus orca*), Dall's porpoise (*Phocoenoides dalli*), harbour porpoise (*Phocoena phocoena*), and harbour seal (*Phoca vitulina*) (Wada 1996). Resident killer whales are present in the summer from May to September (Volker Deecke, pers. comm.). Adult and subadult male Steller sea lions (*Eumetopias jubatus*) and California sea lions (*Zalophus californianus*) are in the Strait from November to May (Andrew Trites, U.B.C. Fisheries Centre, pers. comm.).

In addition to the marine mammal species that presently inhabit the Strait of Georgia, three other species were present 100 years ago. Humpback whales (*Megaptera novaeangliae*) occured in the Strait from May to January (Merilees 1985). Another migratory species, the gray whale (*Eschristius robustus*), may also have been present in the Strait (Andrew Trites pers. comm.), although no independent record of this occurrence could be found. According to their migration schedule, if they did enter the Strait it was probably in the months of June to October (Pike and MacAskie 1969). Minke whales (*Balaenoptera acutorostrata*) were found in the Strait all year round (Andrew Trites pers. comm.; Pike and MacAskie 1969). It was also thought that sea otters may have been present in the Strait at the turn of the century, but this is now questioned (Jane Watson, pers. comm.). Perhaps these were river otters (see also Pitcher, this vol.)

	Mean wt. (kg)	Daily ration ($kg \cdot day^{-1}$)	Q/B ($year^{-1}$)	Pop. (n)	Biomass ($t \cdot km^{-2}$)	Food Cons.. ($t \cdot km^{-2} \cdot year^{-1}$)
Orca (resident)						
Male	2587	53.73	3.178	40	0.0151	0.0479
Female	1974	43.28	3.354	40	0.0115	0.0386
Orca (transient)						
Male	3068	61.59	7.327	6	0.0024	0.0179
Female	2761	56.60	7.483	6	0.0022	0.0165
Dall's porpoise						
Male	63.10	2.754	15.93	563	0.0051	0.0820
Female	61.40	2.695	16.02	563	0.0050	0.0803
Harbour porpoise						
Male	32.60	1.624	18.18	250	0.0012	0.0215
Female	29.50	1.499	18.55	250	0.0011	0.0198
Harbour seal						
Male	63.90	2.020	11.54	7163	0.0663	0.7654
Female	56.40	1.780	11.52	7163	0.0585	0.6745
Steller's Sea Lion Male	458.0	13.45	6.225	1500	0.0996	0.6198
Cal. sea lion Male	188.0	6.597	7.439	1500	0.0409	0.3040
TOTAL				**19043**	**0.3089**	**2.6882**
Weighted mean			**8.701**			

Table 1 - Strait of Georgia present day model: marine mammal parameters for Ecopath.

Methods

Individual weights were taken from Trites and Pauly (1998). This excludes the two sea lion species (see Table 1). All daily rations, except harbour seal, were calculated from $R=0.1☜W^{0.8}$ (Trites and Heise 1996a), where R, in kg, is daily intake and W is body weight, in kg. Harbour seal ration which was taken from Olesiuk (1993). Q/B for each species was calculated from Q/B = (daily ration☜number of days in the Strait annually)/mean weight. All population sizes assumed a 1:1 sex ratio and were taken from Wada (1996), except for the sea lions. A population size of 1 500 was used for each sea lion species (Andrew Trites, pers. comm.).

All biomasses were calculated as: B = [(mean weight☜population size)/6 900 km^2]/1000. All food consumptions were calculated as: FC = population biomass☜Q/B. P/B for each species was taken from Christensen (1996). All diet compositions were taken from Wada (1996), except for the harbour seal and sea lions. The diet composition of the harbour seal was taken from Olesiuk (1993). Steller and California sea lion diet was considered to be the same as harbour seal diet in the winter (Andrew Trites, pers. comm.), and according to Olesiuk (1993) the major shift in winter is to a dominance of herring. Therefore I derived rough estimates of percent herring and hake in the winter diet of the harbour seal from Olesiuk et al. (1990a).

Mean weight, daily ration, Q/B, population biomass, food consumption estimates, and P/B ratios for the 100 year ago Ecopath model were adapted from the same sources and calculated in the same way as for the model of the present Strait of Georgia.

Results

Present Day Model

When a preliminary Ecopath model was run, incorporating the above estimates, it was found that estimated ecotrophic efficiency, i.e. (EE), was greater than one for the harbour seal, harbour porpoise, Dall's porpoise, and miscellaneous demersals. Therefore, some of the inputs had to be changed in order to reduce these EEs to less than one. The reason EE was high for the marine mammal species was the high predation by transient killer whales. The harbor seal and porpoise populations were too

small and had too low production to support the predatory pressure imposed on them. The miscellaneous demersals group was also experiencing high predation pressure although not to the extent of the marine mammal species.

First I changed the population size of some of the species. This is generally acceptable as these inputs were originally rough estimates, often with large ranges. I increased the harbour seal population to 25 816, derived from an annual growth rate of 12.5% and a population of 14 326 in 1988 (Olesiuk 1990b). This increase was only five years of growth so even if the population growth rate has later decreased, the biomass increment is probably justified. Further, I increased the harbour porpoise and Dall's porpoise populations to 4 000. These were the maximum estimates of population size in Wada (1996). I also decreased the transient killer whale population to 6 or 7 individuals. This was only a decrease of 4 or 5 individuals, and this is acceptable as the original input was a rough estimate, and transient orcas are constantly moving in and out of the Strait.

Secondly, I changed the production (P/B) of the harbour seal, harbour porpoise, and Dall's porpoise populations. All these P/B ratios were increased by 0.02 year^{-1}. I believe this was justified as it is only 1/10 of the change made in Venier (1996) to balance a similar Strait of Georgia model.

Thirdly, I changed the transient killer whale diet composition. Transient orcas did not feed on sea lions in the original input. This is of course not true, and so I reduced predation pressure on the porpoise species (only 3% of the diet each) and made each sea lion species contribute 15% of the diet of the transient killer whales.

These changes reduced the harbour seal, harbour porpoise, and Dall's porpoise EE's to less than one. The change in transient killer whale diet, however, resulted in both sea lion EE's being greater than one. In order to reduce these EE's, P/B was increased by 0.02 year^{-1} for Steller and California sea lions, and population size was increased to 2 000 for the California sea lion.

In order to reduce the EE of miscellaneous demersals, predation pressure was reduced by changing the diet compositions of the resident marine mammal species. Some of the predation on demersals by pinnipeds was decreased, and this predation was shifted to salmon (Venier 1996; Scott Wallace, pers. comm.). For the cetacean species, the reduction in the contribution of demersals in the diet was compensated by increasing the contribution of small pelagics. These changes reduced the miscellaneous demersals' EE to less than one.

100 Years Ago Model

According to Andrew Trites (pers. comm.) the number of transient killer whales that use the Strait has probably not changed over the last one hundred years However, Volker Deecke (pers. comm.) suggests there were 20-30 individuals at the turn of the century. Therefore, a range of 11 to 30 was used. The number of resident killer whales in the Strait in summer has not changed over the last one hundred years, and Volker Deecke (pers. comm.) estimates there were 100-150 at the turn of the century. Therefore, a range of 80 to 150 was used.

The number of Dall's porpoises in the Strait has not changed in the last one hundred years, so a range of 150-4 000 was used (Wada 1996). Harbour porpoises were probably more abundant in the past so the current minimum of 50 was used, and the maximum was arbitrarily set at 1/3 greater than the current maximum, or 5 333 (Wada 1996).

The current population of harbour seals is approaching historic levels, and Andrew Trites (pers. comm.) believes the population size has either not changed in the last 100 years, or that possibly there were fewer in the past due to an aboriginal harvest. Therefore the range was set at 13 000-15 000.

Andrew Trites (pers. comm.) believed the number of individuals entering the Strait each year has not changed in the last one hundred years. Therefore a range of 1 500 to 2 500 was used. The number of California sea lions using the Strait has not changed in the last hundred years. A range of 1 500-2 500 was used.

The total number of humpback whales harvested in the Strait of Georgia around the turn of the century was at least 208 and possibly as high as 596 if all five stations present after 1905 caught the same number of whales (Merilees 1985). Since the entire stock was extirpated, I assumed a population size range of 208-596. Less than 100 gray whales used the Strait, Andrew Trites (pers. comm.), but I could find no record of gray whales in the Strait. I set the range from 0-100. According to Andrew Trites (pers. comm.) there were less than 20 minke whales in the Strait 100 years ago, and according to Pike and MacAskie (1969) they were present in "small numbers". I set the range at 10-20.

The diet compositions used for those species that are still present in the Strait were the same as those in the Strait of Georgia model of the present. The diet compositions of humpback, gray, and minke whales were taken from Trites and Heise (1996b).

The Ecopath model was run using mean biomasses (on the range provided) and again the ecotrophic efficiencies (EE) of the harbour seal, harbour porpoise, Dall's porpoise, and miscellaneous demersals were greater than one. In order to correct this, I made similar changes to those I made with the model of the present.

There were three differences regarding population size. The transient killer whale population was reduced to 9 or 10, close to the minimum for 100 years ago. The harbour porpoise population was increased to its maximum estimate of 5 333. The California sea lion population did not need to be increased.

Species	Mean wt. (kg.)	Daily ration (kg·day^{-1})	Q/B (year^{-1})	Pop. (n)		Biomass (t·km^{-2})		Food Cons. (t·km^{-2}·year^{-1})	
				Max	Min	Max	Min	Max	Min
Humpback									
Male	28323	364.5	3.552	298	104	1.223	0.427	4.345	1.516
Female	32493	406.8	3.456	298	104	1.403	0.490	4.850	1.692
Gray whale									
Male	15920	229.9	2.210	50	0	0.115	0	0.255	0
Female	16453	236.0	2.195	50	0	0.119	0	0.262	0
Minke whale									
Male	6121	107.0	6.382	10	5	0.009	0.004	0.057	0.028
Female	7011	119.3	6.211	10	5	0.010	0.005	0.063	0.032
Orca (res.)									
Male	2587	53.73	3.178	75	40	0.028	0.015	0.089	0.048
Female	1974	43.28	3.354	75	40	0.021	0.011	0.072	0.038
Orca (trans.)									
Male	3068	61.59	7.327	15	5.5	0.007	0.002	0.049	0.018
Female	2761	56.60	7.483	15	5.5	0.006	0.002	0.045	0.016
Dall's porpoise									
Male	63.1	2.754	15.93	2000	75	0.018	0.001	0.291	0.011
Female	61.4	2.695	16.02	2000	75	0.018	0.001	0.285	0.011
Hbr. porpoise									
Male	32.6	1.624	18.18	2667	25	0.013	0.0001	0.229	0.002
Female	29.5	1.499	18.55	2667	25	0.011	0.0001	0.211	0.002
Harbour seal									
Male	63.9	2.02	11.54	7500	6500	0.069	0.060	0.801	0.695
Female	56.4	1.78	11.52	7500	6500	0.061	0.053	0.706	0.612
Stell. sea lion									
Male	458	13.45	6.225	2500	1500	0.166	0.100	1.033	0.620
Cal. sea lion									
Male	188	6.597	7.439	2500	1500	0.068	0.041	0.507	0.304
Total				30229	16509	3.367	1.213	14.150	5.645
Weighted mean		Min	4.202						
		Max	4.656						

Table 2 - **Strait of Georgia "100 years ago" model: initial inputs**

Again the transient killer whale diet had to be changed. The percent composition of porpoises was again reduced to 6% total. Not all of this was compensated by increasing the predation on sea lions. One hundred years ago there were also other whale species in the Strait to feed on. Therefore I transferred some of the transient killer whale predation from the sea lions and harbour seal to other whale species (5% gray, 5% humpback). The low Minke whale population was unable to support predation (even 1% caused the EE to increase beyond 1).

The same changes were made to reduce the EE of miscellaneous demersals to less than one, except the sea lions' diet composition was changed to feed even more heavily on salmon than in the model of the present.

Conclusions

This exercise showed that significant changes in marine mammal population populations of the Strait of Georgia, suggested by many historical sources, can be confirmed by the application of the Ecopath mass balance approach (see also

Dalgaard et al, this volume). The inclusion of large cetaceans in the historical ecosytem also implies a large shift of the trophic flow in the ecosystem, which was confirmed by the model. The historic model showed that total consumption by marine mammals was likely an order of magnitute greater than today. Such results would be helpful in setting realistic management goals for the maintenance and potential rebuilding of marine mammal populations in the Strait of Georgia.

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Changes in Human Exploitation of Marine Resources in British Columbia (Pre-Contact to Present Day)

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Abstract

Ecosystems are constantly in a flux governed by physical and biotic factors. Humans have long been a biotic factor in the structure of B.C.'s ecosystems, primarily as a top predator. The marine ecosystem structure of B.C. observed today is an artefact of past human exploitation imbedded in an ever-changing physical environment. This contribution outlines the major changes in human exploitation of marine resources in B.C. from pre-contact to the 1990s. Human activities prior to 1873 are qualitatively described using a variety of sources. Post 1873 changes are identified using analyses of historical landings, primary productivity requirements to sustain yields, average trophic level of species caught and species composition of landings. The post 1873 analysis uses a database comprised of 122 years of landing data, and 48 species groups. Major shifts in human exploitation are identified to gain insight on corresponding impacts on the ecosystem.

Introduction

Before 1873

Steller's sea cow was widespread in the North Pacific as recently as 20 000 years ago. By 1741, when G.W. Steller first described this animal, it had already been extirpated from essentially all but a small area of marginal habitat in the Commander Islands (see also Pitcher, this vol.). Their decline cannot be explained by natural enemies or climate (Domning, 1972). Due to the ease in which these animals could be approached and harpooned, we can infer that early humans hunted these animals to near extinction. The sea cow, being the only large animal known to eat macro algae (kelp) would have been a keystone species in the ecosystem. By the time Europeans arrived on the B.C. coast, this system was already structured by human influence. Not only had the Steller sea cow disappeared, but, as well, the First Nations of coastal B.C. were consuming considerable amounts of salmon, eulachon, clams, marine mammals, and in some regions, bluefin tuna (Crockford 1997). Midden remains indicate that native peoples along the entire Pacific rim exploited sea otters, perhaps driving otter populations locally extinct (Simenstad et al. 1978). Furthermore, by the 1800s, Steller Sea lion populations were also depleted by the aboriginal hunt for meat, hides, and oil. Their numbers increased in the late 1800s and early 1900s. This increase was an effect of the reduction in aboriginal hunting due to introduced European diseases. Disease decimated aboriginal populations to one third of their pre-contact numbers (Duff 1964, Newcombe and Newcombe 1914). And so the Stellar sea lion enjoyed a brief respite.

The arrival of Europeans to the west coast of Vancouver Island in 1774 initiated another phase of marine resource extraction from the coast. In 1778, Captain James Cook traded with the Mowachaht people for 300 sea otter pelts (Arima 1983). By the end of the 18th century the west coast of North America was swarming with ships engaged in trading and hunting for otter pelts (Pethick 1980). The trade for otters lasted only 60 years, and by 1830 the trade ground to a halt (Robinson 1979). The total sea otter population during this time had dropped from 300 000 to 2000 animals (Reidman and Estes 1990). The ecological consequences of the sea otter's near extinction went largely unnoticed (Estes et al. 1989). The sea otter is a keystone species in structuring near shore communities (Estes 1974). The absence of this animal would have profoundly altered the ecological functioning of B.C.'s coast (see Pitcher, this vol.).

The next target species by the Europeans were the northern fur seals. In B.C., this trade began much later than the Russian trade and was initially a seasonal pelagic hunt during the fur seal migration in early Spring. The largest harvest recorded by B.C. sealers was in 1894, when 94 474 seals were taken for their pelts (Anon. Sessional Papers 1895). Although these animals were only part time migrants in B.C. waters, the sheer biomass and abundance would have altered the outer coast's ecosystem functioning.

Species	Fishery	Years	Source
Salmon	Commercial	1873-82	Shepard et al. (1985), Shepard and Argue (1989)
		1983-96	Anon, DFO catch statistics
	Aboriginal	1873-51	Argue et al. (1990), Hewes (1973)
		1951-84	Bijsterveld and James, (1986)
		1985-94	Anon., DFO catch statistics (1997)
	Recreational	1953-94	Anon., DFO catch statistics (1996)
Herring	Commercial	1884-18	Anon., Sessional Papers
		1918-37	“
		1938-50	Hourston, (1980)
Dogfish	Commercial	1877-82	Ketchen (1986)
		1983-96	Anon., DFO catch statistics
Lingcod	Commercial	1889-85	Cass et al. (1990)
		1986-96	Anon., DFO catch statistics
Sablefish	Commercial	1913-50	Stocker (1994)
Halibut	Commercial	1884-37	Carrothers, (1941)
		1938-50	Anon., Sessional Papers
		1951-96	Anon., DFO catch statistics
	Aboriginal	1873-00	Carrother, (1941) average
	Recreational	1982-96	Anon., DFO catch statistics (1996)
Sturgeon	Commercial	1880-18	Anon., Sessional Papers
		1919-37	Anon., Sessional Papers
	Aboriginal	1879-00	Carrothers, estimate
Pilchard	Commercial	1917-37	Anon., Sessional Papers
		1938-48	Culley (1971)
Smelt	Commercial	1890-38	Hart and McHugh (1944)
Eulachon	Commercial	1880-35	Hart and McHugh (1944) Stacey (1995)
Whales	Commercial	1905-67	Pike and MacAski, (1969)
Harbour Seals	Bounty	1880-13	Anon., Sessional Papers
		1914-64	Bigg, (1969)
Steller Sea Lion	Cull	1914-68	Bigg, (1988)
N. Fur Seal	Fur Trade	1877-39	Anon., Sessional Papers
Oyster	Cultured	1913-29	Elsey, (1933)
		1930-39	Anon., Sessional Papers
		1951-82	Anon., DFO catch statistics
Clams	Commercial	1923-32	Anon., Sessional Papers
		1933-48	“
Prawns	Commercial	1932-39	“
Crabs	Commercial	1928-39	“

Table 1: Sources of data for major commercial, recreational, and aboriginal fisheries in British Columbia from 1873-1996. Landings after 1951 are from DFO catch statistics unless otherwise mentioned.

In 1842 whaling began in B.C. but very few whales were taken. The first onslaught started in 1866 with the establishment of whaling in the Strait of Georgia and by 1873 most of the whales had been extirpated from the Strait (Merilees 1985). The second onslaught began in 1905. Four whaling stations were built along the outer coast which were in use until the end of whaling in 1967. During this time a total of 23 436 whales were taken from B.C.'s waters (Pike and MacAskie, 1969). However, prior to 1905, American vessels were whaling in what is now Canada's exclusive economic zone, and therefore, the actual take from what is now Canada's waters was much higher. Similar to the sea cow, sea otter, and northern fur seal, the ecological impact of whaling has not been studied in detail.

Post 1873 Analysis

This section compares historical fisheries landings in B.C. with present day fisheries in order to assess impacts to the marine ecosystem resulting from consumption of marine resources. Global analysis of fisheries show a steady increase in fish landings from 1900 to the peak in 1989 (Weber 1994). However, most historical analysis only examine commercial fish species, and exclude marine mammals and non-commercial landings. This analysis of B.C.'s fishery includes all forms of marine biomass removal including commercial, aboriginal, and recreational fisheries.

Data Sources

Commercial catch statistics from a variety of sources are used to determine the biomass landed by the commercial fishery in B.C. from 1873 to present day. Annual reports to Ottawa from the Inspector of Fisheries for B.C. commenced in 1873 and are published in the *Canada Sessional Papers*. These reports were the first attempts in B.C. to quantify landings and economic value of the fishery and are the primary source for information until 1951. After 1951, landings were published in *British Columbia Catch Statistics*. For some species, review articles have been published which summarize commercial landings. When available this information was used (see Table 1). All landings were converted into wet weight expressed in metric units (Table 2).

Recreational catch statistics for salmon started in 1953 (Anon 1955, DFO 1996). Prior to this date there are no published estimates of recreational catch.

Starting in 1981, estimates of other species such as lingcod and rockfish are included in the annual recreational catch surveys. Other recreational fisheries such as clam digging, and urchin harvesting are still unreported. The values used here are therefore inherently conservative.

Aboriginal catch of salmon has been recorded by the Department of Fisheries and Oceans since 1951 (Bijsterveld and James 1986). Prior to 1950 there were no systematic records of aboriginal catch. However, there are published estimates of both 20th century aboriginal fishing and pre-contact estimates which are included in this analysis (Argue et al. 1990, Hewes 1973).

Methods

Forty-eight groups of animals used in the fishery are analyzed. Some groups consist of many species, others consist of only one species. Catch data was compiled, converted into wet weight units and entered into a database by year and by species. The first component of the analysis examines the total catch of all species groups for each year to examine the historical trend in biomass removal from B.C. waters. Next, is an analysis to determine the primary productivity requirements of the fishery over time. This requires converting wet weight landing data into a primary production requirement (PPR) expressed in grams of carbon per year. This is done using:

$$PPR = (\text{Landing wet weight}/9) \cdot 10^{(TL-1)} \quad ...1)$$

where TL is the trophic level of each species group and 10 refers to the mean transfer efficiency between trophic levels of 10%, estimated by Pauly and Christensen (1995). All landed catch weights are divided by 9 to reflect a conservative 9:1 ratio for the conversion of wet weight to carbon (Strathmann 1967). The third component of the analysis is a calculation of the mean trophic level of the fishery using the following equation:

$$\text{Mean } TL = \Sigma(Y_i \cdot TL_i)/ \Sigma y_i \quad ...2)$$

where Y_i is the catch of each species group in year i. The trophic levels used in (1) and (2) for each species group are taken from Pauly and Christensen (1995).

Species	Original Units	Metric equivalent	Source
Chinook Salmon	1 fresh fish	9.05 kg	Argue et al. (1990)
Sockeye	"	2.71 kg	"
Chum and Coho	"	4.52 kg	"
Pink Salmon	"	1.81 kg	"
Steelhead Trout	"	4.52 kg	"
Oysters	490 dozen	1 t	Heath (1997)
"	1 Barrel	91kg	Qualyle (1988)
Harbour Seal	1 cull	81 kg	Fisher (1952)
Northern Fur Seal	1 skin	160 kg	Jefferson et al. (1993)
Steller Sealion	1 cull	535 kg	Schusterman (1981), Bigg (1988)
Humpback whale	1 kill	40 t	Jefferson et al. (1993)
Blue whale	"	160 t	"
Sei whale	"	30 t	"
Fin whale	"	75 t	"
Minke whale	"	14 t	"
Right whale	"	80 t	"
Grey whale	"	35 t	"
Sperm whale	"	57 t	"
Baird's Beaked whale	"	12 t	"

Table 2. Values used to convert reported quantities into metric fresh weight equivalent.

The final section of this analysis determines the percentage of resident species in B.C.'s commercial fishery. The purpose of this analysis is to show how the fishery has shifted in prey composition and how the change may reflect the need for other types of management. This was done by categorising the 48 species groups as either a 'resident' or 'migratory' species and then dividing the total catch of resident species by the total of all species. Resident species are those which can be assumed to move less than 10 km during the adult phase of their life cycle.

Results and Discussion

According to Ehrlich (1994), impact on ecosystems is a function of the energy humans appropriate from that system. In marine ecosystems, primary productivity required to sustain the fishery is a good measure of energy appropriation Small changes are undetectable as we have no precise measure of ecosystem changes. However, when landings increase, changes can be detected. The results of this analysis indicate major shifts in human exploitation of marine resources in B.C.

Biomass Landed

In the last 100 years, overall resource appropriation by humans in B.C. has been greater than any other period in history. This is not surprising; however what is interesting is how early in the century humans were dominating the marine ecosystem. From Figure 1 it is clear that as early as 1910 we were exploiting marine resources at levels similar to present day. By 1930, the fishery had higher catches than anytime after 1970. As early as 1910, a number of fish stocks including herring, lingcod and halibut were heavily exploited. By the 1930s substantial amounts of pilchard and whales were landed. At the same time, herring was being landed in tremendous quantities to satisfy the reduction fishery. The present day landings in B.C. do not include marine mammals and the small pelagic fishery is much reduced. The present catch has a large component of invertebrates, and in recent years, hake. Salmon has remained relatively constant throughout the century with fluctuations occurring at both annual and decadal scales.

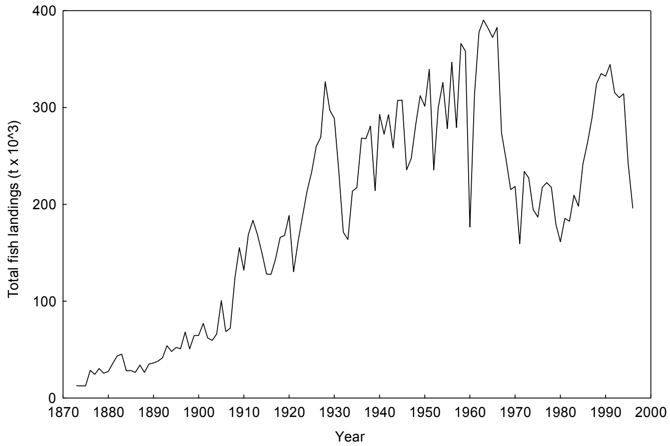

Figure 1: Total biomass landed in British Columbia from 1873-1996. Catches include whaling, sealing, aboriginal, and recreational fisheries.

Primary Production Requirements

If energy appropriation is used as an indicator of human interference of natural ecological processes in the marine environment, then by 1910, we had a fully disrupted natural energy flows (Figure 2). The pattern of high primary productivity requirements persisted until the late 1960's. By 1967 commercial whaling in B.C. had ended, and in 1969 herring stocks had also collapsed to the point of commercial closure. Primary productivity requirements dropped off as landings decreased but also as lower trophic level species (invertebrates) entered the fishery.

Average Trophic Level

From the 1870s to the 1920s, the fishery in B.C. consisted of high trophic level species such as whales, fur seals, halibut, dogfish, and salmon (Figure 3).

As B.C. became more industrialized in the 1920s, markets became available for meal and oil produced from the reduction of herring and pilchard. As a result, the landings of pilchard increased from 60 t to 78 000 t in only 12 years. Herring and pilchard, being low trophic level species, caused a decrease in the average trophic level, although considerable amounts of salmon, whales, and halibut were still being landed. The pattern of decreasing trophic level continued, corresponding to an increasing catch of herring until 1969. At this time, the combination of a crashed herring fishery and a small invertebrate fishery caused the average trophic level of the fishery to increase. Since 1975 there has been an increase in the average trophic level, primarily due to combining salmon, a high trophic level species, with increased catches of hake, also a high trophic level species.

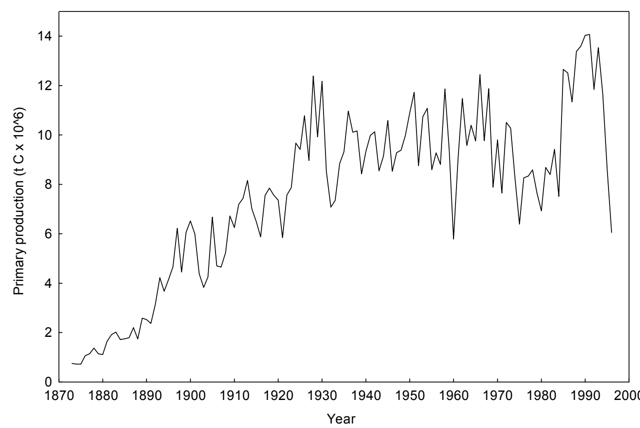

Figure 2: Primary productivity requirements of all British Columbia's fisheries from 1873 to 1996

Species Composition of the Fishery

A shift to non-migratory invertebrates in the last 20 years can be seen in Figure 4. Prior to the 1970s non-migratory species consisted primarily of lingcod, rockfish, and crabs. Post 1970, non-migratory species include a variety of clams, geoducks, urchins, sea cucumbers, and prawns. The shift from migratory to non-migratory species raises questions about proper management. Prior to 1970, the majority of the primary productivity requirements of the fishery were met by fish drawing in energy from large marine areas, and then channeling it to the human system. The notion of spatially managing the fishery had little relevance. However, with increasing non-migratory species which derive their energy from smaller

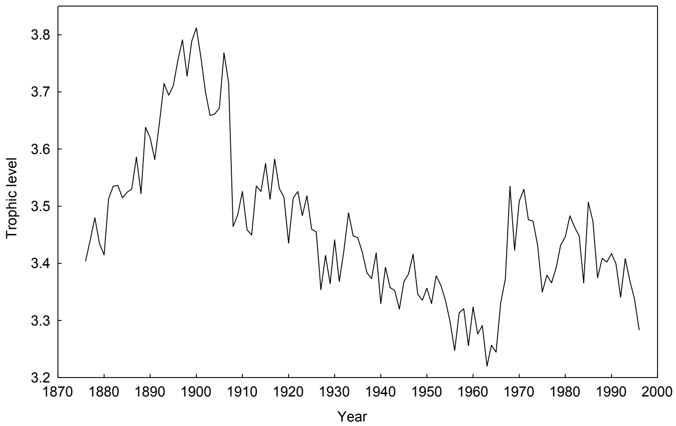

Figure 3: Average trophic level of all fisheries in British Columbia from 1873 to 1996.

areas, spatial closures and marine protected areas becomes more relevant.

It is impossible to account for all catches during the last 100 years, and thus the catch figures used here are by no means exact. In general, data are more readily available for fisheries in the last forty years. Moreover, the early published landings do not account for by-kill, discards, or unreported fish. Therefore, these published historical accounts tend to be conservative. For example, during the harbour seal culls, only one in five seals was actually accounted for, as seals sink immediately after being shot (Fisher 1952). By-kill is another form of human take which has always existed in B.C.'s fisheries. Historical accounts of the lingcod fishery indicate that incidental catch of rockfish was very common, sometimes four discarded rockfish per lingcod (White and Spilsbury 1988).

Estimating the aboriginal and recreational catch is another potential

source of error. Historical aboriginal catch was based on per capita estimates of consumption which have inherently large error. Even when aboriginal catch is recorded, it is based on actual observations of landed fish. Similarly, recreational catches are based on actual numbers of fish observed landed, and are therefore conservative. However, all major fisheries are included, and given the scale of these fisheries, small imperfections in data will not change the trend. Thus, we can still achieve the goal of the research, which was to examine how major shifts marine resource extractions have impacted ecosystem structure.

In the last 100 years there have been four major shifts which have gradually changed the marine ecosystem from one governed primarily by natural forces to one heavily influenced by human impacts. The first shift was the development of the salmon fishery which by 1890 was taking more than the aboriginal people ever did. The second shift was induced by the fishing for marine mammal. Whaling accounts for the majority of marine mammal landings. Although whaling in B.C. was from 1905 to 1967, the greatest single year was in 1911 when approximately 52 000 tonnes of whale was landed. Removal of this group would have opened a lot of food sources to other groups in the system, thereby altering the relative abundance of

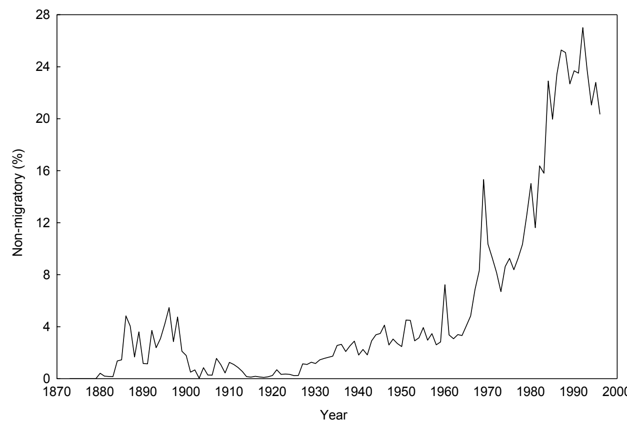

Figure 4: Percentage by weight of non-migratory species in British Columbia's commercial fishery. Non-migratory species are those who move less than 10 km in the adult stage of their life cycle

species and overall ecosystem functioning.

The third shift in the fishery was the fishery for small pelagics including herring and pilchard. In the peak year, 1963, 258 000 tonnes of these species were landed. Since 1967, the total for all fisheries has not reached this level. Small pelagics are an important food source for hundreds of other species in the ecosystem including whales, lingcod, rockfish, and birds. The repercussions of this food source being depleted should have had a dramatic impact, but no documentation exists. The last phase of the fishery, which we are now in, is the targeting of invertebrates. Once again, like all other phases in history from the removal of seacows to the small pelagics, the ecosystem changes due to the removal of invertebrates are unknown.

Summary

Most of the concern facing marine ecosystems has developed in the 1990s as a response to the levelling off or steady decline of global fisheries.

This analysis allows B.C fisheries managers to place present day conservation in a historical perspective. Thus, it appears that from an energetic perspective, humans have been a dominant force in the ecosystem for at least 85 years. Furthermore, early exploitation of otters and sea cows should have led to a functional response capable of impacting our baseline. Since we have no objective baseline, and the subjective baselines change as memories disappear (Pauly, 1995, this data base can be used as a reminder of what existed, and therefore be used to set conservation objectives.

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PART 4: SYNTHESIS: RECONSTRUCTION OF PAST & PRESENT STRAIT OF GEORGIA ECOSYSTEMS

Combining Knowledge of the Strait of Georgia: Report from Workshop Discussions

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Abstract

A two day workshop was held at the First Nation's House of Learning, University of British Columbia, Canada, on November 21 and 22, 1997. This workshop had the objective of gathering participants from a variety of disciplines to discuss species abundance in the Strait of Georgia at present and one hundred years ago. The information assembled was used to create two ecological models of the Strait of Georgia - present day and one hundred years ago. This paper summarizes those parts of the discussions that contributed information used in changing and/or validating the models. The first section is a summary of the discussion following the information presented in the morning's session of Nov. 21. The second section reviews the information presented by guest speakers on the afternoon of the same day. The third section is a summary of the findings of the working groups presented on the morning of the second day and concerning the construction of a model of the Strait of Georgia one hundred years ago.

Introduction

The account below of workshop discussions is incomplete: we made no attempt to cover all discussion, rather, we noted those points raised by discussants which include information relevant to trophic models of the Strait of Georgia in the present or in the past. This information is presented, for the first section, as paragraphs attributed to discussants (**named in bold**) in the form of brief summaries of presentations, <u>by authors</u> in the second section, and as working group (WG) reports in the third and final section.

Section 1:

Summary of First Day Discussion

Tony Pitcher raised the point of the inherent difficulty of rebuilding both populations and ecosystem diversity. He used the analogy of a ratchet to describe the effect of removing species from an ecosystem as comparatively easier than replacing them.

Richard Beamish commented on the Ecopath approach used to create the ecosystem models used in the workshop. He was interested in what **Daniel Pauly** described as "identifiable nonsense outputs". **Richard Beamish** said that, while he appreciated the importance of being able to clearly identify nonsense output, he appreciated much more the fact that Ecopath provides a mechanism for establishing what parts of the ecosystem need to be studied more intensively in order to further our understanding of the Strait of Georgia.

Peter Tyedmeyers queried **Johanne Dalsgaard** about the phytoplankton biomass estimate in the 100 years ago model as being 1.3 times greater than today. He reasoned that there would be an increased input of nutrients from agricultural runoff, forestry, and sewage from population centres to the present day Fraser River system.

Daniel Pauly replied, on Johanne Dalsgaard's behalf, that the phytoplankton biomass estimate had no effect on model outputs, as the bulk of the phytoplankton production is, in any case, directed toward a large component of the detritus pool which is poorly defined, even in the present day model. Also he noted that there may have been much nutrient suspension in the 100 years ago system from marine mammal excretion.

Richard Beamish added that while nutrients contributed by the Fraser River have likely increased, the overall effect on the system has been negligible. The phenomenon of estuarine circulation is responsible for a far greater contribution, 5–6 times greater, of nutrients to the Strait of Georgia.

Doug Hay raised the question of the role played by herring in the models presented. He thought the estimate of 2.2 times as many herring in the 100 years ago model, compared to the present day model, was excessive. He called attention to the factor of 2.2 times as being estimated from the extremely high catches of the 1960s. He said this was not directly applicable, since those fisheries captured many pre-recruits, thus demanding a different method to estimate biomass than is used in present day estimates from catch data. He also stated that the biomass of herring used in the 100 year model would imply a herring density greater than anywhere else in the world. He was, nevertheless quite enthusiastic about the models that had been presented. He felt that they would be of even greater use if they were applied to larger areas, such as the whole coast of British Columbia.

Richard Beamish said that with respect to interdisciplinary and inter-institutional work, feedback has been often one of the largest problems to overcome. He felt that while the Department of Fisheries and Oceans (DFO) was often called upon as a source of data by outside researchers, they rarely heard back from these partners about results. He was therefore appreciative that the *Back To The Future* project had hosted the workshop, as it provided the type of feedback he wanted.

Nigel Haggan agreed with this view and said that the success of a project such as this depended on the continued and open flow of information between partners.

Daniel Pauly and **Tony Pitcher** said that a further source of feedback for partners will be the report on the workshop (this volume), which would also provide a forum for participants to elaborate on specific issues raised in the workshop or indeed their own work, as it related to the task at hand.

Silvia Salas said that problems of inadequate feedback have been experienced by First Nations people. She was responsible for the early interviews done with First Nations people and pointed out the importance of their continued involvement.

Tony Pitcher called attention to the U.B.C. Fisheries Centre web page as an additional source of feedback for the project and said it will be updated accordingly as time goes by (see: www.fisheries.com).

Doug Hay and **Richard Beamish** both stressed that the herring stocks of the Strait of Georgia are quite healthy and expansion of the fleet was a reflection of increased harvestable stock as it recovered from overfishing in the 1960s. They also observed that the herring stock is now being harvested at a sustainable level.

Section 2:
Review of First Day Speakers

Invited speakers from different disciplines presented their papers in the first portion of the afternoon session (excepting J. Williams, see below). These contributions were related to exploited populations in the Strait of Georgia, the dynamics of the ecosystem, the development of fisheries in British Columbia, the integration of native knowledge, and archeological information. The highlights are as follows:

Richard Beamish: The presentation focused on factors contributing to regime shifts in the Strait of Georgia. Indicators of these changes include: salinity in relation to Fraser river flow, El Niño, pressure indexes and winds. He addressed the fact that the ecosystem itself is different than it was in the past.

Jo-Ann Archibald: In this talk, an overview of oral traditions and cultural protocols of First Nations was given (see Archibald et al., this vol.). Jo-Ann explained that the process of involving native people in the project was based on the interest of producing something useful for them. She described the fruitful interaction that has been generated between the First Nations House of Learning and the Fisheries Centre.

Doug Hay: This presentation focused on abundance of small pelagics in the Strait, in particular herring, eulachon, and capelin (see Hay, this vol.). He explained how there has been a spatial shift in herring spawning locations. However, overall abundance has not changed. This has implications for using people's perceptions of the resource, as they may not appreciate the spatial changes. He also was concerned about the loss of capelin in the Strait. Capelin, being the only Fall-spawner, was important in providing what he called "secondary production", i.e. a pulse of high production in the Fall, which no longer exists.

Duncan Stacey: This presentation was an historical overview of the development of the fisheries in B.C.. This included the role of native people in the commercial fishery.

Carl Walters: The focus of this talk was on an important, if unknown, process is presently occurring which is affecting the dynamics of the ecosystem and its carrying capacity for certain migratory species like salmon and herring. He also pointed out that stories of the 'good old days' of salmon filling the rivers are due to the past mode of catching salmon in rivers, which contrast with present approaches. In many cases, just as many salmon are now returning to spawn as did before. On the other hand, the abundance of resident salmon (as posed to the transient ones) should have been, in the past, much greater than presently, perhaps as much as 10 times.

Judy Williams (Saturday Morning): This talk focused on the sources of information available from using petroglyphs and stressed the importance of including people who can interpret this information (see Williams, this vol.).

Section 3: Summary of Working Group Discussions

Two working groups were formed by randomly assigning workshop participants to either of two groups. Each working group discussed the same topics based on the following terms of reference: (1) Species presence: discuss species which no longer exist in the Strait of Georgia but may have in the past; (2) Species distribution: using a map, mark the location of species that no longer exist or have changed dramatically in terms of distribution and abundance over the last 100 years; (3) Species abundance: using a table of relative abundance, comment on the values in the 2nd column of Table 1; (4) Identify major groups that should be included in the model or separated out from other functional groups; (5) Identify potential sources of information of past aboriginal harvest of non-salmon species; (6) Suggest alternative methods to improve the approach used, and, in particular, how to most effectively use traditional ecological knowledge. The two working groups varied in their approaches, and thus the discussion of each working group is summarized separately (see also Table 1, columns 3 and 4).

Working Group 1

Participants**:** **Sophie DesClers** (Chair), **Richard Beamish, Johanne Dalsgaard, Robert Kreutziger, Ken Millard, Daniel Pauly, Tony Pitcher, Dave Preikshot, Peter Tyedmeyers, Bruce Ward.**

The discussion of this working group (WG) focused on evaluating and determining the abundance of species groups relative to present day abundance in the ecosystem and/or in the preliminary Ecopath model, starting at the base of the food web. None of the other questions in the terms of reference were discussed.

Phytoplankton: The WG was unaware of any evidence to suggest there should be an increase in phytoplankton biomass in the Strait of Georgia (SoG). It was noted that while the abundance of phytoplankton would be highly dependent on long term climate changes, these are difficult to assign for the window in time examined (100 years). The climate was relatively stable and therefore would not cause major changes in abundance. It was concluded that while everyone in the WG seemed to agree that there would be abundance changes, it seemed to be that these were at too small a scale to be discernible in the model. Thus it was suggested that the same abundance should be used for both models.

Kelp and Seagrass: The discussion started by noting that there has been a decline in the amount of kelp and seagrass in areas around pulp mills and in areas of urbanization (i.e., Richmond). It was suggested that these changes are sufficient to justify the creation of a separate box for seagrasses, since this ecological change may otherwise be masked if these are lumped in with kelp. Alternately, kelp and seagrass may be left in the same group, but their past abundance should be 1.25 times greater than today.

Functional Groups	Prelim. Model	WG 1	WG 2
Phytoplankton	1.3	1	0.7-0.9 (nutrient increase in recent years)
Kelp & seagrass	1	1.25 (marsh areas)	1
Herbivorous zooplankton	1.6	1.6	1.6
Carnivorous zooplankton	1.4	1.4	1.4
Shellfish	1	1	1 (c.f. oysters)
Grazing invertebrates	1	1.25 (follows kelp & seagrass)	1
Predatory invertebrates	1	Increase P/B: leave biomass unknown	2 (crabs)
Jellyfish	1	1	1
Herring	2.2	1.75-2.2	2.2 (resident (30%))
Eulachon	2	2	2.3 (smelts)
Small pelagics	1.6	1 (& cannibalism)	1.6 (intertidal)
Misc. demersal fishes	3	7 (increase P/B for present day)	3 (intertidal)
Resident salmon	5	6	10 (coho decrease)
Transient salmon	2	2	2
Hake	1	0.25 (+ 10% cannibalism)	1 (possibly less)
Dogfish	0.7	1	1
Halibut	36	30	n.a. (c.f. whales)
Lingcod	3	10	25 (hindcasting)
Lampreys	1	1	1
Sturgeon	>100	>100	n.a. (c.f. whales)
Shorebirds	2	2	2
Seabirds	1	1	1
Resident whales (Toothed)	5	5	5
Baleen whales	n.a.	n.a.	n.a.
Transient orcas	1	1	1
Seals & sea lions	1	1	0.75 (aboriginal harvest)

Table 1: Suggested biomasses of Strait of Georgia functional groups (1st column) one hundred years ago relative to present as suggested in preliminary one hundred years ago model (2nd column) and by Working Group 1 (3rd column) and Working Group 2 (4th column).

Carnivorous and herbivorous Zooplankton: Since the biomass estimates for this group were model outputs, it was decided to leave this the same for a revised model. It was felt that both zooplankton groups had changed and the Ecopath model should be left to estimate the magnitude of zooplankton changes based on the changes in the ecosystem as a whole.

Shellfish: A general question arose among the WG members as to why the original model did not suggest an increase in historic abundance for this group (but see Calderon Aguilera, this vol.). In support, it was noted that, while there had been great changes in the abundance of particular members of this species group, there is no direct evidence to suggest any marked change for the group as a whole over the last 100 years. On the other hand, the First Nations population had already seriously declined 100 years ag, and the aboriginal shellfish fishery may have been much greater 500 years ago (see Salas et al. this vol.).

Grazing invertebrates: Due to the loss of kelp beds, it was suggested that nudibranchs and sea urchins may have been in higher abundance 100 years ago, and that perhaps this group's abundance should be tied to that of the seagrass and kelp group. The WG then concluded that the 100 years ago Ecopath model should include a 1.25 times greater abundance of grazing invertebrates.

Predatory invertebrates: Because of the opportunistic nature of many members of this group, there was some consideration of whether or not there may have actually been less of them in the past. It was noted, though, that production per unit biomass changes in the group would be heavily influenced by the changes in the age caused by fishing. The WG became divided between those who thought the group had declined over the last 100 years and those who though it had increased over that time. Daniel Pauly tried to resolve the issue by pointing out that a decrease in the inputted P/B ratio in the 100 year ago model would indirectly decrease the group's abundance years ago, if this was left to be a model output.

Jellies: It was noted that in other areas around the world, where fishing had severely depleted their ecosystems, the number of jellies was often greatly increased. On the other hand, while there is a lot of fishing pressure in the SoG, jellyfish abundance has not yet appeared to have increased. Thus, no modifications to the original models were recommended.

Herring: Daniel Pauly pointed out that there was a discrepancy between the estimates of historic herring biomass used by the project team and those suggested by DFO researchers. For the Ecopath model to balance, it was necessary to increase biomass by 2.2 times. This provided an example of inferences the model may allow us to make on past biomasses from information on the feeding requirements of its predators. The WG suggested that although the DFO opinion is that the Strait of Georgia herring stock is presently as big as ever, there should be at least 1.75 and perhaps as much as 2.2 times as many herring in the 100 years ago model.

Eulachon: There was general consensus that eulachon has been subject to much depletion, even though oceanographic phenomena may also have played a role (see Hay, this vol.). Since no one offered any evidence to refute the doubling of eulachon biomass in the preliminary version 100 years ago model, this was deemed as acceptable by the WG.

Small Pelagics: Again, the WG agreed that according to the model there was not enough evidence to suggest changes in abundance. However, after the discussion on the cannibalism of hake (see below), it was pointed out that this was a phenomena that should also be considered with regards to small pelagics. Therefore the WG recommended the group's diet should include small pelagics as well, i.e., consider cannibalism.

Miscellaneous Demersals: The WG decided that for this group, the abundance of rockfish in the historic model should be seven times greater than the present day. It was also suggested that the P/B ratio also be lower in the present day model than in the 100 year model, to reflect one effect of overfishing. Indeed, this principle should be applied to all groups that had been overfished.

Resident and Transient Salmon: There was general agreement that the estimates of increased abundance used in the original historic model were acceptable for both groups. It was suggested that 'resident' be changed to 'chinook and coho', while 'transient' be changed to 'sockeye, chum, and pink'. There was concern on whether or not steelhead should be explicitly included in the model. It was decided that this required further investigation (but see Dalsgaard et al. this vol.).

Hake: The WG agreed that there was likely far fewer hake in the Strait of Georgia 100 years ago. It was noted that hake tend to be cannibalistic which should be reflected in the model. It was proposed that the historic model be changed so that the abundance was 0.25 times that of the present day, and that the group's diet be modified such that 10% originate from the hake group itself.

Dogfish: There was concern in the WG that the historical model indicated lower dogfish abundance than at present. It was pointed out that there was a significant fishery for the dogfish at the time for liver oil. Moreover, archaeological evidence indicates there has always been a native fishery for this shark. Based on this, the group decided to recommend the historic abundance be the changed to the same value as present day.

Halibut: The massive increase assumed for the historic model was tempered somewhat by the WG recommending it be reduced to 30 times greater.

Lingcod: Everyone in the WG regarded the original factor of three times greater abundance in the historic model as too conservative. It was generally agreed that the abundance would have been closer to ten times larger. It was suggested that there be further research into present day abundance of the group.

Lampreys, Sturgeon, Shorebirds, Seabirds, Resident Whales, Baleen Whales, Transient Orcas, Seals and Sea Lions: The group agreed with all of the abundance estimates used for these groups in the historic model.

Working Group 2
Participants**: Nigel Haggan** (Chair), **Doug Hay, Ross Lodge, Silvia Salas, Duncan Stacey, Andrew Trites, Scott Wallace, Carl Walters.**

The discussion started off with the Native oyster which was very abundant 100 years ago but is nearly absent today. Places such as 'Oyster Bay' near Nanaimo were named because of this oyster. Another species which is virtually absent today, but supported a substantial fishery 100 years ago was sablefish (Black Cod). It was also mentioned that capelin no longer exist in the Strait of which it may have been an important component, in being the only Fall-spawners. Grey whales were also mentioned, as there are native reports of them; however, they are absent today.

Phytoplankton: It was suggested that abundance may be slightly higher today than in the past due to land-based sources of nutrients (See Table 1).

Kelp and Seagrass: This was not discussed in detail, except for the comment that kelp beds may have been greater, and because of the structural role of macro-algae, this may have an impact on other processes. It was thought that seagrass abundance has decreased, but at the same time the introduced *Sargassum* has increased, resulting in no change overall. However, the community in question may be functionally quite different.

Carnivorous and herbivorous Zooplankton: Lacking better information it was suggested to keep this the same as present day.

Shellfish: Same as for group above; however, it was recommended that historical oyster harvests be examined in detail.

Grazing Invertebrates: Same as for above; however, it was thought that the sea urchin and sea cucumber fisheries may have an impact.

Predatory invertebrates: It was suggested that this group be doubled to reflect the impact of the crab fishery.

Jellyfish: No changes were suggested.

Herring: The value of 2.2 in the 100 year model was considered too high by DFO scientists. If the value of 2.2 was true, this would be the highest abundance of herring anywhere in the world. The biggest difference over the last 100 years is not the overall abundance, but rather the relative proportions of resident to migratory herring stocks. As present day residents make up less than 5% of herring biomass. One hundred years ago, this may have been as high as one third of total biomass. There was talk about breaking herring down into two groups to reflect this difference.

Eulachon: There was discussion as to whether or not eulachon should be included in a larger 'smelt' group. If this is the case, then the decrease in eulachon would be insignificant as they never existed in great abundance compared to other smelts. One group of smelts not included in the model was the Deep sea smelt, which is estimated to be at 100 000 tonnes in the Strait compared to Eulachon (3 000-4 000 tonnes of spawning biomass).

Small Pelagics: No change was suggested however, there was concern as to whether or not small intertidal fishes were included (i.e., sculpins, perch, sticklebacks).

Misc. Demersal Fishes: The biggest concern here was the abundance of rockfish which was decided to be left as suggested (3 times present value, see Table 1).

Resident Salmon: It was suggested this should be changed to a historical abundance of 10 times greater to reflect the recent declines in Coho stocks.

Transient Salmon, Hake, Dogfish, Lampreys, and Shorebirds: No basis for changing original values.

Halibut and Sturgeon: It was suggested that these species exist in such low numbers at present day, that it is impossible to estimate a factor of relative abundance. Therefore these should be left blank similar to baleen whales with Ecopath estimating the biomass.

Lingcod: Based on historical landing of lingcod, it was suggested that past abundance may have been much higher (up to 25 times). It was suggested that a hindcasting analysis be conducted. (This advice was followed; see Martel and Wallace, this vol.).

Seabirds: These were left the same, but it was recommended that the staff of the Canadian Wildlife Service examine the values.

Marine Mammals: The only change in this category was the recommendation that harbour seals may have been less abundant as they were targeted by aboriginal groups 100 years ago. The value of 0.75 present day estimate was suggested.

It was recommended to split demersal fishes to reflect the different biomasses at different depths. It was also urged that shrimp and prawns be separated out from macrobenthos due to the former's commercial and ecological importance.

The WG thought that the impact of birds on fish should be more closely examined, to then possibly separate the piscivorous from planktivorous birds. Finally, it was then suggested that the deep sea smelt be added as well as capelin. Regarding macrobenthos it also was suggested that aboriginal groups ate a lot more clams and crabs then what we may have considered (see Calderon Aguilera, this vol.) It was finally recommended that project members interview elder commercial fishers of European and Japanese ancestry. Also, core samples were recommended as a method of testing presence and absence of certain species.

Conclusions: Working Group Findings

The working groups proved to be a good way to test the assumptions inherent in the original model. For most of the functional groups, the abundances were either left the same, indicating that the assumptions made in the original model were considered valid, or in the cases when changes were thought to have occurred, their directions were the same in both WGs (Table 1). For example, lingcod and rockfish, were both changed to reflect a greater increase in historical abundance.

The general impression was that the multidisciplinary background of the WG members, the constructive style of their discussion, and the fact that we set up two independent WGs with the same terms of reference brought a much appreciated degree of objectivity into the *Back To The Future* process. We recommend a similar approach for any (BTF) Worskhops which might follow.

Mass–Balance Model Reconstructions of the Strait of Georgia: the Present, One Hundred, and Five Hundred Years Ago

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Abstract

Two mass-balance ecosystem models representing the Strait of Georgia today and one hundred years ago (the 1880s) were constructed using the Ecopath modelling approach and software. Fisheries literature and statistics from the 1980s - 1990s were used as input for the present day model, while the one hundred year model was constructed using traditional and local environmental knowledge, historical information and scientific literature from the last 100 years. The main difference between the two models was the relative abundance of functional groups, though the species therein also differed. Baleen whales, extirpated in the Strait in the early 1900s, and sturgeons, perhaps close to a similar fate, were thus included in the one hundred year model. In November 1997 the two pilot models were presented and discussed at a multidisciplinary workshop and suggested improvements were subsequently incorporated. The Strait of Georgia five hundred years ago, prior to human contact, was reconstructed in three scenarios, consisting of increasing the top-predator biomass of the one hundred year model by 10%, 20%, and 30%, respectively, omitting catches and keeping the same primary production as in the one hundred year model. The models representing past states were relatively easy to balance, but the flow characteristics of the 500 years ago models did not correspond to theoretical estimates.

Introduction

This contribution synthesises the information pertaining to the present and earlier state of the Strait of Georgia ecosystem, presented in the previous contributions in this report. The synthesis is presented in the form of three Ecopath models, viz:

1. a revised version of a pre-existing model of the present day Strait of Georgia ecosystem, originally documented in Pauly and Christensen (1996);
2. a representation of the Strait of Georgia as it might have been about one hundred years ago, based on outputs documented in the other contributions of this report, and recalled in the text below;
3. a representation of the same system as it might have been 500 years ago, well before the arrival of Europeans.

Material and Methods

An existing mass-balance model of the Strait of Georgia (Venier, 1996a) served as a skeleton for building the present day model. Ten functional groups were added, and the season covered was changed from ‘summer only’ to the mean of four seasons. For many groups, the Ecopath input parameters including diet composition, production / biomass (P/B), ecotrophic efficiency (EE), and, consumption / biomass (Q/B), or the earlier model remained unchanged, while our efforts were concentrated on improving the biomass and harvest estimates. Therefore, in the following, only those parameters that were modified with respect to the original model are examined (see contributions in Pauly and Christensen, 1996 for details on the other parameters).

A model representing the Strait of Georgia one hundred years ago (in the 1880s) was then constructed based on the present day ecosystem representation. Two groups, sturgeon and baleen whales, were added, while the inputs for other groups were modified when documentation (including the working group reports in Wallace et al. this vol.) was available to suggest that their abundance one hundred years ago was different from today’s. No changes of the P/B and Q/B values were made between the present day and the 100 year model. Commercial harvest data are described under the relevant groups, in Table 1 and in Box 1.

Except for contemporary salmon catches, First Nation harvest data were hard to obtain and are dealt with in a separate section. Several students attending the 1997 Fisheries Centre Ecopath graduate teaching module contributed inputs for several groups and these can be found (in the form of the four 'Boxes' paper includes).

Group	Mean catch (t·year⁻¹)	Catch by area (t·km⁻²·year⁻¹)
Grazing invertebrates	1399	0.203
Pred. invertebrates	523.6	0.076
Shellfish	1835	0.266
Herring	13178	1.910
Eulachon	14.7	0.002
Misc. demersal fishes	663	0.096
Resident salmon	401	0.058
Transient salmon	10197	1.480
Hake	6806	0.986
Dogfish	440	0.064
Halibut	8.4	0.001
Lingcod	2.8	<0.001

Table 1. Average commercial catch of various groups in the Strait of Georgia (statistical areas 13-19, 28 and 29) from 1990 to 1996 (Source: DFO, Vancouver).

The Strait of Georgia prior to European contact was simulated based on an approach by Christensen and Pauly (1998) for simulating ecosystems near carrying capacity. With the one hundred years ago model as a starting point, the primary production was fixed while all catches were set to zero, and the biomass of top predators was increased by 10%, 20% and 30% representing three different scenarios. Top predators are here defined as baleen whales, toothed whales, halibut, lingcod, seals, sea lions and transient orcas. Using the Monte Carlo resampling routine of Ecopath (Ecoranger), all parameters (B, P/B, Q/B and EE) and the diet matrix were allowed to vary ± 20% within uniform distributions. The routine was run until 200 thermodynamically acceptable runs were achieved (runs are rejected if EE>1 for any group) for each of the scenarios. Of these acceptable runs the best-fitted model was chosen (see Christensen and Pauly 1996b). All parameter values are listed in Tables 3-6.

Table 7 shows a comparison between the models representing these scenarios, the one hundred year model the present day model.

Primary producers.

Two groups of primary producers were identified: phytoplankton and kelp/seagrass. P/B and EE values for phytoplankton were derived from Mackinson (1996) and Venier (1996a), while the biomass was estimated via Ecopath. In the Workshop, consensus was that the phytoplankton abundance in the Strait one hundred years ago, if any different, was lower than it is today (see Wallace et al., this vol.) and the present day biomass estimate was therefore also used in the 100 year model.

Levings et al. (1983) found an average total standing stock of macroalgae in the Strait of $2.94 \cdot 10^7$ kg dw or 20.3 t ww·km⁻² [conversion: dw (dry weight) = 21% ww (wet weight) (Mackinson 1996)]. However, this estimate does not include seagrasses and therefore underestimates the biomass of the kelp/seagrass group. This was later taken into account when balancing the models.

One hundred years ago, the marsh areas around the mouth of the Fraser River, and of the other rivers that flow into the Strait, were much larger than today (Levings and Thom 1994) and it was suggested in the Workshop to increase the present day biomass estimate by 25%. A P/B value for kelp/seagrass of 4.43 year⁻¹ was derived from Mackinson (1996).

Zooplankton

Zooplankton was split into herbivorous zooplankton, carnivorous zooplankton, and jellyfish. All parameters came from Venier (1996a) and no changes were made with respect to the 100 year model.

Benthic invertebrates

Benthic invertebrates were divided into grazing invertebrates, predatory invertebrates, and shellfish. Biomass estimates for all three groups were obtained by regrouping data from Guénette (1996).

Grazing invertebrates includes annelids, polychaetes, sipunculoids, echiuroidea, porifera, arthropods, amphipods, copepods, cumaceans, barnacles, isopods, ophiurids, holothurians, echinoids, amphineura, others. The grouping was based on size and feeding habit of the organisms, and the biomass estimated as 400 t· nemerteans, shrimps, cnidaria and km⁻². A present day commercial fishery of prawns, shrimps, sea urchins and sea cucumbers totals 0.203 t·km⁻²·year⁻¹ (see Table 1).

Predatory invertebrates include starfish, crabs and octopus. All three organisms are relatively large and feed as carnivores and/or scavengers. The biomass was estimated as 9.14 t·km⁻². This estimate was increased by 25% in the 100 year model in agreement with the increase in the kelp/sea grass group which serves as their habitat. The present day commercial harvest of crabs and octopus amounts to 0.076 t·km⁻²·yr⁻¹ (see Table 1).

Shellfish were added as a group because of its importance to First Nation People (see Archibald et al., this volume), and include all bivalves and gastropods living in the Strait. The biomass was estimated as 220.5 t·km^{-2}. A P/B value of 0.5 year^{-1} and a GE value of 0.09 year^{-1} came from Jarre-Teichmann and Guénette (1996). The present day commercial catch of the group consist of clams, geoducks, horseclams, and scallops, and amounts to 0.266 t·km^{-2}·year^{-1} (see Table 1). No commercial harvest data for any of the benthic invertebrate groups were available for the 100 year model. They were therefore assumed low enough to be set equal to zero.

Birds

Seabirds and shorebirds were included as two separate groups. All parameters for the seabirds were taken from Wada (1996) and no changes were made with respect to the one hundred year model. Shorebirds include sandpipers, dunlins, and plovers, for which Newlands (Box 1) estimated a biomass of less than 0.001 t·km^{-2}. The P/B and Q/B values were set equal to those for seabirds. In the 100 year model, shorebird biomass was doubled considering a now absent population of Brant's geese which used to frequent the Strait in extremely large numbers (Campbell et al. 1990; White and Spilsbury 1987).

Box 1. Bird Component of the model: marine shoreline and estuarine species

The bird component of the present day ECOPATH model was expanded to include estuarine bird species which were not considered in the previous Strait of Georgia ECOPATH model (Wada 1996). The historic model should use present day inputs, with the assumption of consistency in trends in the bird migration patterns and the resulting residency numbers over time. This is due to the lack of sufficient counts of the bird populations for the end of the 19th century. The new birds to be added are:

1. **Western sandpipers, which occur in the Fraser estuary from April to May, and July and August. Their main diet in the area are amphipods;**
2. **Dunlins, which occur in the Fraser estuary from September to December and eat which gastropods, bivalves and marine worms;**
3. **Black-bellied plovers, which occur in the estuary year round, but are more numerous in the winter. They are known to eat polychaetes, molluscs, and crustaceans;**
4. **Trumpeter swans and Tundra swans, which overwinter in the Fraser River delta from November to March and which eat cover crops and bullrush rhizomes.**

Species	Ind. weight (kg)	Pop. (N; max.)	Biomass (t⋅km^2)
Western sandpiper	0.023	839 400	0.002800
Dunlin	0.058	62 000	0.000520
Black-bellied plover	0.220	1 700	0.000053
Trumpeter & tundra swans	11.600	400	0.000670
All shore birds	11.881	903 500	0.004043

Estimated biomass of estuarine bird species in the Strait of Georgia based on their mean body weight (Dunning 1993). Estimates of P/B are set at 0.1⋄yr^{-1} as in Wada (1996).

Nathaniel Newlands

Box 2. Fish Catches in the Strait of Georgia, 100 years Before the Present

Data on fisheries catches in the Strait of Georgia were found in Parliamentary Sessional Papers, specifically the Fisheries Statements and Inspector's Reports for the Department of Fisheries. Catch data for the years 1890 to 1894 were retrieved and averaged and then converted to tonnes to provide data for the Ecopath model for 100 years before present. The areas included were Fraser River south to the US Boundary, Fraser River to Howe Sound, and Comox to Victoria for the years 1890 to 1893 inclusive, and Fraser River including Howe Sound and Burrard Inlet and Comox to Victoria for 1894. The species harvested, the units in which the data were originally reported, and the average catch in kilograms for the pertinent areas for 1890-1894 are presented below.

Species	Mean Catch (t) from 1890 to 1894.
Salmon	11,600 pickled[a], 1,000 fresh, 34.5 smoked, and 10,300 canned[b]
Sturgeon	190
Halibut	511
Herring	152 fresh, 8 barrelled[c], and 6.7 smoked
Herring, smoked	6.7
Eulachon, salted	16 salted[d], 56 fresh, and 4 smoked
Trout	20
Mixed fish	139[e]
Smelts	39
Rock cod	94
Tooshqa	80
Skill	1.8[f]

a. One barrel of salmon was equal to 200 lbs, and 300 lbs of raw salmon were needed to produce 200 lbs of pickled salmon (Shepard and Argue, 1989);
b. 7 lbs of raw salmon were required to produce every 4 lbs of canned salmon (Shepard and Argue, 1989);
c. The average production of herring was 59 bbls. The conversion to tonnes followed Shepard and Argue (1989);
d. The average production of salted eulachon was 117 bbls. The conversion from bbls. to tonnes was by Shepard and Argue (1989);
e. Note that mixed fish includes sardine, anchovy, whiting, flounder, sole, skate, and other small

Herring

Surveys in the 1940s and 1950s indicated nine major migratory stocks of herring in British Columbia, two of which were found in the Strait of Georgia (Ketchen et al. 1983). Glavin (1997) suggested that there are two views of the present day herring stock in the Strait. One is that there is one migratory stock spawning in the Strait with other smaller resident stocks, the later comprising approximately five percent of the herring in the Strait. The other view claims that there are several migratory stocks spawning in the Strait, and a dozen smaller resident stocks comprising about 1/3 of the herring (see also Wallace et al., this vol.). Based on this, we assumed that 20% of the herring today is resident. Furthermore, we assumed that the migratory stock(s) reside in the Strait from November to April - approximately 20 weeks (Buckworth 1996). These assumptions combined with herring stock assessment data from DFO (Schweigert et al. 1996) give an average present day biomass of 6 $t \cdot km^{-2}$. A P/B value of 0.6 $year^{-1}$ from Buckworth (1996) and a Q/B value of 18 $year^{-1}$ from Venier (1996a) were used. However the Q/B value was halved to 9 $year^{-1}$ taking into account that herring eat very little in the winter (Doug Hay, DFO, pers. comm.).

In the Workshop it was put forward that the amount of herring living in the Strait today is close to carrying capacity (Wallace et al., this vol.). There is therefore no reason to believe that the biomass of herring one hundred years ago was much higher than it is now. However, the fraction of resident fish might well have been higher so that, overall, the biomass would have been slightly higher. Assuming that 30% of the herring was resident in the Strait one hundred years ago, compared to 20% today, mean biomass would have been approximately 7 $t \cdot km^{-2}$.

Today, 1.91 $t \cdot km^{-2} \cdot year^{-1}$ of herring is caught in the Strait (see Table 1) compared with 0.024 $t \cdot km^{-2} \cdot year^{-1}$ in the 1890s (Anon. 1888-1899, Power, Box 2).

Eulachon

Historically, eulachon has played a very important role to the First Nation peoples. They caught the fish in the spring as it ascended the Fraser River to spawn, extracted its oil and used the product as a supplement to the diet (Drake and Wilson 1991). Macfie (1865) wrote: “The Indians catch this species of fish by impaling them on rows of nails at the end of a stick about four feet long, and so thickly do they swarm, that every time this rude implement is waved in the water, two or three of them adhere to it.” It could take up to 12 t of eulachon to produce 200 gallons of oil (Glavin 1995). Aside from local use, the product was traded with inland tribes, and it is from this the so-called ‘grease trails’ have their origin (Harrington 1967).

Despite the history of this fish, little is known about its abundance through time. In Anon. (1888-1899), the Fisheries Inspector wrote: “As the delicacy of these fish becomes better known, each year finds an increasing demand, and when the Fraser River fails to supply them they are brought from the Naas, these being the only two streams in this Province where they are found in quantities, especially in the latter, and where hundreds of tons are wasted each season by being caught (principally by American Indians) and allowed to decay on the bank”. Certainly, there used to be a lot more eulachon, but how much more, nobody knows. Nobody even knows how much there is today and what caused the decline of returning spawners, though ocean changes have been mentioned as a possible explanation (Glavin 1995, see also Hay, this vol.).

Besides diet information and the present-day commercial harvest of 0.002 $t \cdot km^{-2} \cdot year^{-1}$ (see Table 1), no data were found so eulachon were given the same features as small pelagics. The present biomass was estimated as an Ecopath output.

Considered a conservative guess, the biomass estimate from the present day Ecopath model was doubled and entered in the 100 year model. But one could easily argue that it may have been 5 or possible 10 times higher than now.

Small pelagics

This group consists of squid and fish such as smelt, sardines, anchovies, sandlance, and others. The biomass was estimated via Ecopath, and P/B, Q/B, and EE were taken from Buckworth (1996) and Venier (1996a). In the 100 year model, the biomass was assumed to have been the same as today’s. A suggestion in the Workshop was to include 10% of cannibalism because squids are known to have a high rate of cannibalism. This, however, would have made balancing the models impossible, as the group would have itself consumed most of its own production, leaving little to nothing for its predators.

A commercial catch of 0.013 $t \cdot km^{-2} \cdot year^{-1}$ consisting of smelt (0.006 $t \cdot km^{-2} \cdot year^{-1}$) and miscellaneous fish such as sardines and anchovies (Power, Box 2) was included in the 100 year model. A minor harvest of squid takes place in the Strait today but is too small to warrant inclusion in the model.

Miscellaneous demersal fishes

Except for lingcod, halibut and dogfish, this group includes all fish living near the sea bottom. The most prominent members of the group are rockfishes, Pacific cod, walleye pollock and flatfishes. A biomass estimate of 4.84 t·km^{-2} for the present day model was computed using data from Venier and Kelson (1996), and Stocker and Fargo (1994).

Catch/effort data on sole from Levy et al. (1996) suggest that from the late 1970s to the early 1990s, their biomass decreased to one third of its original value. Based on this, the biomass of the group was, conservatively, assumed to have been three times higher one hundred years ago.

Commercial catches of demersal fishes today consist primarily of flounder, Pacific cod, Pacific ocean perch, pollock, rockfish, sablefish, skate, sole, turbot, and perch, and amount to 0.111 t·km-

Box 3. Salmon Population Parameters

According to Stacey (1982) sockeye salmon were the most important commercial species in the Fraser River fishing industry from 1871 to 1912. Catch statistics for the years 1898 to 1905 indicate that the production capacity per day averaged 1200 cases for all canneries operating on the Fraser River (Stacey 1982), with one 'case of fish' being equal to 48 lbs. Between the years 1889 and 1901, the number of canneries rose to 49. The estimated catch based on these values is 438 000 cases of salmon per year, or 467 200 t. Instantaneous rates of growth and mortality were taken from sources in Ricker (1976). P/B values were determined from these instantaneous rates, according to the method in Allen (1971), which assumes that these rates are constant during the life span of the salmon. It is recommended that the Q/B ratio for the model be set at 0, indicating that salmon do not act as predators within the system.

Species	Age at maturity (years)[a)]	Weight at maturity (kg)[a)]	Time in freshwater (years)
Sockeye	4	1.4 - 3.2	1
Chinook	3-5	6.8 – 13.6	1
Pink	2	1.4 – 2.7	<<1
Coho	2-4	1.8 – 7.3	1
Chum	3-6	3.6 –5.4	<<1

a) Age and weight at age for Pacific salmonids, from Browning (1980)

Sockeye catch in the Strait of Georgia was 7.55 t (1.09 t◊km^{-2}) in 1955 and 18.73 t (2.72 t◊km^{-2}) in 1897. Total salmon catch was 60.99 t (8.34 t◊km^{-2}) in 1955 and 467.20 t (67.71 t◊km^{-2}) in 1897 (Anon. 1977 and Stacey 1982). Catches per area are based on the area of the Strait of Georgia being 6900 km^2 (Christensen and Pauly, 1996c).

Group	Years at sea	Ration[a]	Growth[b]	Mortality[c]	P/B[d]
Sockeye	3-4	83	0.11	0.056	0.11
Chinook	3	-	0.10	-	-
Chinook	4	-	0.07	0.035	0.18
Chinook	5	-	0.06	0.035	-
Pink	2	162	0.29	0.019	0.33
Coho	2	-	0.27	0.063	0.23
Chum	4	71	0.17	0.019	0.18

Ecological parameters for salmon components in the historic ECOPATH model (based on Ricker 1976).

a) Q/B, per year
b) instantaneous rate of growth (month^{-1})
c) instantaneous rate of morality (month^{-1})
d) (year^{-1})

^{2}·year^{-1}. Catch statistics from one hundred years ago imply an average catch of 0.024 t·km^{-2}·year^{-1}, (Power, Box 2) consisting mainly of cod and flatfishes.

Salmon

Chinook and coho salmon are resident in the Strait and can be caught all year round. Sockeye, chum and pink salmon, on the other hand, only pass through the Strait on their way back to spawning rivers. Salmon was consequently split into two groups, a resident and a transient group, with steelhead trout included in the former.

No biomass estimates were found in the literature and this, therefore, had to be estimated by Ecopath, with EE fixed as 0.95 for resident salmon and as 0.50 for transient salmon. The later was a guess, reflecting our assumption that about 50% of the salmon escape to the spawning rivers.

Newlands (Box 3) lists P/B values for salmon. Since these values are very similar for all species, means were used. This resulted in a P/B value for resident salmon of 3.9 year^{-1} and 0.76 year^{-1} for transient, the latter assuming that transient salmon occurs in the Strait only two months every year. In this period they presumably do not eat, and Q/B is zero. A Q/B value for resident salmon was estimated using Pauly's empirical equation (Pauly 1980) with a caudal fin aspect ratio of 4 and a temperature of 10°C.

During his Workshop presentation, C. Walters, UBC Fisheries Centre, suggested that one hundred years ago, resident salmon might have been 10 times more abundant than today, while transient salmon (mostly sockeye) may have been twice as abundant (see Wallace et al. this vol.). These suggestions were used to set biomasses for the 100 year model.

At present, the catches of salmon averages 0.058 t·km^{-2}·year^{-1} for resident and 1.478 t·km^{-2}·year^{-1} for transient (see Table 1). Catch statistics from a hundred years ago (Anon. 1888-1899; Power Box 2) do not list catches by species. The biomass ratio between the two groups was therefore used to split the catch with roughly 1/3 or 0.343 t·km^{-2}·year^{-1} on resident salmon and 2/3 or 0.686 t·km^{-2}·year^{-1} on transient salmon. Added to the resident catch was also a small recorded catch of undefined 'trout'. Work is currently being done in DFO which might imply major changes in the parameters for the present day salmon boxes (Richard Beamish, pers. comm.).

Hake

Pacific hake is the most abundant resident fish in the Strait of Georgia (McFarlane and Beamish 1985) estimated as 245 000 tonnes in 1993 (Stocker and Fargo 1994). The stock was first discovered in 1974, but not commercially exploited until 1978 (Levy et al. 1996). The fishery, however, quickly expanded and following salmon and herring, it is now the third largest fishery in the Strait in terms of tonnes landed: 6 806 t·year^{-1} (see Table 1). P/B and Q/B values were taken from Venier and Kelson (1996).

Since hake was only recently discovered, no historical information exists. Biomass estimates from the 1970s (Levy et al. 1996) were about 1.5 times lower than in 1993 and R.J. Beamish (pers. comm.) suggested that hake might have been 10 times less abundant one hundred years ago. A conservative guess of ¼ of the present day hake biomass was used in the 100 year model. A catch of 0.003 t·km^{-2}·year^{-1} was derived from old catch records (Power, Box 2), where it was listed as 'whiting' ('whiting' was also the name for walleye pollock) in the group called 'mixed fish'.

Dogfish

The dogfish living in the Strait of Georgia and in Puget Sound are considered to belong to the same stock (Ketchen et al. 1983) and is estimated as 60 000 tonnes (Stocker and Fargo 1994). For the purpose of this work, we assumed the stock to be evenly distributed with one half in Puget Sound and the other half in the Strait of Georgia, leading to 4.3 t·km^{-2} in the Strait. Present day commercial catches are estimated as 0.064 t·km^{-2}·year^{-1} (see Table 1).

Dogfish was caught for its liver and body oil, and has historically undergone several periods of intensive harvest. The earliest commercial harvest started in the late 1870s and ran through the 1880s (Ketchen 1986). The result was declining catches in the 1890s (the period we are considering). The stock, however, recovered and forty years later, in 1930, the harvest peaked at 12 000 tonnes. We chose to ignore the decline in the 1890s and considered the present day biomass as representative for the 100 year model. Commercial landings in the 1890s averaged 0.169 t·km^{-2}·year^{-1} (Ketchen 1986).

Halibut

If there ever was a big stock of halibut in the

Strait, it had disappeared by the 1890s. There are very few records witness a fishery in the Strait. One of them is from Thompson and Freeman (1930) who wrote: "Captain Lunberg of Vancouver and Captain Grant of New Westminister fished (1888) in the Strait of Georgia [...] and the Strait of Juan de Fuca [...] from small boats, but marketed their fish in Seattle." Another is from Bell (1981) who wrote: "English Bay, now the outer harbor of Vancouver, was in the 1880s a fishing location for a few small boats catching halibut for the local trade of Gastown, as Vancouver was earlier called. Some were taken in Burrard's Inlet." Most of the fish landed in Vancouver and listed in the catch statistics from a century ago were taken outside the Strait, on the rich banks of Juan de Fuca and the west coast of Vancouver Island.

Halibut is occasionally caught in the Strait today, but the average catch is less than 0.001 $t \cdot km^{-2} \cdot year^{-1}$ (see Table 1). A biomass estimate of 0.004 $t \cdot km^{-2}$ was obtained assuming a fishing mortality of 24% (Venier 1996b). A Q/B value of 1.73 $year^{-1}$ and a P/B value of 0.44 $year^{-1}$ was taken from Venier (1996b) who estimated these values for halibut on the Southern B.C. Shelf.

Data are not available which would allow estimating the biomass or event the annual catch of halibut from withing the Strait of Georgia one hundred years ago. Thus, pending access to appropriate historical records, we assumed the biomass of halibut to be 20 times that of the present. This is probably an underestimate. Further, we assumed the same fishing and natural mortalities for the present model.

Lampreys

All data for this group were derived from Beamish and Youson (1987), where the life history and abundance of the anadromous river lamprey *Lampetra ayresi* is described. Lampreys enter the Strait for about 10 weeks where they feed on herring (86%) and salmon (14%). Buckworth (1996) estimated, from the same contribution, a biomass of 1.04 $t \cdot km^{-2}$. On a yearly basis this equals 0.2 $t \cdot km^{-2}$. He likewise estimated a P/B value of 4.6 $year^{-1}$ or 0.9 $year^{-1}$ accounting for the only 10 weeks the lampreys occur in the Strait. While lampreys are in the Strait, they kill and/or consume roughly 19 600 t of herring, most of which are age 2 herring of approximately 50 g each. Lampreys also attack all five species of salmon, which at the time range from 12 to 24 cm. Assuming that salmon in this size weigh the same as age 2 herring, and that they constitute 14% of the lampreys' diet, a total consumption by lampreys of 22 791 t can be derived. Divided by the total biomass, this results in a Q/B of ~3 $year^{-1}$. No changes were made with respect to the 100 year model.

Lingcod

The commercial harvest of lingcod in the Strait of Georgia dates back to the 1860s, where the fish were caught from small vessels and kept alive until sold (Cass et al. 1990). According to Anon (1888-1899) lingcod was then named "tooshqua" or "ling", and a harvest of 0.012 $t \cdot km^{-2} \cdot year^{-1}$ was registered by the Fisheries Inspector (Power; Box 2).

Based on catch and effort data starting in 1951, Martell and Wallace (see this vol.) estimate a present day lingcod biomass in the Strait of 0.05 $t \cdot km^{-2}$. For the one hundred year model, they suggest a conservative abundance estimate of 1.5 $t \cdot km^{-2}$.

Cass et al. (1990) estimated the fraction of adult male and female lingcod surviving from age 6 to 12 to range between 0.52-0.68 with an average of 0.6. This gives a total mortality rate of 0.4 $year^{-1}$, used here to estimate P/B. A Q/B value of 3.3 $year^{-1}$ was contributed by Venier and Kelson (1996).

Box 4. The Sturgeon (*Acipenser transmontanus* and *A. medirostris*)

Though an extensive commercial fishery existed in the late 1800's on the Fraser River, an almost total collapse of the fishery occurred in 1901, indicating that the stock of >25-year old fish had been exhausted (Semakula and Larkin 1968). A much smaller fishery continued to exist until the 1990s, consisting of a native food fishery and a commercial gillnet fleet (Echols 1995). The greatest effort in these fisheries was concentrated above Mission (Echols 1995). In 1994, a complete ban on retention of sturgeon in the commercial and recreational fisheries was instituted, and the sturgeon is now considered endangered (Echols 1995).

Table 1 summarizes the suggested values for biomass, P/B and Q/B for the present day, 100 years ago and 500 years ago. The Fraser River contains the largest known population of sturgeon in the Strait of Georgia area (Echols 1995), and was assumed to account for the entire population found in the Strait. Since most biomass estimates are reported for freshwater, and movement into marine waters is likely small, only 4%, of the total stock is assumed to be within the study area (DeVore and Grimes 1993). The endangered status of the sturgeon in the present day suggests that no catches occur in the Strait. Stock size for one hundred years ago is taken from the commercial landing statistics of the fishery in 1880 to its collapse in 1901, which were assumed to represent a removal of nearly 100% of the entire stock. As such, the estimate represents a minimum stock size. The 500-year estimate is unchanged from the 100-year estimate as it was assumed to be a stable, virtually unexploited stock until the onset of the commercial fishery in the 1880s (but see Archibald et al. this vol.). Diet composition of sturgeon varies with size. Juveniles were generally found to eat invertebrates, individuals larger than 48 cm, mainly fish. Semakula and Larkin (1968) reported that sturgeon stomachs contained more fish than invertebrates.
Biomass (wet weight), P/B, and Q/B for sturgeon in the Strait of Georgia.

Time Period	Biomass (t/km^2)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)
Present	0.000	0.050[b]	5.616[a]
100 years	0.019[c]	0.219[b]	5.616[a]
500 years	0.019[c]	0.050[b]	5.616[a]

a. From empirical equation in Christensen and Pauly (1992)
b. From Semakula and Larkin (1968);
c. Biomass estimated from commercial catch times $0.04/9600km^2$.

Sturgeon

Though sturgeon still occur in the Strait, the biomass is so low that they are considered non-existing in the present day model. However, one hundred years ago, there still was a big stock of sturgeon. Wilkeson (1817-1889) wrote: "Sturgeon of immense size are plenty off the mouths of the Fraser and other rivers. So abundant is this fish that isinglass made from it is a regular article of export by the Hudson's Bay Company" [Isinglass is a gelatin made from fish bladders]. All parameters for the 100 year model are described by Beattie (Box 4). In the official harvest records from the 1890s (Power; Box 2) the catches of sturgeon averaged $0.027\ t \cdot km^{-2} \cdot year^{-1}$. However, Beattie (Box 4) assumed that only 4% of the stock occurred within the Strait, and found that most of the catch was taken above Mission. Accordingly, only 4% of the catch ($0.001\ t \cdot km^{-2} \cdot year^{-1}$) was assumed to come from the Strait.

Marine Mammals

Marine mammals were divided into four groups: toothed whales (resident orcas, Dall's porpoise, and harbour porpoise), transient orcas, baleen whales (minke, gray, and humpback whales), and seals and sea lions (harbour seal, Steller sea lions, and California sea lion). The baleen whales were included only in the 100 year model, since they no longer occur in the Strait. Biomass estimates, Q/B values and diet compositions are described by Winship (this volume). P/B values were derived from Trites and Heise (1996). That whales once were very abundant in the Strait was witnessed by Macfie (1865) who wrote: "I have seen in the month of September whales innumerable sporting in the Gulf of Georgia…"

Whaling took place in the Strait from 1866 to 1873 when it stopped, only to start again in 1905 (1888-1899; Merilees 1985). After just 2 years all baleen whales had been caught and they have never since been able to re-colonise the Strait. A nominal catch of 0.001 $t{\cdot}km^{-2}{\cdot}year^{-1}$ was entered in the 100 year model.

Native catches

There is no question of the importance of seafood to the First Nation People (Archibald et al., this volume). Salmon was probably the most important species, followed (in no particular order) by shellfish, eulachon, herring, other pelagic fishes, dogfish, flatfishes, rockfishes, porpoises and others.

Species	**Harvest ($t{\cdot}km^{-2}{\cdot}year^{-1}$)**
Resident salmon	0.08
Transient salmon	0.15
Eulachon	?
Dogfish	0.09
Herring	0.05
Misc. demersal fish	0.23
Shellfish	0.23

Table 2. Suggested First Nation catches from the Strait of Georgia, one hundred years ago.

Hewes (1973) estimated that First Nation People in British Columbia on average consumed 583 pound of salmon per capita per year (around 1879). Assuming that 6 000 First Nation people lived around the Strait one hundred years ago (Duff 1964) gives a total consumption of 1 590 tons or 0.23 $t{\cdot}km^{-2}{\cdot}year^{-1}$. The biomass ratio of resident to transient salmon was used to divide this consumption with 0.08 $t{\cdot}km^{-2}{\cdot}year^{-1}$ on resident salmon and 0.15 $t{\cdot}km^{-2}{\cdot}year^{-1}$ on transient salmon. At present, the First Nations catch of resident salmon is 169 tons (0.024 $t{\cdot}km^{-2}{\cdot}year^{-1}$) and 1 228 tons (0.178 $t{\cdot}km^{-2}{\cdot}year^{-1}$) for transient salmon (Laurie Nagy, pers. comm.).

To estimate the consumption of other fish species, midden data from the J. Puddleduck site in the Comox Harbour area on the east coast of Vancouver Island were used (Mitchell 1988). We are well aware that these data dates back much longer than a hundred years ago, and that, using data from a single site and a single tribe within the Strait is of limited use. For the moment, however, it is the only approach available. The midden data (based on Mitchell 1988) dating back between 317 B.C. ± 173 and 1012 B.C. ± 270 show the following proportions of fish remains (minimum live weight): salmon 50%, dogfish 20%, demersal fish 19%, and herring 11%. Using the estimated annual consumption of salmon and knowing that salmon constituted 50% of the fish diet, 0.23 $t{\cdot}km^{-2}{\cdot}year^{-1}$ of other fish must have consumed. This consumption has to be distributed between dogfish, herring and demersal fish in the proportions listed above. Ideally, the catch of demersal fish should be broken further down into lingcod, miscellaneous demersal fish, halibut and sturgeon. But because the abundance of the miscellaneous fish group is much higher than the others, all the harvest was assigned to this group.

Shellfish also made up a large part of the midden, though, the proportion changed in the different layers. For the purpose of this study, we assumed that 1/3 of the seafood diet was shellfish and the rest fish. Table 2 shows the suggested First Nations harvest one hundred years ago. Eulachon probably was caught in large amounts, but no estimate was derived. Marine mammals were also caught.

That halibut probably did not play an important role to the people of the Strait is emphasized in Anon (1891), where it is written that: "Halibut…are most abundant on the west coast of Vancouver Island, though occasional fish are taken on the eastern shore. They appear to vary greatly in quality and size, according to the locality, they are found in. Those brought to Victoria are very inferior…Halibut are to the westcoast Indian what the salmon are to those residing on the east coast or mainland." Likewise, Thompson and Freeman (1930) wrote:

> *"… the halibut was most important to the coast Indians, especially as Neah Bay (near Cape Flattery)…, Sitka…, and the Queen Charlottes… Elsewhere the salmon exceeded it in amount, and on the whole, very greatly. Many other species were used also, such as the eulachon, or oolakan, and the herring. The oil of the eulachon and seal were preserved, and dried halibut was dipped in it before eating."*

The harvest data from Table 1 were added to the commercial harvest data and entered in the 100 year model.

Results and Discussion

Present day model

To balance the model, changes to the diet matrix had to be made for many groups. Especially the large biomass of hake was a problem as it generated predation pressure on herring. After a second round of consulting the literature, the diet of hake was shifted much more towards zooplankton and away from herring.

As mentioned by Venier and Kelson (1996), the diet composition of miscellaneous demersal fish was difficult to derive because of over-aggregation within the box. Ideally, the groups should be split, e.g., into flatfish, rockfish, cod, and pollock.

Shellfish were separated from large macrobenthos in the original model (Guénette 1996; Venier 1996a), and species previously preying on this group had 75% of this diet shifted to shellfish.

Because the salmon group was split into resident and transient salmon, groups preying on them had their diet split, with 5/6 on resident and 1/6 on transient. Some of the predation by resident salmon on herring was shifted to eulachon.

The biomass of transient orcas was lowered to 0.004 $t \cdot km^{-2}$ to decrease its predation on other marine mammal groups. Furthermore, some predation was shifted from whales to seals and sea lions. The predation by seals, sea lions and resident whales on herring was decreased and transferred to hake and, in the former case, salmon.

The EE value for phytoplankton was lowered from 0.76 to 0.6 and the biomass of kelp/sea grasses (which was known to be an underestimate) increased by an order of magnitude from 20.3 $t \cdot km^{-2}$ to 200 $t \cdot km^{-2}$. This lead to an overall biomass of primary producers slightly below the biomass in the orginal model (Venier 1996a), but was necessary in order to lower the EE of detritus below 1.

Group / parameter	Biomass ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Harvest ($t \cdot km^{-2} \cdot yr^{-1}$)	Trophic level
Phytoplankton	**41.460**	200.00	0.0	0.600	0.000	**1.000**
Kelp / sea grass	20.300	4.43	0.0	**0.021**	0.000	**1.000**
Herbivorous zooplankton	**15.572**	55.00	183.3	0.950	0.000	**2.000**
Shellfish	220.500	0.50	5.6	**0.258**	0.266	**2.000**
Grazing invertebrates	400.000	3.50	23.0	**0.377**	0.203	**2.053**
Carnivorous zooplankton	**33.035**	12.00	40.0	0.950	0.001	**2.400**
Predatory invertebrates	9.100	1.65	8.8	**0.713**	0.076	**2.528**
Shorebirds	0.001	0.10	92.0	**0.000**	0.000	**3.047**
Jellyfish	15.000	3.00	12.0	**0.120**	0.000	**3.113**
Herring	6.000	0.60	9.0	**0.966**	1.910	**3.185**
Eulachon	**0.661**	2.00	18.0	0.950	0.002	**3.200**
Small pelagics	**14.467**	2.00	18.0	0.950	0.020	**3.205**
Seabirds	0.020	0.10	91.7	**0.044**	0.000	**3.300**
Misc. demersal fishes	12.600	1.00	4.2	**0.435**	0.111	**3.372**
Chinook / coho	**0.653**	3.90	10.5	0.950	0.082	**3.624**
Hake	35.500	0.72	5.0	**0.900**	0.986	**3.530**
Dogfish	8.700	0.20	5.0	**0.040**	0.064	**3.749**
Transient salmon	**6.365**	0.76	0.0	0.500	1.656	**4.040**
Toothed whales	0.040	0.02	7.3	**0.740**	0.000	**4.089**
Halibut	0.004	0.44	1.7	**0.568**	0.001	**4.135**
Lampreys	0.200	0.90	3.0	**0.000**	0.000	**4.260**
Lingcod	0.050	0.58	3.3	**0.753**	0.001	**4.293**
Seals / sea lions	0.600	0.06	8.1	**0.802**	0.000	**4.547**
Transient orcas	0.004	0.02	7.4	**0.000**	0.000	**5.533**
Detritus	-	-	-	**0.938**	0.000	**1.000**

Table 3. Parameter estimates of the groups of the balanced present day Strait of Georgia model by trophic level. Values **in bold characters** were calculated by the program, while dashes mean that no value was entered.

The 100 Years Ago Model

This Ecopath model was relatively easy to balance (see Table 5), and mostly adjustments to the diet matrix had to be done, because some groups had increased and others decreased in abundance (Table 6).

As the biomass of hake was lowered by 75% compared to the present day model, some dogfish predation had to be shifted to carnivorous zooplankton.

Miscellaneous demersal fish were tripled from the present day model and some of their diet was shifted from predatory invertebrates to grazing invertebrates and carnivorous zooplankton. Furthermore, cannibalism (10%) was introduced, decreasing the pressure on small pelagics and hake.

Lingcod predation on herring and hake was lessened by 10% in both cases (from 25% to 15%), and the excess 20% transferred to miscellaneous demersal fish.

The biomass of resident salmon was increased by an order of magnitude from the present day model, and some of the diet was shifted from herring to eulachon.

Group / parameter	Biomass ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Harvest ($t \cdot km^{-2} yr^{-1}$)	Trophic level
Phytoplankton	41.000	200.00	0.0	**0.607**	0.000	**1.000**
Kelp / sea grass	200.000	4.43	0.0	**0.021**	0.000	**1.000**
Herbivorous zooplankton	**15.659**	55.00	183.3	0.950	0.000	**2.000**
Shellfish	220.500	0.50	5.6	**0.437**	0.230	**2.000**
Grazing invertebrates	400.000	3.50	23.0	**0.404**	0.000	**2.053**
Carnivorous zooplankton	**32.284**	12.00	40.0	0.950	0.000	**2.400**
Predatory invertebrates	11.000	1.65	8.8	**0.875**	0.000	**2.528**
Shorebirds	0.002	0.10	92.0	**0.000**	0.000	**3.047**
Jellyfish	15.000	3.00	12.0	**0.120**	0.000	**3.113**
Herring	7.000	0.60	9.0	**0.985**	0.029	**3.185**
Eulachon	1.300	2.00	18.0	**0.921**	0.009	**3.200**
Small pelagics	15.000	2.00	18.0	**0.996**	0.013	**3.205**
Seabirds	0.020	0.10	91.7	**0.044**	0.000	**3.299**
Misc. demersal fishes	38.000	1.00	4.2	**0.688**	0.254	**3.366**
Baleen whales	1.900	0.02	3.4	**0.110**	0.001	**3.479**
Hake	9.000	0.72	5.0	**0.997**	0.003	**3.530**
Chinook / coho	6.500	3.90	10.5	**0.173**	0.423	**3.624**
Dogfish	8.700	0.20	5.0	**0.257**	0.259	**3.664**
Sturgeon	0.020	0.22	5.6	**0.482**	0.001	**3.922**
Transient salmon	13.000	0.76	0.0	**0.242**	0.836	**4.040**
Toothed whales	0.200	0.02	2.3	**0.740**	0.000	**4.089**
Halibut	0.140	0.44	1.7	**0.552**	0.034	**4.134**
Lampreys	0.200	0.90	3.0	**0.000**	0.000	**4.260**
Lingcod	1.500	0.58	3.3	**0.264**	0.030	**4.290**
Seals / sea lions	0.470	0.06	8.1	**0.827**	0.000	**4.546**
Transient orcas	0.004	0.02	7.4	**0.000**	0.000	**5.380**
Detritus	7.000	-	-	**0.976**	0.000	**1.000**

Table 4. Parameter estimates of the groups of the balanced one hundred years ago Strait of Georgia model. Values **in bold characters** were calculated by the program, and dashes mean that no value was entered.

As in the present day model, the biomass of transient orcas was lowered, in this case from 0.009 $t \cdot km^{-2}$ to 0.004 $t \cdot km^{-2}$.

The biomass of shorebirds was doubled from the present day model because of Brant's geese. Since they feed on sea grass 50% of the diet of the group was transferred to kelp/sea grass.

The 500 Years Ago Model

Table 7 shows trends in selected ecosystem attributes when moving from the present day system back in time, toward a presumably more mature, less stressed systems. Note that these numbers are unaffected by the inclusion of sea otters; their structuring role may have been important (see Pitcher, this vol.), but this effect is not identifiable using Ecopath.

Ecosystem attribute	Today	100 years ago	500 years ago 10%	20%	30%
P_P/R	1.067	1.023	1.204	0.912	1.084
P_P/B	8.993	8.750	9.157	8.701	8.711
Biomass/ throughput (%)	3.1	3.1	3.3	2.9	3.3
Total consumer biomasses	780	797	751	803	802
Average size (B/P)	0.111	0.114	0.109	0.115	0.115
Finn's cycling index (%)	18.0	16.7	15.3	16.9	15.6

Table 7. Selected system attributes for different time periods in the Strait of Georgia (based on Christensen and Pauly 1998). The 10%, 20%, and 30% refer to the increase in top predator biomass in the simulation models where the primary production was fixed as in the one hundred year model, and all catches set to zero. P_P is primary production, R is system respiration, B is system biomass, and P is total production.

The trend in attributes test Odum's (1969) theory of ecosystem development. According to this theory, P_P/R, which indicates the fate of assimilated food, should decrease towards 1 in maturing systems (or here: back in time, with increasing % of top predator biomass increasing) so that all fixed energy goes to maintaining the system (no accumulation of biomass). In immature systems, $P_P > R$ and biomass accumulates so that, as the system moves toward maturity, P_P/B declines as biomass builds up. The available energy flow in a systems hence support an increasingly larger biomass reflected as an increase in the biomass/throughput ratio, as well as in the total consumer biomass and in the size of the organisms. Finally, as the system matures it becomes 'tighter' and better at retaining and recycling detritus, which should be seen as an increase in Finn's cycling index (Odum 1969, Christensen 1995 and Christensen and Pauly 1998). Such trends, very visible in the systems studied by Christensen and Pauly (1998) do not occur here, and this will have to be explored elsewhere.

Conclusions

The present day model and the one hundred years ago model were constructed using a variety of sources. The results illustrate the relative ease of integrating not only quantitative, but more importantly, qualitative information into the Ecopath framework, although the five hundred year model did not appear to confirm Odum's theory of system maturity. The question of ecosystem maturity must be examined in more detail, since this would help define what the Strait might have looked like, as well as what might be its inherent potential.

It was fairly easy to simulate a situation where the Strait sustained a population of humpback whales and considerably larger stocks of 'more desirable' high trophic level fish species. That such system configuration existed is not just an utopia, but is supported by the historical information.

Finally, it should be emphasised that although extensive information was consulted, the search was by no means exhaustive. The models could still be improved, using data not yet accessed. Most of the data originated from specific sites/areas within the Strait and it was necessary to assume a homogenous distribution of resources. Please note that the files describing these and other Ecopath models may be freely downloaded from www.ecopath.org, along with the Ecopath software. The next important step therefore is to consider local patterns and incorporate local expertise from all over the Strait of Georgia. The interviews with Elders in the native communities (Archibald et al., this vol.) and the presentation and subsequent discussion of the models in the Workshop (Wallace, et al. this vol.) were only a start. Trust and patience are needed, both within the scientific community and between it and the outside world, to bring together the necessary expertise so that the potential of the *Back To The Future* approach can fulfil its potential.

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Epilogue: Reconstructing the Past and Rebuilding the Future of the Strait of Georgia

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Fisheries resources are rapidly being lost throughout the world, mainly as a result of excessive modification, by fishing, of the ecosystems in which these fisheries resources are embedded. (Pitcher 1999a, Pitcher and Pauly 1998, Pauly et al. 1998).

For British Columbia, this gradual process of grinding down one resource after the other was documented in Glavin (1996), based on data and concepts of up to the mid 1990s. Nothing has much has changed since, except that straightforward approaches for examining fisheries impacts in an ecosystem context of have become widely disseminated and accepted (NRC 1998). These new approaches, notably Ecopath, as presented in this report, and Ecosim (Walters et al. 1997), have helped quantify impacts previously thought to be inaccessible. Recent analyses based on these approaches show human impacts to be far more profound than previously anticipated (see e.g. Pauly and Christensen 1995, and Pauly et al. 1998).

In British Columbia, the strategy to deal with such problems has been to date to conduct an 'Enquiry' - the current one is the 'Peckford Enquiry' - then to issue a report calling for 'better management' of the resources. The resources don't notice much difference after the recommendations are implemented – increases in catching power usually more than offset the bandaids.

The problem is that the fish - particularly salmon - are no longer there that would meet the combined demand by the various fishery sectors, which leads to acrimonious debates about who should get what (Walters 1995).

Yet there was undoubtedly more fish in the Strait of Georgia in the past (Glavin 1996; and contributions in this volume). So why not aim at rebuilding the stocks? To a large extent, the measures that should be taken to rebuild stocks are the same as those that will have to be taken to prevent species from being lost in the near future (e.g. coho salmon), and added to the many that have already gone locally extinct in the Strait of Georgia. These measure include: (1) a strong reduction of fishing effort, especially by unselective industrial gear (e.g. trawlers and purse seiners); (2) the establishment of substantial marine protected areas, as required esp. for sedentary organisms, such as abalone and other invertebrates, but also for many fish species, such as rockfishes and homing local herring stocks; and (3) small stream rehabilitation (for the large number of small salmon runs that jointly could restore a formerly massive abundance).

Public support can be expected for an explicit strategy of the Strait of Georgia ecosystem, as shown for example, by the strong positive response which followed the recent publication, in the *Georgia Straight*, of a thoughtful article on these and related issues (Baron 1998), and the similar series in the Vancouver Sun (see e.g. issue of Friday 5, June 1998).

The "Back to the Future" process includes the model reconstruction of past and present ecosystems, Ecosim and Ecospace exploration of the limits to fishing Walters et al. 1997, 1998, and the evaluation of economic and social benefits for each alternative ecosystem. The "Back to the Future" approach is structured such that it encourages discussion of what might be achieved from, and is open to contributions by, diverse elements interested in the fisheries resource, including fishers, scientists, First Nations, historians, conservationists and laypersons. All can contribute to the models representing past ecosystems. Once consensus on previous system configurations is achieved, the discussion can move on to desired ecosystem configurations, and thence on how to achieve those (Pitcher at al. 1999). The alternative to such an open process is the opaque allocation scheme we presently have, which satisfies no one, to which only a high priesthood can contribute, and which tends towards elimination of one resource species after the other.

This report represents only just over three months work by our graduate students team, the 2-day workshop, and some intensive weeks of effort on the part of the editors. As far as the Strait of Georgia is concerned, it is incomplete and far from definitive. We likely need ten times as much effort to reach the next stage of understanding, before the modelling system could reliably be used to structure policy choices. Fortunately, there exists an immense archive of painstaking ecological research, historical documents and archaeological records concerning Strait of Georgia resources which can be tapped by such a project – all older research surveys, analyses and records have a value and can be used in the "Back to the Future" approach. In addition we have barely scratched the surface of the Traditional Ecological Knowledge that might be harnessed for the first time to real policy evaluations with the consent and support of the First Nations bordering the Strait of Georgia.

The next methodological work that needs to be done is to formalise ways of examining the ecosystem that maximises benefits to society; to design practical instruments to achieve this policy goal; to find ways of evaluating the costs of these management measures; and to devise adaptive ways to implement policy and monitor recovery and compliance. The benefits evaluated can include total catch, economic value, diversity of fishery products, employment, biodiversity and inter-sectoral conflict. Using Ecoval (Pitcher et al. 1999), the ecosystem and associated fisheries that maximize total benefit to society may be adopted as a policy goal, taking into account the costs of restoration, monitoring and enforcement when shifting from the present system. Pitcher (1999b) suggests that the "Back to the Future" process has a number of advantages in fostering public support for management goals, and public participation as sentinels of recovery process.

We hope that the momentum created by 'Back to the Future' will continue, that various interested groups will carry on, and help turn around what right now is a rather bleak situation in the Strait of Georgia.

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