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Back to the Future: Reconstructing the Hecate Strait Ecosystem

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Preface and Acknowledgements

This report continues a series of ecosystem reconstructions begun only recently at the Fisheries Centre. The Strait of Georgia reconstruction was a large project involving many participants from diverse backgrounds, both academic and non-academic. On the other hand, this report is unique in that the majority of the participants were not from an academic background, but were primarily local people with lifelong ties to the ecosystem.

Three papers were contributed to this volume, two of which are long overdue in the literature: the Haida and Tsimshian annotated dictionaries of fish and marine related words. These works are not complete; there may never be fully complete documentaries of traditional First Nation interaction with their environments. These dictionaries may, nonetheless, provide invaluable clues of how the ecosystem may have been, even if it is only that a word for something existed. It is interesting to note, for example that the Tsimshian people have a word for Hammerhead shark, presently very rare along the BC coast. The third contributed papers, on lingcod, presents a more traditional stock assessment and serves to underscore how little is known, even in scientific circles about this fairly remote region. We hope that the contents of this report will be seen as contributing to overcoming this situation.

We gratefully acknowledge financial contributions of $7,000 from the Canadian Ocean Frontiers Initiative (COFRI), $10,000 from the Science Branch of the Department of Fisheries and Oceans and $20,000 from UBC Research. We thank the Haida Fisheries Program for contributing travel and expenses for Haida Elders. We acknowledge the Tsimshian Nation for their support for the concept and the warm welcome from Tsimshian Tribal Council President Bob Hill. We also acknowledge Dr. Jo-ann Archibald, Director of the UBC First Nations House of Learning for her role in developing and supporting the BACK TO THE FUTURE concept and attending the opening session. Particular thanks are due to George Hayes, Director of the Northwest Maritime Institute for help in organizing the participation of retired commercial fishers and experts in local history and archaeology. Thanks are also due to DFO for the participation of Dr. Glen Jamieson of the Pacific Biological Station. Above all, we thank all the workshop participants for the time, thought and energy they put into re-creating the Hecate Strait system as it might have been 100 years ago.

Director's Foreword

We humans like to define where we are going by where we have been. The problem with present day fisheries is that we have entered uncharted territory of stock collapses, species shifts and unprecedented alterations in the nature of marine ecosystems.

'Back to the Future' (BTF) is the model reconstruction of past marine ecosystems that, by comparison with the present day, may inform and shape fisheries policy and decisions. Specifically, it encourages the rebuilding of marine resources and makes explicit the trade-offs that must be faced to maintain and restore biodiversity, and ultimately, the nature and value of fishery products. The technique is in its infancy but has attracted a curious, but encouraging mixture of enthusiastic support and deep criticism. At the Fisheries Centre, we continue to develop the methodology and its scope.

This report is the second in a series of Fisheries Centre research reports on the (BTF) process. The first, on the Strait of Georgia, (Pauly *et al.* 1999) reported the work of sixteen researchers over about a year, but was able to present only a preliminary analysis. The work reported here is less extensive than that on the Strait of Georgia, but attempts to examine the fisheries of the Hecate Strait ecosystem in northern British Columbia as they are today and as they were 100 years ago. It derives from a workshop held in Prince Rupert, BC in May 1998 supplemented by additional research following that event.

BTF 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.

Fisheries Centre Research Reports publishes results of research work carried out, or workshops held, at the UBC Fisheries Centre. The series focuses on multidisciplinary problems in fisheries management, and aims to provide a synoptic overview of the foundations, themes and prospects of current research. Fisheries Centre Research Reports are distributed to appropriate workshop participants or project partners, and are recorded in Aquatic Sciences and Fisheries Abstracts. A full list appears on the Fisheries Centre's Web site, http://www.fisheries.com. Copies are available on request for a modest cost-recovery charge.

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Pauly, D., T.J. Pitcher and D. Preikshot (Editors). 1999. Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Centre Research Reports 6(5): 99 p.

Preface

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Three papers were contributed to this volume, two of which are long overdue in the literature: the Haida and Tsimshian annotated dictionaries of fish and marine related words. These works are not complete; there may never be fully complete documentaries of traditional First Nation interaction with their environments. These dictionaries may, nonetheless, provide invaluable clues of how the ecosystem may have been, even if it is only that a word for something existed. It is interesting to note, for example that the Tsimshian people have a word for Hammerhead shark, presently very rare along the BC coast. The third contributed paper, on lingcod, presents a more traditional stock assessment and serves to underscore how little is known, even in scientific circles about this fairly remote region. We hope that the contents of this report will be seen as contributing to overcoming this situation.

Report of the BTF Workshop on Reconstruction of the Hecate Strait Ecosystem

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Abstract

Participants gathered at a workshop held in Prince Rupert, May 20 and 21 1998, to discuss changes to the Hecate Strait ecosystem (see Appendix I for list of participants). Hecate Strait is defined here as DFO statistical areas 5C and 5D and includes Dixon Entrance. A preliminary mass-balance model of Hecate Strait in the early 1900s was constructed from information provided by participants, and a preliminary mass-balance model representing the same area during the early 1990s. Changes in biomass from the previous model were based on input from workshop participants. Thus, it presents a test of whether ECOPATH can be used to develop a picture of how the ecosystem looked based almost entirely on local knowledge. Unless otherwise noted, biomass values were adjusted according to the consensus of the workshop participants. Most changes in biomass ranged from a 25% to a 100% increase, back through time. Where information was lacking, ECOPATH was allowed to calculate new biomass values. The results indicate that a coherent mass-balance model can be developed, based on the experience gained from long histories of personal association with an ecosystem.

Introduction

First Nations, fishers, scientists, managers, conservationists and the general public are concerned about the depletion and possible disappearance of entire fish populations. This was brought forcibly to the attention of Canadians by the closure of the East Coast cod fishery. Coincident with the opening day of the workshop, the Minister of Fisheries announced the most severe salmon fishery closures in BC history to preserve depleted coho salmon (*Oncorynchus kisutch*) populations. Introductory comments reflected a deep sense of loss and fear for the future. One hoped that we had not just gathered to write an epitaph. The Aboriginal and commercial fishers present represented several hundred years of experience of the Hecate Strait ecosystem and its fisheries for salmon, herring, halibut, lingcod, dogfish, rockfish, trawl, crab, and other fish and invertebrate species. The degree of overlap and exchange of information not only on 'commercial' species, but also on the rise and fall of seal, seal lion, whale and seabird populations was particularly striking.

Some participants had over 50 years personal experience - lifetimes spent on the water, some could draw on generations of experience. Aboriginal participants drew equally from their personal and family experience of commercial fishing, subsistence fishing for many species and a rich oral history (Jones, this vol.; Watkinson this vol.). Others drew on history and archaeology for insights into past abundance and previous occurrences of the shift, now apparently under way, between herring vs. sardines and anchovies as the dominant pelagic species.

The volume and diversity of information was impossible to fully absorb in the time available. This is because it reflects the complexity and diversity of the ecosystem itself. It also contains information about the processes of change, not only over the last 100 years, but reaching back through archaeological evidence to a time when Hecate Strait was a grassy plain (Fedje *et al.* 1996; Fedje and Josenhans 1998).

Box 1. The 'Back to the Future' approach

The BTF approach (BTF) is based on two beliefs. First, understanding ecosystems as they were before modern industrial fishing is a good first step to setting goals for rebuilding. Second, that all concerned have important contributions to make to reaching a broader and deeper understanding of how ecosystems work. BTF workshops use recent advances in ecosystem modelling to bring the knowledge of commercial fishers, First Nations, government scientists and managers, historians, archaeologists and others together. For additional information on BTF please see (Haggan *In press*; Pauly *et al.* 1998; Pitcher *in press*; Pitcher *et al.* 1999; Pitcher 1998a,b,c).

The greatest strength of BTF is that it enables many different actors to capture the interplay between ecological, economic, social and cultural forces in the ecosystems upon which they rely. For this reason, it has a ceremonial aspect of coming to terms with the depletion of the marine environment. With recognition that all sectors have knowledge that can contribute to good management, balanced by an acknowledgement that aquatic ecosystems are severely compromised and that all concerned – government, First Nations, fishers, scientists, managers, processors and policy-makers – share responsibility, an agreement can be forged to treat different knowledge systems with respect and work towards sharing knowledge in the interest of improved understanding (Haggan *in press*; Haggan *et al.* 1998; Haig-Brown and Archibald, 1996; Salas *et al.* 1998).

Ecosystems are still far too complex for us to grasp completely. Thus, ECOPATH (Christensen and Pauly 1992 and 1993) simplifies an ecosystem by combining species in up to 50 groups or 'boxes.' Groupings are usually made up of fish or other animals that eat, and are eaten by, the same things. For example, we have grouped lemon, rock, petrale, rex, and dover soles together in a box called 'Flatfish'. Done with care, the boxes will implicitly include all the animals and plants making up the system. This approach represents a significant advance over previous models of food webs, for instance multispecies virtual population analysis (MSVPA). The application of MSVPA is hampered by the high degree of expertise required by modellers, data needed are both difficult and expensive to obtain and the overall lack of transparency in the estimation procedure (for a more detailed citique, see Walters *et al.* 1997). Perhaps most importantly, MSVPA only includes harvested fish. In contrast, the relative ease of the application of ECOPATH has resulted in its increasing use to model aquatic ecosystems. A recent cooperative project between the UBC Fisheries Centre and University of Tennessee constructed a 47 group model of Prince William Sound for the period after the *Exxon Valdez* oil spill (Okey and Pauly, 1998). In addition, more than 100 ECOPATH models have been published world-wide describing upwelling systems, shelves, lakes, rivers, open oceans and terrestrial farming systems (http:\\www.ECOPATH.org).

ECOPATH is designed to help understand the ecological process of eating and being eaten. ECOPATH works like an accounting system. Each ECOPATH box gains or loses capital as the creatures in it feed, or are fed upon. ECOPATH tracks the flow of capital between boxes, ensuring the amount eaten does not exceed what is available. Furthermore, there must be a balance between all levels within the 'food chain'. A food chain consists of many links, each one of which represents a species, or a group of species. Each chain has a 'bottom' and a 'top'. At the base are the primary producers (plankton and kelp), which produce their food directly from sunlight. At the top are the predators, such as killer whales and of course, humans. At each level in the food chain animals are either eating prey, or are being eaten by predators.

The food chain is a very simple way of thinking about an ecosystem. In fact, ecosystems consist of many different food chains linked together like a spiderweb – a food 'web'. The figure in Appendix II shows the boxes and connections in the Hecate Strait model, giving some idea of how complex systems can be. ECOPATH requires five main types of information in order to model these food webs:

- The average weight of each group for the period covered by the model;
- The amount each group grows during a year;
- The amount each group eats during a year;
- How much of each group is caught during a year;
- The kind of food each of the groups eat.

If all of the above information is available, you have more than enough to proceed with the building of an ECOPATH model. Most often, not all of the above is available. In those cases, as long as you have any four of the above, ECOPATH can calculate the missing one.

Summary of Participant Input and Biomass Values

The following summary of the main parts of the Hecate Strait ecosystem 100 years ago is based on information provided by participants and research by graduate students at the UBC Fisheries centre. Where information is lacking, the ECOPATH software treated the value as an unknown, to be estimated from the balance of the various inputs.

Initially, it was planned that the model would reconstruct the ecosystem of 50 years ago. During discussion, however, participants pointed out that there had been fairly extensive steam trawl fisheries in the early 1900s. It was therefore agreed that reconstructing the system of 100 years ago would give a better sense of what the system was like prior to modern industrial fishing. Note that all references to the 'present day model' refer to Beattie (this vol.). As well, a detailed account and map of the study area may be found in Beattie (this vol.)

Transient killer whales, dolphins and porpoises (Odontocetae)

Information from Aboriginal and commercial fishers indicated a reduction in killer whales since their early days, but their numbers are now on the increase. There was some discussion about transient killer whales including an account of Orcas apparently trying to drown two Grey whales (*Eschrictius robustus*) by 'jumping' on top of them, thus preventing them to surface and breathe. It was agreed that a modest recovery in the population of both resident and transient killer whales is attributable to higher numbers of salmon and seals over the last 20 years. Porpoises (*Phocoenoides dalli*) were harpooned during the war as oil from a sack in the nose has a high freezing point and was valued for use on rifles and equipment in the Arctic. The meat was also used. Porpoises were previously "thick" in Juan Perez and Skincuttle inlets. Porpoises also followed eulachons (*Thaleichthys pacificus*) to the Nass. An association was made between dolphins and tuna, both being associated with warmer water. A recent coastwide increase in Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) was also noted.

Despite the recent recovery in killer whales, it was agreed their present biomass is still low. The 100-year biomass was increased by 20% based on a rationale that there was "more of everything" before industrial fishing started. More food allows for more top predators.

Seals and Sea Lions

Seals are an emotive topic these days. There was concern about the effect of Harbour seals (*Phoca vitulina*) on salmon populations, particularly the presence of large numbers of seals in river systems when juvenile salmon are out-migrating. Examples included the Skeenan River and Oweekeno Lake/Rivers Inlet. This was tempered by comments that human impacts such as fishing, pollution and habitat loss were also to blame and a realization that ecosystems are complex. Seals are highly visible taking salmon from gillnets, lying in wait in rivers for in-migrating adult salmon or hatchery releases, but seals also eat hake (*Merluccius productus*), a major predator of juvenile salmon. Some recalled the Department of Fisheries and Oceans bounty on seals in the 1970s, but no one expressed any real desire to return to those days. One Haida participant recalled a stack of fur seal (*Callorhinus ursinus*) bones on the beach at Tow Hill, near Masset and said that fur seals used to be "like the buffalo on the prairies." Steller sea lions (*Eumetopias jubatus*) were said to be up since the 1950s when they were shot for mink feed and the skins used as anti-chafe material on beam trawls. More recently, Steller sea lions have decreased sharply, but have been largely replaced by California sea lions (*Zalophus califonianus*).

For the model, Seals and Sea Lions were left the same on the assumption that any decline of the Steller sea lion population has been offset by the increase in the California sea lion and Harbour seal populations

Baleen whales (Mysticetae)

It was noted that the Haida hunted whales (Jones, this vol.). Grey whales in particular have increased over the last 15 years and cause some problems for the spawn-on-kelp fishery on Haida Gwaii due to silt stirred up by their feeding habits. Grey, Humpback and Minke whales are believed to have recovered from past industrial whaling operations. Blue and Fin whales have not. Since the former group comprises the main bulk of the biomass, the 100-year biomass was assumed to be the same as at present.

Seabirds

General comments reflected the conceptual split between how fishers and fisheries scientists regard birds. All who make their living from fisheries pay close attention to the presence, absence and behaviour of birds. Negative impacts on Ancient Murrelets (*Synthliboramphus antiquus*), Auklets (*Ptychoramphus aleuticus*) and other bird populations include logging, the introduction of rats and raccoons (*Procyon lotor*) that prey on eggs and young and overall reduction in food availability due to intensive fishing. Discards from the trawl fishery, on the other hand, provide a new food source for some species.

Participants provided a wealth of information on this area that, up to now, has not had a formal place in fisheries science. This is not to say that there is a lack of good research, just that there has been no tradition of fisheries scientists and ornithologists working together. It is thus a rich area for ecosystem research and one place where ECOPATH provides a new opportunity to link seabirds to the marine ecosystem (Bishop and Okey 1998; Esler 1998; Kelson *et al.* 1996; Okey and Pauly 1998; Ostrand and Irons 1998; Wada and Kelson 1996). Perry and Waddell (1994) also address plankton availability to seabirds in Queen Charlotte Island waters. Areas for further research therefore include correlation of past and present studies, Audubon Society Christmas counts on Haida Gwaii and Prince Rupert, interviews with birdwatchers, fishers and other observers and archaeological research now under way at pre-contact village sites around Hecate Strait. Incorporating the impact of rats and raccoons on seabirds and their prey will be a challenge.

In view of the overall negative impacts, the 100-year biomass is tentatively increased by 100%.

Spiny dogfish (*Squalus acanthias*)

There was a general impression that dogfish had recovered well from an intensive WWII era fishery. The 100-year biomass is tentatively left unchanged, on the assumption that the population has recovered from the directed fishery. More research and follow-up interviews are needed to correlate observations on the relative abundance of dogfish in halibut and other fisheries over time.

Ratfish/skates

There was a small fishery for ratfish (*Hydrolagus collei*) in order to process them for oil used for guns and on slipways, though primarily it was a bycatch species in the dogfish fishery. Skates (*Raja* sp.) were only recently the target of a directed fishery. Tentatively the 100-year biomass will be left the same as for the present day model.

Pacific halibut (*Hippoglossus stenolepsis*)

Halibut have always been very important to BC First Nations, indeed, for the Haida, halibut may have been more important than salmon. Input included 6,000 years evidence of halibut in middens and a pre-contact catch estimate of close to 1,400t per year north of Cape Caution. In fact, Tsimshian elders were unable to attend the workshop primarily because they were at camp drying halibut and picking seaweed (*Porphyra* spp.). First Nations fished from canoes, with lines made of variously twisted cedar, animal sinew/intestine, or kelp (*Macrocystis* spp.), and wooden hooks with boned barbs (Jones, this vol.). By the turn of the century, gasoline and diesel engines were used, and in 1907 the commercial halibut catch reached more than 20,000 t. After 1915 catches were declining, and the International Fisheries Commission (IFC), later renamed the International Pacific halibut Commission (IPHC) was formed in 1923 to ensure proper management.

The discarding of bycatch is a major concern; several participants referred to the number of red snapper discarded in the halibut fishery before a market developed. One comment was that the sea looked "like a pumpkin patch." Bycatch in the trawl and blackcod fisheries is an ongoing concern. There is also a belief that small 'homesteader' populations of halibut may have been depleted or fished out in a similar manner to small herring stocks. This should be the default assumption in the absence of unequivocal scientific evidence to the contrary. There was also concern that although the sport fishery catch is a fraction of the commercial take, sport fishers have a tendency to fish out the corners where commercial vessels do not necessarily go. This has a dual role of eroding populations of resident species and impacting the Aboriginal subsistence fishery that depends on the ready availability of stocks that are nearby and can be easily accessed using small boats.

Overall, the recovery of the stock appears to be a rare fishery management success. The consensus of the workshop was that there were more halibut today than before, perhaps twice as many. The available data suggest, however, that there is perhaps only as many as there were 100 years ago. For the purpose of this model, halibut are tentatively left the same as for the present day model.

Pacific cod (*Gadus macrocephalus*)

Between 1918 and the late 1950s, Pacific cod landings increased from about 400 to 8000 t. There is a spawning ground at the north end of Banks Island. Substantial amounts were landed at Bellingham. Data may be available through the University of Western Washington.

The consensus of the participants is that cod have only 10% of their historical abundance, and the 100-year biomass is tentatively set at that figure.

Walleye pollock (*Theragra chalcogramma*)

Despite mention of a winter midwater fishery at the top end of Two Peaks, the consensus was that pollock were never very common. The 100-year biomass was tentatively left as in the present day model.

Juvenile and Adult blackcod (*Anoplopoma fimbria*)

Blackcod were considered to be reduced in numbers, by as much as 33-50%. The BC blackcod fishery began sometime in the 1890s as a setline fishery, but landings were minor until 1913. The current blackcod fishery is by trap. The 100-year biomass for juveniles and adults was tentatively increased by 33%.

Herring (*Clupea harengus pallasi*), small pelagic fish

The herring reduction fishery was cited as an example of how little is known about unfished levels and the importance of herring to other ecosystem components (Jones *in press*; Newell 1993). Fishers, the Union and First Nations concerns were disregarded by DFO biologists until a crash forced a six-year closure. There was a consensus on the crucial ecosystem role of herring. Fishers also believe that the Hecate Strait area is (or was) home to a very large number of small discrete stocks as well as one (or more) large stocks of bigger herring. Skidegate Inlet, Prince Rupert Harbour and Chismore Pass were cited as areas where stocks had been virtually eradicated. Chismore Pass was also given as an example of how sport fisheries can target small stocks for bait. Concern was also felt about inconsistencies in the way herring spawn is measured and reduction in effort in this program.

Based on the critical role of herring, it was agreed that a precautionary approach that considers the ecosystem role of herring is essential (Jones *in press*). Recent examples were given of Haida and Tsimshian (Kitkatla) fishers opposing DFO openings. In the absence of information to the contrary, the default assumption should be that stocks are discrete, fishing strategies should also be very conservative. The idea of 'sanctuaries' (marine protected areas) to protect small local herring stocks as well as other species was discussed and well received.

The relative abundance of herring compared with sardines/pilchards, anchovies and mackerel was a recurrent topic. Observations tallied that the 1990s have seen a significant rise in pilchards. There was also a fishery for sardines/pilchards in the 1960s and other species

The consensus of the workshop was that herring biomass was in general down, with some areas showing more of a reduction than others. For eulachons, the general feeling was the biomass is down 25-30%. The average reduction for the entire study area for herring was estimated to be 75%. The 100-year biomass was be tentatively increased 75% above present day model levels.

Juvenile salmon (*Oncorhynchus* spp.)

Loss of spawning and nursery habitat, coupled with decades of heavy fishing has forced a decrease in the amount of salmon spawning in BC waters, and therefore the number of juvenile salmon in the Strait. Possible negative impacts include increase in seal populations and more mackerel due to El Niño. However, little information has been found on how much of a reduction has taken place. For the want of better data, the biomass will be left the same as for the present day model.

Pacific Ocean perch (POP, *Sebastes alutus*)

The general feeling was that POP were down, although no overall percentage was obtained. Until the 1950s, POP were not an important species to the BC fisheries, comprising less than a 1/4 of Pacific cod landings and about the same for total flatfish landings (Figure 1). In the 1960s and 1970s, POP were heavily targeted by foreign fisheries, including Japanese and U.S. fleets (Westrheim 1987). Little is known about actual quantities of fish removed, or how well the population has recovered. For this model, the biomass was thus left for ECOPATH to estimate.

Flatfish

Information provided indicated a reduction in Dover sole, lemon sole and Arrowtooth flounder, previously taken in large amounts and used for mink feed. The overall impression was a reduction in flatfish numbers of about 1/3. The 100-year biomass will therefore be set 1/3 higher.

Rockfish and small bottom dwelling fish

The consensus was that rockfish are at 10% of their historical abundance. In particular, it was felt that Yelloweye rockfish or red snapper, (*Sebastes ruberrimus*) were significantly reduced (see above on bycatch in the halibut fishery). Within this model, however, they are grouped with a variety of small bottom-dwelling species. It is not known whether the biomass of these has decreased, increased, or remained the same; indeed, this box was problematic for the present day model. The biomass was therefore left for ECOPATH to estimate, as was done for the present day model.

Turbot (*Atheresthes stomias*)

Although turbot has only recently been the target of directed fisheries, it was used in the past for mink food, although apparently retained principally as by-catch. Turbot is very common in the trawl catches today. For

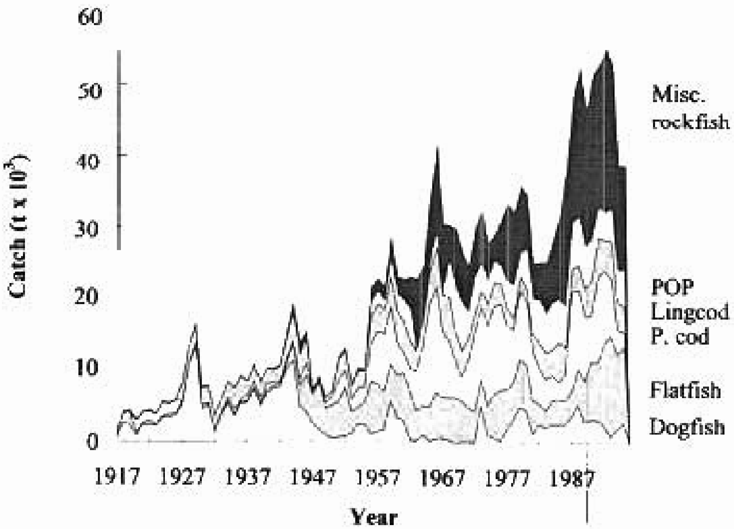

Figure 1. Catches by species for the Canadian trawl fleet for the years 1917-1994. Data from Forrester *et al.* (1978), Forrester *et al.* (1983), Westrheim *et al.* (1986) and Pauly *et al.* (*In press*).

this model, the biomass is tentatively left as for the present day model.

Lingcod (*Ophiodon elongatus*)

lingcod provoked a great deal of discussion. Input included a belief that male lingcod migrate across Hecate Strait to Haida Gwaii returning in February to spawn and guard eggs. This is based on large seasonal catchers by bottom trawlers ('draggers'). Longtime participants in the fishery spoke of severe reduction in numbers and size attributed to the introduction of longlines (including ghost fishing by lost gear), catch by draggers and cleanup of the corners by charterboat (sportfishing) operations. One longtime participant recalled that landings for a good day trolling would be 450 kg with 110 kg on a poor day. Average size jigging was 14 kg., 3.5 kg. trolling. Average weight in the sport fishery is now 3.5 kg.

Overall, lingcod are considered to be severely reduced in abundance (Martell, this vol.). Biomass for the 100-year model is tentatively set for a 95% increase, based on Martell and Wallace (1998), who estimated a 95% reduction in Georgia Strait lingcod.

Jellyfish, Zooplankton, Phytoplankton and Detritus

No consensus was reached during the workshop. For phytoplankton and zooplankton, any large increase or reduction seems unlikely as climatic conditions seem to be constant over the period. The 100-year biomasses are tentatively left the same as for the present day model.

Crustaceans, Shellfish and Echinoderms

It was felt that biomass of clams and prawns were in general down. Other groups such as sea urchins were thought to have increased. Haida participants expressed great concern about the number of traps in the crab fishery as well as ghost fishing, i.e., killing of fish by lost or discarded gear. Concern was also expressed about the depletion of abalone (*Haliotis kamtschatkana*), including an interesting observation about the role of raccoons in depleting abalone in Naden Harbour. The biomass 100 years ago was tentatively left unchanged from the present day model.

Fishery harvests

Modern commercial fishery harvest in the Hecate Strait region apparently did not begin in earnest until 1910. Thus, commercial harvest was left at zero. The Aboriginal harvest figure calculated in the Strait of Georgia BTF project was used in the absence of better information (Pauly *et al.* 1998). This is probably low as a verbal report on archaeological information by David Archer indicates that the study area had one of the highest Aboriginal population densities in North America. Boyd (1990) gives figures of approximately 14,500 for both the Haida and Tsimshian, but allows that these are probably low.

Results

Figure 2 shows the results of the trophic flows estimated by ECOPATH. Note that the diagram is virtually identical to the one obtained for the present day model, as also confirmed by the similar or identical trophic levels of the various groups (Table 1, also see Table B, Appendix II for more details).

Both models are preliminary in nature, and as such we will not attempt a detailed analysis of their structure. It is worth noting, however, that the perceptions of the people involved in the workshop as to the state of the Hecate Strait ecosystem as it was 100 years ago were found to be entirely plausible under the ECOPATH mass-balance assumption. Thus, with more study, such results (subject to further verification) may provide a solution to, or at the very least mitigate the effects of the 'shifting baseline syndrome of fisheries' (Pauly 1995).

Table 1. Comparison of the trophic levels calucualted for the present day and 100-year models. Differences are highlighted.

Group name	Trophic level	
	Present	100-year
Adult sablefish	**3.6**	**3.7**
Carnivorous jellyfish	**3.0**	**3.1**
Crustaceans	2.2	2.2
Flatfish	**3.1**	**3.5**
herring, small pelagic fish	3.1	3.1
Juvenile sablefish	**3.8**	**3.7**
Juvenile salmon	3.1	3.1
lingcod	4.0	4.0
Macrobenthos	2.1	2.1
Mysticetae	3.1	3.1
Odontocetae	4.1	4.1
P.O. perch	3.1	3.1
P. Cod	3.4	3.4
P. halibut	3.9	3.9
Pinnipeds	4.1	4.1
ratfish, skates	**3.4**	**3.5**
rockfish, small benthic fish	3.2	3.2
Seabirds	3.6	3.6
Spiny dogfish	3.2	3.2
Transient orcas	**5.0**	**5.1**
turbot	3.7	3.7
Walleye pollock	3.3	3.3
Zooplankton	2.1	2.1

Unanswered questions

There are two kinds of unanswered question. The first relates to an absence of data on individual species or groups. Earlier discussion pointed to significant uncertainty about present and past numbers of a range of species, particularly rockfish, ratfish, skate, bottom dwelling species, even adult and juvenile salmon. Mention was made of the disappearance of tomcod *Microgadus proximus* from both Prince Harbour and Skidegate Inlet. Other information requirements include:

- Pre-contact and early fisheries harvests;
- biomass of adult salmon, and changes in abundance from 100 years ago;
- the abundance or presence of squid in the ecosystem; and,
- Information on types, abundance and harvest of sharks.

The second type of question relates to the ecosystem interactions between say herring, seals, sea lions, seabird, salmon, lingcod and commercial fisheries. This bears directly on the ability of commercial species to sustain fisheries or indeed recover from previous overfishing; the slow rate of recovery of Atlantic cod, despite 7 years of closure is a case in point. Jones (*In press*) discusses the impacts of commercial herring fisheries on Haida Gwaii stocks. Bycatch is another complex area that calls for ecosystem modelling.

Another area pertains to large changes in ecosystem structure. For example, in his introductory remarks, Tsimshian President Bob Hill mentioned a kelp forest that used to stretch from Kitamaat to Dundas. It is generally believed that the disappearance of kelp is related to the rise in sea urchin populations after the demise of the sea otter (*Enhydra lutris;* Paine 1980). However, this

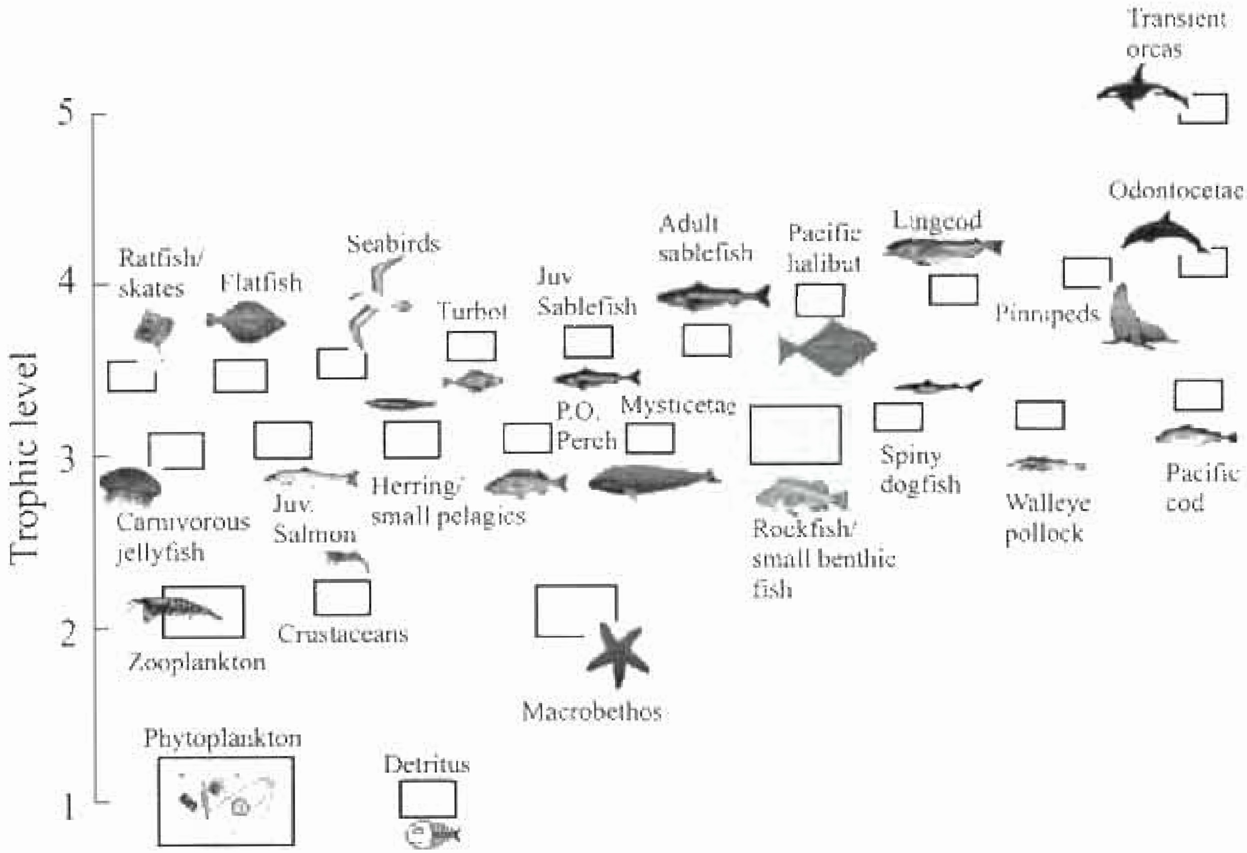

Figure 2. Pictorial representation of the elements of the Hecate Strait ecosystem, as it might have been 100 years ago. For comparison, this diagram and the diagram for the present day model are scaled to the same size, using the biomass of the phytoplankton box as reference.

large change in ecosystem structure will have profound implications for the presence, absence and relative abundance of species that depend on kelp forests for cover. Kelp is also important for herring spawn and the spawn on kelp fishery. The second example was of 'red tree' (gorgonians) in trawl fisheries. The effect of trawling on bottom structure is beginning to be documented (Auster 1998; Engel and Kvitek 1998; Watling and Norse 1998). On the credit side, ECOPATH can now accommodate the species that change actual ecosystem structure (C. Walters, UBC Fisheries Centre, pers. comm.), even if their impacts is due to effects other than predation. This should make it rewarding to revisit the models presented here.

References

Auster, P.J. 1998. A Conceptual Model of the Impacts of Fishing Gear on the Integrity of Fish Habitats. Cons. Biol. 12 (6):1198-1203.

Bishop, M.A. and T.A. Okey. 1998. Consumption of herring Eggs by Birds. p. 61-63 *In*: T. Okey and D. Pauly (eds.) 1998. A Trophic Mass-Balance Model of Alaska's Prince William Sound Ecosystem, for the Post-Spill Period. UBC Fisheries Centre Research Reports. 6(4).

Boyd, R.T. 1990. Demographic History, 1774-1874. p. 135-148 *In*: W. Suttles (ed.). Northwest Coast. Vol. 7 of Handbook of North American Indian. Smithsonian Institution, Washington, D.C.

Christensen, V. and D. Pauly. 1992. ECOPATH II - A system for balancing steady-state ecosystem models and calculating network characteristics. Ecol. Modeling, 61: 169-185.

Christensen, V. and D. Pauly (Editors). 1993. Trophic models of aquatic ecosystems. ICLARM Conference Proceedings. 26, 390 p.

Engel, J. and R. Kvitek. 1998. Effects of Otter Trawling on a Benthic Community in Monterey Bay National Marine Sanctuary. Cons. Biol. 12 (6):1204-1214.

Esler, D. 1998. Invertebrate-Eating Sea Ducks. p. 55-56 *In:* T. Okey and D. Pauly (eds.) 1998. A Trophic Mass-Balance Model of Alaska's Prince William Sound Ecosystem, for the Post-Spill Period. UBC Fisheries Centre Research Reports, 1998. 6(4).

Fedje, D and Josenhans, H. 1998. Then a Flood Came: Archaeology and Marine Geology in Gwaii Haanas. p 5-9 in Gwaii Haanas Currents. Gwaii Haanas Archipelago Management Board / Parks Canada.

Fedje, D.W., A.P. Mackie, J.B. McSporran and B. Wilson. 1996. Early period archaeology in Gwaii Haanas: Results of the 993 field programme. p. 133-150. *In*: Roy L. Carlson and L. Della Bona (eds.). Early Human occupation in British Columbia. UBC Press, Vancouver.

Forrester, C.R., A. J. Beardsley, and Y. Takahashi. 1978. groundfish, shrimp and herring fisheries in the Bering Sea and Northeast Pacific – historical catch statistics through 1970. Int. North Pac. Fish. Comm. Bull. 37:147 p.

Forrester, C.R., R.G. Bakkala, K. Okada and J.E. Smith. 1983. groundfish, shrimp and herring fisheries in the Bering Sea and Northeast Pacific – historical catch statistics through 1971-76. Int. North Pac. Fish. Comm. Bull. 41:100 p.

Haggan, N. BTF and Creative Justice: Recalling and Restoring Forgotten Abundance in Canada's Marine Ecosystems. *In:* H. Coward, R. Ommer and T. Pitcher (eds.). Just Fish: Ethics in the Canadian Coastal Fisheries. ISER Books, St. Johns, Newfoundland. (*In press*)

Haggan, N., J. Archibald, and S. Salas. 1998. Knowledge Gains Power When it is Shared. p. 8-13. *In:* D. Pauly, T. Pitcher and D. Preikshot (eds.) BTF:

Reconstructing the Strait of Georgia Ecosystem. UBC Fisheries Centre Research Reports. 6(5).

Haig, C. and Archibald, J. 1996. Transforming First Nations research with respect and power. Qualitative Studies in Education. 9 (3): 245-267.

Jones, R.R. The herring fishery of Haida Gwaii - an ethical analysis. *In:* H. Coward, R. Ommer and T. Pitcher (eds.). Just Fish: Ethics in the Canadian Coastal Fisheries. ISER Books, St. Johns, Newfoundland. (*In press*).

Kelson, J., Y. Wada and S. Speckman. 1996. Seabirds in the Alaskan Gyre. p. 31-32. *In:* D. Pauly and V. Christensen 1996. (eds.) Mass-Balance Models of North-eastern Pacific Ecosystems. UBC Fisheries Centre Research Reports. 4 (1).

Martell, S. and S. Wallace. 1998. Estimating Historical lingcod Biomass in the Strait of Georgia. p. 45-48 *In*: D. Pauly, D. Preikshot and T. Pitcher (eds.). Back to the Future: reconstructing the Strait of Georgia ecosystem. Fisheries Centre Research Reports 6(4).

Newell, D. 1993. Tangled Webs of History: Indians and the Law in Canada's Pacific coast Fisheries. University of Toronto Press. Toronto. 306 p.

Okey, T. and D. Pauly (Editors). 1998. A trophic mass-balance model of Alaska's Prince William Sound ecosystem, for the post-spill period 1994-1996. Fish. Cen. Res. Rep. Ser. 6(4):144 pp.

Ostrand, W.D., and D.B. Irons 1008. Seabirds and Seabird Predators. p. 57-60 *In:* T. Okey and D. Pauly (eds.). A Trophic Mass-Balance Model of Alaska's Prince William Sound Ecosystem, for the Post-Spill Period. UBC Fisheries Centre Research Reports. 6(4).

Paine, R.T. 1980. Food Webs: Linkage, Interaction strength and Community Infrastructure. J. Anim. Ecol. 49:667-685.

Pauly, D. Anecdotes and the shifting baseline syndrome of fisheries. TREE 10(10):430

Pauly, D., T. Pitcher, and D. Preikshot (Editors). 1998. Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Center Research Reports, Vol. 6(5): 99 p. University of British Columbia Fisheries Center, Vancouver.

Pauly D., A.I. Beattie, A. Bundy, N. Newlands, M. Power and S. Wallace, (*In press*). Not just fish: ecosystem values and roles off Canada's Atlantic and Pacific coast. In: Just Fish: Ethics in the Canadian Marine Fisheries, H. Coward, R. Ommer and T.J. Pitcher, (eds.). Institute of Social and Economic Research, Memorial University: St. John's, Newfoundland

Perry, R.I., and B.J. Waddell 1994. Zooplankton in Queen Charlotte Island waters: distribution and availability to marine birds. MS, Canadian Wildlife Service, 32 p.

Pitcher, T.J. Ecosystem goals can reinvigorate fisheries management, help dispute resolution and encourage public support. Fish and Fisheries 1(1). (*In press*).

Pitcher, T.J. 1998a. Ecosystem simulation models and the new 'BTF" approach to fisheries management. p. 21-23 *In:* D. Pauly (ed.) The Use of ECOPATH with ECOSIM to Evaluate Strategies for Sustainable Exploitation of Multi-Species Resources. Fisheries Centre Research Reports 6 (2).

Pitcher, T.J., 1998b. BTF: a Novel Methodology and Policy Goal in Fisheries. p. 4-7 *In:* D. Pauly, D., D. Preikshot and T. Pitcher (eds.) Back to the Future: reconstructing the Strait of Georgia ecosystem. UBC Fisheries Centre Research Reports, Vol. 6(5).

Pitcher, T.J. 1998c. Pleistocene Pastures: Steller Sea Cow and Sea Otters in the Straight of Georgia. p. 49-52 *In:* D. Pauly, D. Preikshot and T. Pitcher (eds.). Back to the Future: reconstructing the Strait of Georgia ecosystem. Fisheries Centre Research Reports 6(5).

Pitcher, T.J, N, Haggan, D. Preikshot and D. Pauly. 1999. 'BTF: A method Employing Ecosystem Modelling to Maximise the Sustainable Benefits from Fisheries. Lowell Wakefield Alaska Sea Grant Symposium on Fisheries and Ecosystems, Anchorage. *In press.*

Salas, S., Haggan, N., and Archibald, Jo-Ann, 1998. Aboriginal Knowledge and Ecosystem Reconstruction. P. 22-28. *In* D. Pauly, D. Preikshot and T. Pitcher (eds.). Back to the Future: reconstructing the Strait of Georgia ecosystem. Fisheries Centre Research Reports 6(5).

Wada, Y. and J. Kelson. 1996. Seabirds of the Southern BC Shelf. p. 55-56 *In:* D. Pauly, D and V. Christensen (eds.). Mass-Balance Models of Northeastern Pacific Ecosystems. UBC Fisheries Centre Research Reports. 4(1).

Watling, L and E.A. Norse. 1998. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Clearcutting. Cons. Biol. 12 (6):1180-1197.

Westrheim, S.J. 1987. The rockfish fisheries off Western Canada, 1860 – 1985. Alaska Sea Grant Report 87-2:43-50.

Walters, C., V. Christensen and D. Pauly. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Reviews in Fish Biology and Fisheries 7:139-172.

The Hecate Strait: a preliminary present-day model

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Abstract

A preliminary mass-balance model of the Hecate Strait region of British Columbia, Canada, for a period representing the early 1990s is presented. The model boundaries are defined by the fisheries statistical areas 5C and 5D. The model includes 25 functional groups, ranging from primary producers to top predators. Some problems, including over-aggregation of species within some of the functional groups and a lack of even general biological data for some groups may have biased the results.

The Study area

The Hecate Strait is defined here as the major statistical areas defined in the Canada Fishery Regulations as 5C and 5D. The southern boundary of region 5C is a straight line stretching East-West, from the southern tip of the Queen Charlotte islands to the mainland, along the longitude 52° 10" N. The northern boundary of area 5D is more complicated, extending from the northwestern-most tip of the Queen Charlottes, north to Canada/U.S.A. international boundary, and from there roughly due east to the mainland. The area thus defined includes the Hecate Strait and Dixon Entrance, and incorporates a surface area of ≈ 46,000 km^2 (see Fig. 1; and Tyler 1986). The area boundaries were determined in order to ease the calculation of the harvest rates and management strategies of the important fisheries in the region (including salmon, groundfish, halibut and sablefish), which are often reported by the major statistical areas.

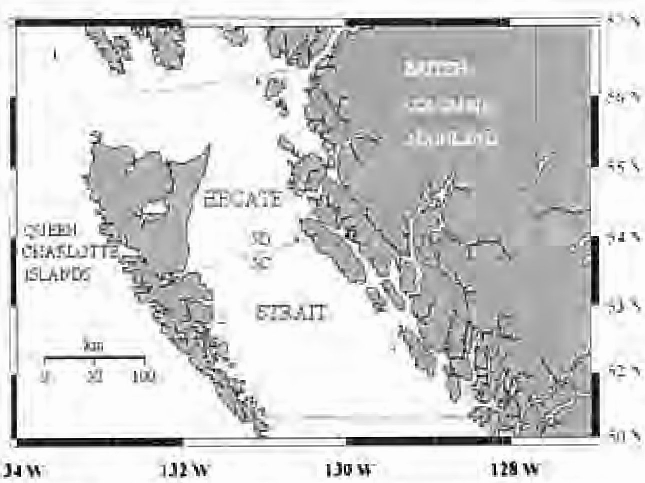

Figure 1. Map of the study area, showing the major statistical areas used as boundaries.

This model is a modification of an earlier model created for the southern B.C. shelf region (see Pauly and Christensen 1996), that had a northern boundary in common with the southern boundary of this model. Other characteristics of the model are similar to the earlier model, including the difficulty of considering this a closed system. The area is not as well studied as other coastal regions within the province, however at least one earlier study attempted a multispecies research agenda, generating over 30 papers, many of which were useful for this study (see Tyler 1986; 1989). Some of the boxes incorporated in this preliminary model were obtained directly from the southern B.C. shelf model, due to a lack of relevant data for Hecate Strait.

Modifications to the Southern B.C. Shelf Model

Several modifications to the southern B.C. Shelf model were made before beginning the building of the Hecate Strait model. These modifications were necessary for several reasons, including:

- the study area is considered oceanographically distinct from that of the previous model;
- the ranges of some species do not extend to the study area;
- and a lack of data for this study area.

First, imports and exports from the system were assumed to be zero (i.e., a closed system is assumed). This was done due to need for simplicity and lack of data.

Second, hake was deleted as element of the model. This was based on the assumption that the northern boundary of their range is generally south of the study area. This assumption was made because the fishery for hake takes place off the West Coast of Vancouver Island, and catches fall dramatically north of Cape Scott (author's pers. obs.).

Third, several boxes were aggregated into a reduced number of boxes, due to a lack of species-specific information for the study area. The aggregations were done using the manual aggregation utility incorporated in the ECOPATH software. The aggregations are as follows:

- The boxes for sea stars, brittle stars, bivalves and polychaetes were aggregated into a single box for 'Macrobenthos';
- The boxes for euphausiids, amphipods, copepodsx, chaetognaths and salps were aggregated into a single box for 'Zooplankton';
- The boxes for shrimp and decapods were aggregated into a single box for 'Crustaceans'.

Once the above steps were taken, no further modifications to the data in the model were performed (i.e., adjusting diet composition) until the new boxes were entered.

Model inputs

Primary productivity

Ware and McFarlane (1989) defined the study area as being within a "Coastal Downwelling Domain". This domain extends from Prince William Sound in Alaska, south to the northern tip of Vancouver Island, and extends offshore to 170°W. Thus, the region is considered distinct, in oceanographic terms, from the area covered by in the southern B.C. shelf model, although there is some overlap in the Queen Charlotte Sound area. The system is largely characterized by coastal waters; these differ from one area to another due to local variations in runoff, winds, heating and cooling, tides and currents. These differences are mediated, however, by the continuity and stability of the adjacent Alaska Current domain. The primary productivity for shelf waters of the domain ranges from 185-330 $gC{\cdot}m^{-2}{\cdot}year^{-1}$, and varies seasonally.

For the purposes of this model, which covers the time span of an average year, a mean of 257.5 $gC{\cdot}m^{-2}{\cdot}year^{-1}$, corresponding to 2,575 $t{\cdot}km^{-2}{\cdot}year^{-1}$ (wet weight), was used.

Zooplankton

The southern B.C shelf model incorporated boxes for several species of zooplankton. By contrast, little species specific information was found for the Hecate Strait region. Two estimates of zooplankton biomass were found. The first suggested a range of 30 – 50 $gC{\cdot}m^{-2}{\cdot}year^{-1}$, dominated by copepods, notably *Neocalanus* sp. (Ware and McFarlane 1989), although other studies have suggested that the zooplankton is in fact dominated by euphausiid species (Hay *et al.* 1986). The contradictory nature of the reports may be due to seasonal variation. As much as five times the annual secondary production may be advected shoreward from offshore production domains such as the Alaskan Gyre (Cooney 1984). Dunbrack and Ware (1986) found a value for all zooplankton to be 30 $gC{\cdot}m^{-2}{\cdot}year^{-1}$, based on plankton hauls from six stations in the Hecate Strait during the months of May, June and July over two years. This value compares favorably with Ware and McFarlane's (1989) estimate. The estimate used for this model was 40 $gC{\cdot}m^{-2}{\cdot}year^{-1}$, corresponding to 400 t·km-2·year-1 (wet weight).

Transient orca, Odontocetae, and Pinnipeds

No information specific to the study area could be found. The number of Steller sea lions, however, may range from 5-12,000 individuals (A. Trites, Fisheries Centre, UBC, pers. comm.). Based on an average weight of 198 kg (Trites and Heise 1996), this would result in a minimum biomass for pinnipeds of between 0.022 – 0.052 t·km^{-2}·year^{-1}. No changes were made to the biomass, or any of the inputs for these boxes, except the diet composition of pinnipeds was modified to include 17% pollock. This change reflects both the lack of hake in the study area and the increased availability of pollock relative to southern shelf areas.

Baleen whales (Mysticetae)

Inputs for this box remained the same as the southern B.C shelf model (Trites and Heise 1996), except for the biomass input. Here data from the IWC whaling base was used to calculate a probable number of animals in the area. The whaling operation was extensive, and here assumed to represent the removal of nearly the entire biomass for the region. This figure was inputted as an upper limit for the present day biomass, calculated by multiplying the total number of whales by an average biomass per whale. The value obtained was 0.31 t·km^{-2}·year^{-1}. All other parameters from the southern B.C shelf model remained the same.

Seabirds

Most parameters for seabirds remained the same as for the southern B.C shelf model (Wada and Kelson 1996). The biomass was changed, however, based on an estimate obtained from Vermeer and Rankin (1984). Their study of the total standing stock found that seabird numbers varied seasonally over several years, from a low of 75,000 in the winter months, to a high of greater than 5,000,000 in the early spring. The estimate used here is based on counts averaged over several years times an average body weight of seabirds. The value obtained was 0.016 t·km^{-2}·year^{-1}.

Spiny dogfish (*Squalus acanthias*)

The parameters for spiny dogfish remained the same as for the southern B.C shelf model (Polovina 1986), except for the biomass, and a shift in the diet composition of 2% to zooplankton, upon which dogfish are known to feed heavily, up to 70%, especially in winter (Hay *et al.* 1986, Simenstad *et al.* 1979), and reflecting the removal of hake from the system. Fargo *et al.* (1990) obtained a biomass estimate through a series of trawl surveys over the years 1984-1987. The values ranged from a low of 27,000 t to a high of 95,000 t. The value entered for this model was based on an average value, 1.25 t·km-2·year-1.

Ratfish/skates

This box is the first new box to be entered into this model. Though relatively little is known about these species, Brinkhurst *et al.* (1986) reported that in some areas of the Hecate Strait, ratfish (*Hydrolagus collei*) and skates combined may account for greater than 50% of the biomass in waters less than 100m deep, as estimated by trawl surveys. Furthermore, as fishery quotas on other species become increasingly smaller, vessels have begun targeting skate species, used in the production of false scallops. Ratfish are often caught in the groundfish trawl fishery, and may at times comprise the bulk of the biomass from individual sets. A biomass estimate for these two species was obtained in Fargo *et al.* (1990, Table 1).

No study was found of diet composition of skates in the study area; however studies on diet composition of skate species are available in the literature. For the purpose of this study, it was assumed that the diet composition of different species of skates would be similar due to constraints such as mouth shape. Based on this, a skate diet composition of 39% crabs, 28% invertebrates, 29% fish and 5% others were constructed (Robichaud *et al.* 1986; see also Table 2). This does not contradict Hart (1973), who indicated the diet of Big skate consisted of crustaceans and fish. Hart also indicated the diet of ratfish consisted of clams, crustaceans, and fishes.

A P/B ratio for skates was calculated using an empirical equation in Pauly *et al.* (1993),

Table 1. Biomass estimates for twelve major species based on trawl surveys in the Hecate Strait 1984-87[a].

Species	Standing Crop (t)		
	1984	1986	1987
Turbot	94229	21424	95444
Spiny dogfish	86003	27199	59441
English sole	37765	49261	15369
Ratfish	28644	54292	14157
Pacific halibut	25830	8073	8204
Dover sole	23497	361	34951
Rex sole	15600	17699	25900
Rock sole	12347	13458	8213
Sablefish	8134	1139	10852
Big Skate	5731	63058	5567
Pacific sanddab	3947	4375	1817
Petrale sole	2285	970	384

[a] from Fargo *et al.* 1990

also available in the 'Ecoempire' utility in ECOPATH, to calculate M (assuming P/B=Z=M, given F=0 and Z=F+M). Data for the equation came from Zeiner and Wolf (1993). No Q/B estimate was available, and thus a GE value of 0.25 was entered and Q/B calculated from GE = (P/B)/Q/B.

Pacific halibut (*Hippoglossus stenolepsis*)

All input parameters for this box were left as they were in the southern B.C shelf model (Venier 1996), except for biomass, which was taken from Fargo *et al.* (1990, Table 1). The value input was the average of the three values, 0.305 t·km-2·year-1.

Pacific cod (*Gadus macrocephalus*)

No data on cod for this area was found, and all input parameters remained as in the southern B.C shelf model (Livingston 1996), except for the diet composition, for which the predation on zooplankton was increased by 9%, to account for the lack of hake in the system. One study found a strong positive correlation between pacific cod recruitment and herring abundance, and *vice versa*, with herring figuring prominently in the diet of cod (Walters *et al.* 1986). However, physical oceanographic factors may be more important in the stock dynamics of the two species (Walters *et al.* 1986). Cod recruitment is subject to large fluctuations in from year to year and exhibits a strong inverse relationship with stock size, suggesting strong density dependence (Welch and Foucher 1986).

Walleye pollock (*Theragra chalcogramma*)

Walleye pollock were added to this model because of a reasonably large directed mid-water trawl fishery, which exists in the Hecate Strait and Queen Charlotte Sound, but not further south. Landings from the fishery have been increasing, and take place mainly in the first quarter of the year, when the stock is most abundant, although pollock are present year round (Saunders and Andrews 1994). It is likely that the stock is contiguous with the offshore stock, however, and that migration in and out of the system does occur (Saunders and Andrews 1994).

The biomass for pollock was reported to be 0.357 t·km-2·year-1 (Saunders and Andrews 1994); a P/B of 0.8, and a Q/B of 4.76 year-1 were taken from Venier and Kelson (1996). The diet composition was, as well, taken from Venier and Kelson (1996), but modified to reflect that the demersal fish box in that model consisted of a large group of dissimilar fish. Values for the diet composition entered into the model were: 15% herring and small pelagics, 60%

Table 2. Skate stomach contents from five samples from eastern Atlantic. Samples are from five tows[a].

	% wet weight (g)					
Prey	1	2	3	4	5	Mean
Crabs	0.65	0.35	0.30	0.35	0.30	0.39
Invertebrates	0.05	0.10	0.50	0.25	0.50	0.28
Fish	0.28	0.50	0.15	0.35	0.15	0.29
Others	0.02	0.05	0.05	0.05	0.05	0.04

[a] from Robichaud *et al.* 1986, (sp=*Raja radiata*)

macrobenthos, and 25% zooplankton.

Juvenile/adult sablefish (*Anoplopoma fimbria*)

All input parameters for this group remained as in the southern B.C shelf model (Livingston 1996), except for the diet composition, for which the predation on zooplankton was increased by 16% for juveniles and 5% for adults. This increase was done in order to reflect the absence of hake in the system.

Herring (*Clupea harengus pallasi*) and other small pelagics

The herring fishery in B.C. is second in commercial importance only to the salmon fishery, and indeed if one considers that it is a single species fishery, it becomes the most important by far (M.C. Healey, UBC, pers. comm.). There is a thriving fishery for herring in the Hecate Strait, where some year -round resident populations exist, and these may be separate stocks (Hay *et al.* 1986). The swelling of the gonads in the winter months may reduce feeding rates, due to gut volume constraints (Hay *et al.* 1986). herring may also exist in a predator-prey system with Pacific cod (Walters *et al.* 1986).

Biomass is estimated every year, although the methodology is dependent on back calculation of year strength, and rests upon the accuracy of an assumed fishing rate, which is generally set for a low risk option (M. C. Healey, UBC, pers. comm.). Research into other methods that would provide more reliable estimates of biomass, including hydroacoustic methods (Hay *et al.* 1986) and a particle-size spectrum estimation method (Dunbrack and Ware 1986) has been carried out. Results of these preliminary experimental models were unclear whether the estimates were more accurate or precise than the back calculation method, although the particle-size method provided similar results to the back calculation method (Dunbrack and Ware 1986). Estimate from the particle size spectrum analysis were 76,000 t, while Haist *et al.* (1985) estimated a value of 88,000 t for the same year using the traditional method.

Relatively little is known about other small pelagics in the region, other than that the group may include anchovies, eulachons, other smelts and sandlance. It is likely that these would be an important component in the diet of many other species, including Harbour porpoise (Trites and Heise 1996), Pacific halibut (Venier 1996), and some bird species (Wada and Kelson 1996); they and are therefore included in the 'herring' box.

Because this box includes other small pelagics for which there is little information, input parameters for this box were left the same as for the southern B.C shelf model, and the model was allowed to estimate the biomass. This allows for the estimates of the biomass of herring to act as a lower limit to the allowable biomass during the ECOPATH run.

Carnivorous jellies

No information was found for this group in the Hecate Strait region. All input parameters remained the same as for the southern B.C shelf model (Arai 1986).

Macrobenthos

This box is the result of an extreme aggregation, as noted above. Consequently, it has a high biomass and is subject to predation from a variety of other groups, including itself. Burd and Brinkhurst (1987) conducted a study on the macrobenthic infauna of the Hecate Strait. Their results (Table 3) indicated that polychaetes, bivalves and amphipods were the most abundant groups, in descending order, for all areas sampled. Individual areas differed significantly in species composition, due to differences in bottom type. Very deep stations sampled had very low biomass, possibly indicating limited water circulation.

The biomass of all taxa were averaged over the three areas, and averaged 3.94 g·m^{-2}. This is very similar to the 40 t·km-2·year-1; thus, no change was made to the biomass of this box. All other input parameters remained as in the southern B.C shelf model (Jarre-Teichmann and Guénette 1996), or as calculated by the manual aggregation performed by the ECOPATH software.

Table 3. Biomass estimates of fourteen macrobenthic infaunal species from the Hecate Strait.

Taxa	Cruise # 1 (t·km^{-1})	Cruise # 2 (t·km^{-1})	Cruise # 3 (t·km^{-1})	Mean (t·km^{-1})
Nemertea	15	683	7	235
Polychaeta	275	1222	814	770
Gastropoda	42	682	1849	858
Pelecypoda	878	70	95	348
Scaphopoda	12	1	10	8
Ostracoda	-	-	3	1
Cumacea	-	38	26	21
Isopoda	8	44	1	18
Amphipoda	13	1	1	5
Decapoda	8	4	80	30
Sipunculidae	7	10	3	7
Ophiuroidea	232	8	220	153
Echinoidea	2	41	568	203
Holothuroidea	125	-	3	43

Juvenile salmon (*Oncorhynchus* spp.)

Juvenile salmon make use of the Hecate Strait as a migratory pathway and as a nursery ground (Healey 1986). Depending on different assumptions about juvenile migratory behavior, the population would be dominated by pink salmon, followed by chum and sockeye (Healey 1986), with Coho and Chinook relatively minor or non-existent components of the system. The biomass of juveniles present in the Hecate Strait can thus vary widely (Table 4), as can the Q/B value required to support the population. For the purpose of this study, the biomass and Q/B were taken as the averages of the high and low model. A P/B/ estimate was obtained from Buckworth (1996), set at 0.75·year^{-1}.

Table 5 (Healey 1991) shows the diet composition for three species of juvenile salmon. In general, the diet was dominated by aescids, followed by euphausiids, and copepods. For the purpose of this model, the diet of juvenile salmon was set at 100% Zooplankton.

Table 4. Summary of biomass estimates and Q/B for a low and high model of juvenile salmon species usage of the Hecate Strait[a].

Species	Biomass (t x 10^3) low	Biomass high	Biomass Mean	t·km^{-2}	Consumption (t x 10^3) low	Consumption high	Consumption mean	Q/B
Sockeye	0.66	95.47	48.07	1.045	0.05	5.80	2.93	0.061
Pink[b]	3.60	101.42	52.51	1.142	0.72	10.51	5.62	0.107
Pink[c]	11.72	111.20	61.46	1.336	2.33	14.36	8.35	0.136
Chum	3.50	56.90	30.20	0.657	0.48	5.16	2.82	0.093
Coho	4.46	11.03	7.74	0.168	0.51	5.74	3.13	0.404
Chinook	1.01	6.15	3.58	0.078	0.13	0.45	0.29	0.081
			Sum= 4.425			Mean Q/B=		0.147

[a]data from Healey (1986)

[b]predictions are for odd year runs

[c]predictions are for even year runs

Pacific Ocean Perch (POP, *Sebastes alutus*)

The trawl fishery is the largest commercial fishery in British Columbia, by weight, although in the study area defined here, the total of Pacific salmon species catches are higher. POP is in turn the largest single species landed in the trawl fishery, and is the rockfish species that is best understood. POP stock assessments are often used by DFO as guidelines by which other quotas are set, for instance the TAC for the shortspine thornyhead is set at 10% of the TAC for POP, based on historical landing data (Richards 1994). In 1997-1998, the TAC for POP was set for 2,818 t in area 5C/5D,

Table 5. Diet composition for three juvenile salmon species in the Hecate Strait, over the years 1986-87. Note that all diet items represent zooplankton species[a].

Prey taxa	Pink (% volume)			Chum (% volume)			Sockeye (% volume)		
	1986	1987	Mean	1986	1987	Mean	1986	1987	Mean
Euphasiid	10.00	20.20	15.10	10.20	4.40	7.30	29.40	21.00	25.20
Calanoida	2.20	26.20	14.20	1.90	20.90	11.40	2.80	36.10	19.45
Brachyura	0.60	23.70	12.15	0.40	1.00	0.70	0.30	5.80	3.05
Pinotheridae	-	1.30	0.65	-	0.10	0.05	-	0.60	0.30
Crangonidae	-	0.10	0.05	-	-	-	-	0.40	0.20
Hyppolytidae	-	-	-	0.10	-	0.05	0.20	-	0.10
Hyperiidae	0.30	1.90	1.10	3.90	2.60	3.25	4.90	2.10	3.50
Cirripedia	5.10	0.70	2.90	-	0.20	0.10	-	0.20	0.10
Pteropoda	0.20	7.50	3.85	-	3.60	1.80	-	3.80	1.90
Polychaeta	-	0.30	0.15	-	-	-	-	0.50	0.25
Gastropoda	-	0.30	0.15	-	-	-	-	0.10	0.05
Ascidiacea	-	16.60	8.30	81.10	64.30	72.70	59.80	27.40	43.60
Chaetognatha	80.40	0.10	40.25	-	0.30	0.15	0.30	-	0.15
Fish larvae	0.90	0.90	0.90	2.00	2.00	2.00	2.10	1.30	1.70
Miscellaneous	0.30	0.20	0.25	0.40	0.60	0.50	0.20	0.70	0.45

greater than 50% of the total rockfish quota of 5,200 t. (DFO 1996) The trawl and hook and line fishery split the quotas at 76% and 24% respectively. In the Hecate Strait area, the majority of trawl catches of POP are from the southern area, and come from the Moresby Gully stock, which straddles our boundaries (author's pers. obs). In the DFO landings database, however, the catches from just south of our area are counted as coming from area 5C. These catches have been assumed to come from area 5C for the purposes of this model as well

Surprisingly for such an important species, there are few published data. Estimates of biomass come from Richards (1995), who estimated a total biomass of 25,200 t, for a value of 0.549 $t \cdot km^{-2} \cdot year^{-1}$. The data for estimating P/B are from Richards (1995), and assume that F=M=0.05, for a P/B of 0.1 year-1. Q/B is set at 3.44 $year^{-1}$ (Buckworth 1996). Diet composition (Table 6) was drawn from several sources, and is set at 89.4% zooplankton, 8.1% crustaceans, and 2.5% macrobenthos.

Rockfish/ Small Benthic Fish

This group was treated the same as the herring and small pelagics box, and includes the majority of sculpins, for which little information exists. Thus, this box is likely over-aggregated. Data for P/B and Q/B were set as for POP. The biomass was left unknown, for the model to generate, and the EE was set at 0.95. Diet composition (Table 6) is set at 4.8% crustaceans, 7% macrobenthos, and 91% zooplankton.

Flatfish

As for rockfish and POP, several flatfish species are heavily targeted in the Hecate Strait area, most notably english sole, dover sole and rock sole (author's pers. obs). They are included in this model for that reason. Published data for this species are difficult to find. Biomass was taken from Fargo *et al.* (1990), and represents a combined total for six species of flatfish, including english, dover, petrale, rex and rock soles, as well as the Pacific sanddab. The value thus obtained is 2.83 $t \cdot km^{-2} \cdot year^{-1}$. Values for P/B = 0.975 (0.4-1.15) and Q/B =3.21 $year^{-1}$ were found in Venier and Kelson (1996). No studies on diet composition for any of the flatfish species were found, except that Hart (1973) suggested that various flatfish species (here combined) eat clams and clam siphons, small

Table 6. Averaged diet composition of several rockfish species, with the diet for the Pacific Ocean Perch (POP) considered separately.

Prey	rockfish[a,b,c] (% volume)	POP[c] (% wet wt)
Crustaceans	0.048	0.084
Euphasiids	0.511	0.841
Copepods	0.392	0.043
Amphipods	0.004	0.010
Larvacae	0.003	0.000
Fish	0.035	0.000
Miscellaneous	0.007	0.025

[a] data from Lorz *et al.* (1983)

[b] data from Reilly *et al.* (1992)

[c] data from Brodeur and Pearcy (1984)

molluscs, small crabs, shrimps, and brittle stars. For the purposes of this model, the diet is set at 100% macrobenthos.

Turbot (*Atheresthes stomias*)

turbot are ubiquitous in the trawl fishery (author's pers. obs.) but until recently, with the introduction of IVQ's and area specific quotas in the fishery, they were considered a 'nuisance' or 'trash' species and generally discarded at-sea. Available data indicate, however, that the species has a high biomass (Fargo *et al.* 1981). Such a high biomass suggests that exclusion of this species from any ecosystem model of the Hecate Strait area must introduce some bias. Only one published source for turbot was found however, which included the biomass estimate, but no other data. The biomass was set at 0. t·km^{-2}·year^{-1}. The P/B and Q/B values used were the same reported for flatfish in general by Venier and Kelsonx (1996). No information was found on diet composition. Based on the physical structure of the mouth and gills and personal field observations, their diet was preliminarily set at 10% ratfish/skates, 20% juvenile sablefish, 20% crustaceans, 40% macrobenthos, and 5% zooplankton and rockfish/small benthic fish. Further information is needed for this group.

Lingcod (*Ophiodon elongatus*)

Lingcod in the Hecate Strait region have the advantage of being far away from most large population centres in British Columbia. As a result, they have not been heavily fished until recent years (McFarlane and Leaman 1996). The group is included here both because it is an important predator of many species, but also because it may be of future interest to compare the results of this model to others developed, for example the Strait of Georgia and the southern B.C shelf model. Both of these models are nearer to larger population centres and have experienced higher fishing pressures for longer. A biomass for this species was calculated using historical catch data from McFarlane and Leaman (1996) entered into a model developed by Martell (this vol.). The biomass calculated was 0.065 t·km^{-2}·year^{-1}. P/B, and Q/B are from Venier and Kelson (1996), their values are as follows: P/B = 0.58 (0.4-0.76); Q/B=3.3 year^{-1}. Diet composition changes as the lingcod grows, during early stages of the life cycle lingcod prey on zooplankton and crustaceans, as they mature they switch to herring, sandlance, pollock, cod and flounders (Forrester 1969). The diet composition entered into the model 29% herring, 15% crustaceans, 12% macrobenthos, 4% herring, 12% flatfish, 12% turbot, 4% spiny dogfish and 4% cannibalism.

Fishery harvests

Fishery catch data were acquired from the Department Fisheries and Ocean's (DFO) B.C. Commercial catches statistics database. The data covered the years from 1990-1995, and the catches reported in Table 7 represent average values over those years, as entered in the model. The catch rates for certain groups, such as the Macrobenthos, are aggregates of different fisheries (*i.e.,* geoduck, sea urchin, sea cucumber).

For most fisheries, however, reported landings underestimate the actual numbers or weight of each species caught (Alverson *et al.* 1994). The underestimation is due to the discards at sea not being reported or being under-reported. Buchary (1996) reported discards rates of 22% for targeted species and a ratio of 2.21 (discarded bycatch to landed catch) for non-target species. The figure for targeted species is based upon a faulty analysis, as the actual discard rates for targeted species are much lower (Table 8).

Table 9 is an adaptation of the one used by Buchary (1996) in order to determine discard rates in the trawl fishery. The higher value for discard rates for targeted species results from the inclusion of data for what historically, and for the most part presently, were by-catch species for the trawl fleet, including the redstripe rockfish, the sharpchin rockfish, sablefish, hake (not fished as a directed fishery except in the summer months), spiny dogfish (bycatch except for a small fishery in the Strait of Georgia), turbot, and skate. High reported discard/landed ratios for these species introduced significant bias to the overall reported average for target species.

Table 7. Reported landings for the Hecate Strait (statistical areas 5C/D).

Groups	Catch ($t \cdot km^{-2}$)
Macrobenthos	0.104
Crustaceans	0.041
Dogfish	0.004
Ratfish/Skates	0.004
Pacific cod	0.056
Herring/Sm Pelagics	0.130
Walleye pollock	0.011
Adult sablefish	0.013
POP	0.056
Rockfish	0.039
Flatfish	0.062
Halibut	0.027
Turbot	0.012
Lingcod	0.011

Reanalysis of the data presented in Tables 8 and 9 is revealing. Note that the reported values in Table 8 are for the summer months, while Table 9 is for the winter months. Hake is fished exclusively in the summer months,

Table 8. Catch and discard data for targeted species of the B.C. trawl fleet for April - July 1998. Neither the amount (tkm-1) nor the proportion of discards to landings were large enough to be entered as values in ECOPATH (<0.001), except for dogfish, for which the discard/landings ratio was 6%. Note that hake makes up the largest proportion of the catch. '-' indicates no data. (Source: DFO catch statistics)

Species	TAC (t)			Retained catch (t)			Discards (t)	Discard/
	5C/D	Others	Total	5C/D	Other	Total	All areas	landings
Rockfish, misc[a]	1,413	13,872	15,285	197	2,277	2,474	3	0.001
P.O. perch	2,817	3,330	6,147	999	1,110	2,109	1	0.000
Flatfish, misc[a]	2,730	3,675	6,405	327	478	805	2	0.002
Pacific cod[a]	1,000	954	1,954	405	48	453	0	0.000
Lingcod[a]	580	1,920	2,500	14	173	187	0	0.000
Spiny dogfish	-	5,440	5,440	-	98	98	6	0.061
Sablefish	-	386	386	-	88	88	1	0.011
Walleye pollock[a]	825	2,905	3,730	6	3	9	0	0.000
Pacific hake	-	84,687	84,687	-	10,498	10,498	0	0.000
Total	**9,365**	**117,169**	**126,534**	**1,948**	**14,773**	**16,721**	**13**	**0.001**
Total (no hake)	**9,365**	**32,482**	**41,847**	**1,948**	**4,275**	**6,223**	**13**	**0.002**

[a]data for 5C/D also includes area 5E for some species within groups

when almost the entire total allowable catch (TAC) is fished (indeed, often overfished) with a near zero rate of discard. The very low value is partly due to gear type (midwater gear as opposed to bottom gear), but also because Hake are caught in such quantities that entire cod-ends are passed whole to foreign vessels in the Joint-Venture fishery, or split directly into the holds without being picked through by the crew (for quality or size etc.) in the domestic shore-based fishery. The result is that all species caught are processed to either fillets or fishmeal, except for dogfish. The by-catch of dogfish in this fishery is very high, but (for the purpose of quota management) the vessels retain and land all of it in the Joint-Venture fishery. In contrast, and assuming all other things being equal, in the shore-based domestic hake fishery large dogfish catches are discarded at sea, likely without reporting or under reporting. It would be sensible to average discard rates for these species over the whole year.

The behaviour of the fishers may contribute to some of the difference between the two tables. In the intervening period between the collection of the data, DFO introduced a new management strategy for the fishery, based on an individual vessel quota (IVQ). Under the IVQ system, each vessel was given a quota for nearly every species of fish, either within a specific area or coastwide, including bycatch species. Exceeding the quota had consequences: the vessel would no longer be able to use bottom gear within the area for which the quota was exceeded unless it acquired more quota. The economic consequences were severe to a vessel that did exceed its quota, as only three choices are available: pay for more quota, do not fish some quota with a real value, or sell quota for an area. As a result, it is likely vessels began avoiding areas with higher bycatch levels in favour of cleaner catches in other areas whenever possible. An example of such a behavioral change is shown below.

Table 10 shows the discard rates for non-target species, grouped according to the functional groups used in this model. Note that the discarded proportion over this period (discarded biomass/[landed + discarded]) for turbot is 0.34; the biomass column gives a total amount of discards for a twelve month period. The rate is about half of the rate for 1996 (0.709). This can be attributed directly to the positive change in value of turbot to the fishers, as a consequence of both the costs of merely discarding it and of declining TACs for other species. The latter results in

Table 9. Discard rates for species caught in the B.C. trawl fishery for a 30 day period in February - May 1996.[a]

Groups	Retained catch (t)		Estimate/	Discarded at sea (t)			Released/
	At sea estimate	Landed	landed	Marketable Dead	Marketable Alive	Unmarketable (Dead and live)	retained
Rockfish	4,463	4,542	0.98	5.81	0.00	170	0.04
Flatfish	1,254	1,254	1.00	1.08	5.69	131	0.11
Turbot	921	775	1.19	0.00	0.05	653	0.84
Sablefish	38	37	1.01	4.43	17.33	45	1.78
Pacific cod	133	129	1.03	0.13	0.23	7	0.06
Lingcod	179	252	0.71	0.19	1.66	5	0.03
Spiny dogfish	64	62	1.03	0.00	0.00	547	8.82
Skate	67	117	0.58	0.00	0.00	112	0.96
Pacfic hake	3	2	1.61	0.00	0.00	35	16.84
Walleye pollock	450	492	0.92	0.00	0.00	41	0.08

adapted from Buchary (1996)

fishers targeting the previously underutilized species.

Several conclusions can be arrived at from the above data. Thus, discard rates for targeted species in the trawl fishery are quite low. Also, discard rates for non-targeted species are much higher, as much as several orders of magnitude. The rates for individual groups vary drastically, however, from as low as 0.37 for rockfish too as high as 38 for ratfish. Finally, it is important for persons with knowledge of a fishery to verify estimates of discard rates. For the purpose of this model, the discards from Table 10 are included in the basic input.

Table 10. Catch and discard data for non-target species in the B.C. trawl fishery for the period April - July 1998. Note that discard ratios may be several orders of magnitude higher than for targeted species, and that it is not legal for trawlers to retain herring. '-' indicates either no data available, or value too small (<0.001) to be displayed.

Species	Total at-sea estimate (t)	Retained catch (t)		Estimate/ landed	Discarded at sea (t)			Discards/ landed
		At - sea estimate	Landed		Marketable	Unmarketable (Dead and live)	Total t/km^2	
Anemone (general)	1	-	-	-	-	1	-	-
Crabs	1	-	-	-	-	1	-	-
Flatfish	137	43	55	15.27	-	93	0.002	1.71
Grenadier	27	-	-	-	0.01	27	0.001	-
Pacific herring	8	-	-	0.28	-	8	-	36.61
Ratfish	86	-	2	0.08	-	86	0.002	37.98
Rockfish	246	173	197	5.24	0.23	73	0.002	0.37
Skate	169	57	96	9.84	-	112	0.002	1.17
Squid	1	-	-	-	-	1	-	-
Turbot	2,557	1,896	1,936	0.98	-	660	0.014	0.34
Total (for species <1000)	**676**	**273-**	**350-**	-	**0.24-**	**1062**	-	-
Total (all groups)	**3,233**	**2,170**	**2,286**	**0.95**	**0.24**	**1,064**	**0.139**	**0.47**

Results and Discussion

Table A (Appendix II) shows the basic parameter estimates and trophic levels as calculated by ECOPATH, and Table C (Appendix II) shows the diet matrix used in the balanced model. Figure 2 shows a graphic version of the model.

As this model is entirely preliminary, I will not attempt a detailed analysis of it at this time.

Balancing the Model

The initial run of the model was surprisingly successful, with only three groups having EE values of greater than 1: Pacific cod (EE=18.4), herring/small pelagic (EE=2.4), and Flatfish (EE=1.1). Dalsgaard and Pauly (1997) identified two approaches to balancing an ECOPATH model: a subjective approach, based on identifying input parameters deemed to be questionable and modifying them according to personal knowledge until balance is achieved; and a rigorous approach, using the Ecoranger utility. This utility, through a Monte-Carlo approach and interpreted within a Bayesian context, identifies the likely values for input parameters. The latter requires more knowledge of the system than available here; therefore the former approach was taken to balance the model.

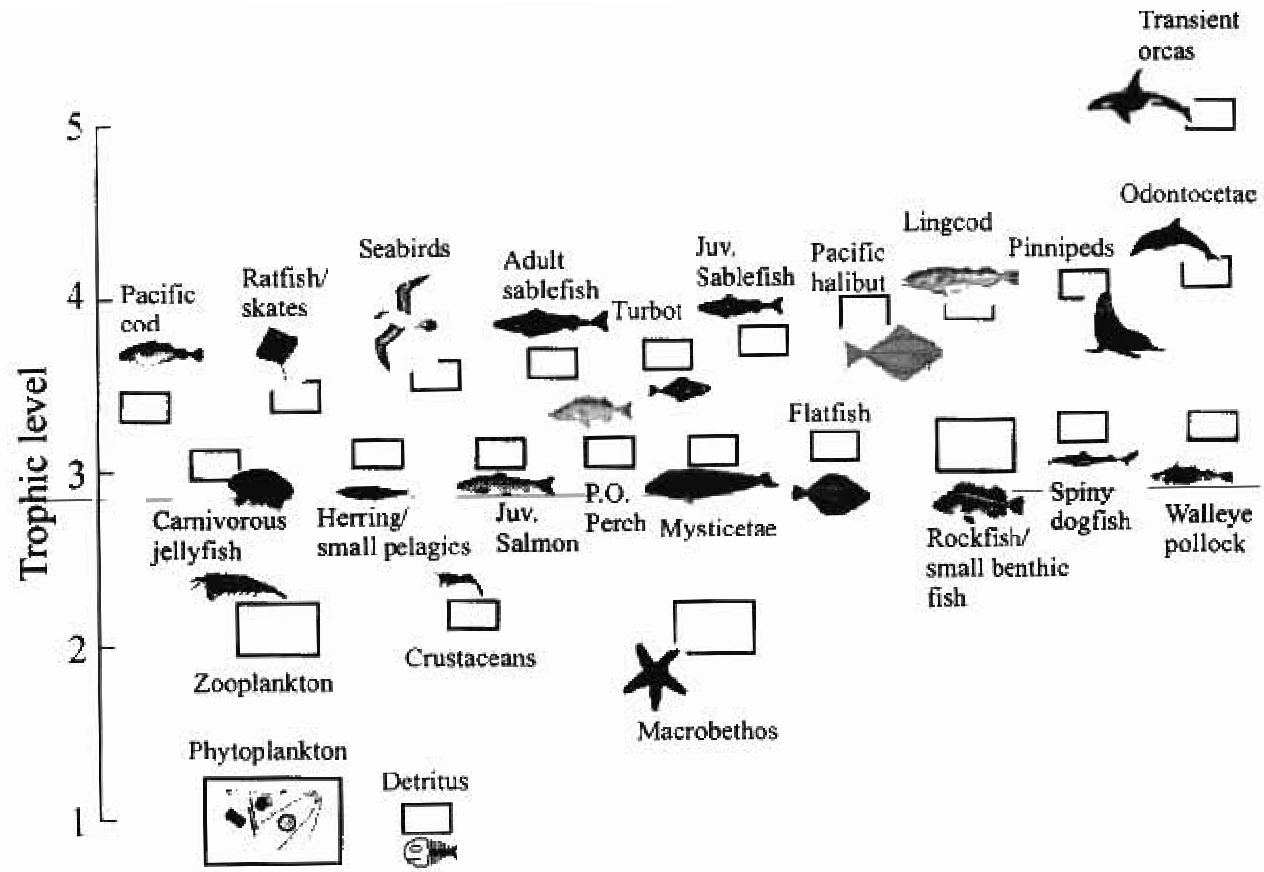

Figure 2. Pictorial representation of the trophic flow diagram produced by ECOPATH, for the present day model. For comparison, this flow diagram and the diagram for the 100 year model are scaled to the same size, using the size of the phytoplankton box as a guide (values did not change between models).

However, very little other than the diet compositions needed to be changed in order to balance the model:

1. The EE for the herring/Small pelagics box was changed to a value of 0.98, to reduce their calculated biomass. Otherwise, the biomass continued to be estimated by the ECOPATH software.

2. The biomass of turbot was increased to the high range, from 0.709 – 1.13 $t \cdot km^{-2} \cdot year^{-1}$. This was done to reflect the probable role it plays in the diets of other species, to reduce the diet pressure placed on other species, and as a reflection of the uncertainty in the biology of the species or of the role it plays in ecosystems.

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References

Alverson, D.L., M.H. Freeburg, S.A. Murawski and J.G. Pope 1994. A global assessment of fishery and discards. FAO Fish. Tech. Pap. 339, 233 p.

Arai, M., 1996. Carnivorous jellies. p. 39-40. *In:* D. Pauly and V. Christensen (eds.) Mass-balance models of Northeastern Pacific ecosystems: Fisheries Centre Res. Rep. 4(1).

Brodeur, R.D. and W.G. Pearcy, 1984. Food habits and dietary overlap of some shelf rockfishes (genus *Sebastes*) from the Northeastern Pacific Ocean. Fish. Bull. 82(2): 269-293

Brinkhurst, R.O., B.J. Burd and D.F. Moore, 1986. Distribution and abundance of benthos in relation to demersal fishes. *In:* A.V. Tyler (ed.) Hecate Strait Project: results from four years of multi-species fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1675.

Buchary, E. 1996. Fisheries catches. p. 57-59. *In:* D. Pauly, D. and V. Christensen (eds.) Mass-balance models of North-eastern Pacific ecosystems. Centre Res. Rep. 4(1).

Buckworth, R. 1996. The pelagic "box". p. 67-69. *In:* D. Pauly, D. and V. Christensen (Eds.), 1996. Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1).

Burd, B.J. and R.O. Brinkhurst, 1987. Macrobenthic infauna from Hecate Strait, British Columbia. Can. Tech. Rep. Ocean. Sci. No. 88:123 p

Cooney, R.T. 1984. Some thoughts on the Alaska coastal current as a feeding habitat for juvenile salmon, p. 256-258. *In:* W.G. Pearcy (ed.). The influence of ocean conditions on the production of salmonids in the North Pacific. Oregon State University Press.

Dalsgaard, J. and D. Pauly. 1997. Preliminary mass-balance model of Prince William Sound Alaska, for the pre-spill period, 1980-1989. Fish. Centre Res. Rep. 5 (2): 33 p.

DFO, 1996. The groundfish trawl fishery management plan. 25 p.

Dunbrack, R. and D.M. Ware, 1986. Particle size spectrum estimation of the standing stock of pelagic fish. *In:* A.V. Tyler (ed.) Hecate Strait project: results of the first two years of multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1470

Fargo, J. A.V. Tyler and R.P. Foucher. 1990. Distribution of demersal fishes in Hecate Strait, British Columbia, based on systematic trawl surveys conducted from 1984-1987. Can. Tech. Rep. Fish. Aquat. Sci. No. 1745

Fargo, J. L. A. Lapi, J.L. Richards and M. Stocker. 1981. turbot biomass survey of Hecate Strait, June 9-20, 1980. Can. Man. rep. Fish. Aquat. Sci. No. 1630. iii + 84 p

Forrester, C.R. 1969. Life history information of some Canadian groundfish. Fish. Res. Board Can. Tech. Rep. 105. 17 p

Hart, J.L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Board Can. 180. 741 p.

Hay, D., R. Keiser and P.B. McCarter, 1986. Distribution of herring in winter pp. 11-16. *In:* A.V. Tyler (ed.). Hecate Strait project: results of the first two years of multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1470

Haist, V., J.F. Schweigart and M. Stocker, 1985. Summary of 1985 herring stock assessments. PSARC Working Paper H85-7, 31 p.

Healey, M.C. 1986. Modeling juvenile salmon utilization of Hecate Strait. *In:* A.V. Tyler (ed.) Hecate Strait Project: results of the first two years of multi-species fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1470.

Healey, M.C. 1991. Diets and feeding rates of juvenile Pink, Chum, and Sockeye salmon in Hecate Strait, British Columbia. Trans. Am. Fish. Soc. 120:303-318

Jarre-Teichmann, A. and S. Guénette, 1996. Invertebrate benthos, p. .38-39. *In:* D. Pauly and V. Christensen (Eds.), 1996. Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1).

Livingston, P. 1996. Pacific cod and sablefishx, p. 41-42. *In:* D. Paulyx and V. Christensen (eds.). Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1).

Lorz, H.V., W.G. Pearcy and M. Fraidenburg, 1983. Notes on the feeding habits of the yellowtail rockfish, *Sebastes flavidus*, off Washington and in Queen Charlotte Sound. Calif. Fish. Game 69(1): 33-38

McFarlane, G.A. and B.M. Leaman 1996. Offshore lingcodx stock assessment and recommended yield options for 1997. PSARC Working Paper G96-2.

Pauly, D. and V. Christensen (Editors), 1996. Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1).

Pauly, D., M. Soriano-Bartz and M.L. Palomares. 1993. Improved construction, Parameterization and interpretation of steady-state ecosystem models. In: V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26.

Polovina, J. 1986. Spiny dogfish. p. 45. *In:* D. Pauly and V. Christensen (eds.), 1996. Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1).

Reilly, C.A., T.W. Echeverria and S. Ralston, 1992. Interannual variation and overlap in the diets of pelagic juvenile rockfish (Genus: *Sebastes*) off central California. Fish. Bull. 90:505-515

Richards, L.J. 1994. Trip limits, catch, and effort in the British Columbia rockfish trawl fishery. North Amer. J. Fish. Mgmt. 14:742-750

Richards, L.J. 1995. Slope rockfish assessments for 1995 and recommended yields options for 1996. PSARC Working Paper G95-9.

Robichaud, D. A., Bailey, R.J.F. and R.W. Elner. 1986. The predatory behavior of cod (*Gadus morhua*) and skate (*Raja radiata*) on crab species (*Chionoecetes opilio, Hyas araneus*, and *H. coarctatus*). ICES C.M. 1986/G: 47.

Saunders, M.W. and W. Andrews, 1994. Walleye stock assessment for 1994 and recommended yield options for 1995. PSARC Working Paper G94-8.

Simenstad, C.A., B.S. Miller, C.F. Nyblade, K. Thornburgh, and L. Bledsoe, 1979. Food web relationships of Northern Puget Sound and the Strait of Juan de Fuca: A synthesis of the available knowledge. University of Washington Press.

Trites, A. and K. Heise, 1996. Marine Mammals. P. 25-30. *In:* D. Pauly and V. Christensen (eds.). Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1): 16-36.

Tyler, A.V. 1986. Hecate Strait Project: Results of the first two years of

An Annotated List of Tsimshian (Sm'algyax) Words Pertaining to the Marine Ecosystem

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Abstract

Recently there has been a trend to incorporate into science the traditional ecological knowledge (TEK) of First Nations in Canada. This in turn has created a need for cross validation between the two. Bridging the language barriers between scientists and First Nations will contribute toward this cross-validation. One initial step in this process is to catalogue and annotate the terms used by the local people to describe the flora and fauna of a given area. Such word lists can then give historical clues about species diversity and abundance. This contribution annotates a list of previously published Tsimshian words that are relevant to the marine ecosystem. The words are arranged into the following groups: fish, fish-related, marine plants, invertebrates, birds, mammals, and general fishing terms.

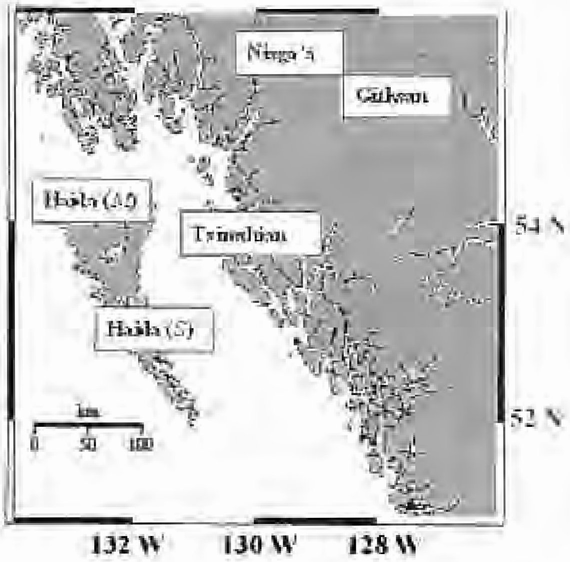

Figure 1. Map of the British Columbia coast showing the approximate location of the Tsimshian, Nisgz'a and Gitksan. The locations of Haida dialects are also shown ('*S*' = Skidegate, '*M*' =, see Jones, this volume).

Introduction

Scientists have a long history of ignoring the knowledge and observations of First Nations people. Though First Nations groups have occupied their territories for thousands of years, their observations of the land and/or ocean often have been dismissed as mere stories or myths. Recently, however, a trend to incorporate the traditional ecological knowledge (TEK) of First Nations people into the corpus of scientific knowledge has established itself.

Most notably, it has become obvious that TEK can be an invaluable source of information when trying to piece together historic trends of species abundance and distribution. The initial step to tap into this vast resource of knowledge is to catalogue and annotate the terms used by the local people to describe the flora and fauna of a given area (see e.g., Danko 1998, Jones, this vol., Preikshot and Leer 1998). Such a catalogue, when annotated with information pertaining to abundance, distribution, and behavior of organisms, can be a useful source of qualitative information to supplement scientific study.

Presently, scientific studies concern themselves mainly with well-documented quantitative facts and figures. In many cases, however, comparing recent trends with historical conditions requires that qualitative local knowledge is available. Archaeological evidence shows that the Tsimshian have occupied some coastal sites for over ten thousand years (Seguin1985). Consequently, much information has been passed on orally, not stored electronically or published. Thus, a lack of quantitative information should not be seen as a hindrance, but rather an opportunity to incorporate local TEK into science. Pauly *et al.* (1998) used this approach to model the Strait of Georgia as it might have been 100 and 500 years ago. This approach allowed for a more complete picture of the ecosystem, wherein its evolution was considered rather than just a snapshot in time.

TEK is also useful to track trends for single species. Historical inventories for local areas can be compiled in scientific databases such as Fishbase (Froese and Pauly 1998) so that trends in species distribution or diet may be seen. For instance, the Tsimshian people have one word, 'gaksaa', for both blue and hammerhead sharks (Dunn 1978). While blue sharks occur off the coast of British Columbia (Hart 1973), reports of hammerheads occurring in our waters could not be found in other sources. It is unlikely that the hammerhead could be confused with any other shark species due to its distinctively shaped head. If the possible occurrence of hammerheads in British Columbian waters is then reported in Fishbase, TEK is then transformed into a scientific format.

The Tsimshian language family encompasses four related groups: the Nisga'a, along the Nass River; the Gitksan, on the Upper Skeena; the Coast Tsimshian, along the lower Skeena and adjacent coast; and the Southern Tsimshian, on the coast and southern islands. Out of these four groups arose two languages, Nass-Gitksan and Coast Tsimshian (Haplin and Seguin 1990). This paper focuses only on the Coast Tsimshian language. The relative position of the territories of the Gitksan, Nisga'a, Tsimshian, and Haida (see Jones, this vol.) can be seen in Fig. 1.

The following list of Tsimshian words was adapted from Dunn (1978), who presented Tsimshian words in both Roman and phonetic characters. The latter are omitted here. The terms that were extracted were chosen based on their relevance to the marine ecosystem, and then grouped according to the following: fish names, fish terms, marine plants, invertebrates, birds, mammals, and general fishing terms. Whenever possible, each term is annotated. The reference number column refers to the word number in Dunn (1978).

The Dictionary

Fish names

TERM	TSIMSHIAN	REFERENCE
Black bass (Pacific sea bass) – B.C. fishers usually refer to the black rockfish (*Sebastes melanops*) when they use black bass.	Gakgak	293.1
Black cod - also known as sablefish (*Anoplopoma fimbria*)	Hadani	
Bullhead - cabezon, sculpin, sea raven, muddler (*Hemitripterus americanus, Myoxocephalus octodecemspinosus, Scorpaenichthys marmoratus*, and *Cottus bairdi*)	k'ayeet	
Chinook salmon - spring or king salmon (*Oncorhynchus tshawytscha*)	yee	
Chum salmon - dog salmon (*Oncorhynchus keta*)	Gayniis	
Old chum salmon (*Oncorhynchus keta*)	Ⱡgum'yee	
Coho salmon - silver salmon (*Oncorhynchus kisutch*)	wüüx, waak,üük	2002; 2018; 2123
Coho salmon turned red (*Oncorhynchus kisutch*)	Ksihoon	965
Pink salmon - humpback salmon (*Oncorhynchus gorbuscha*)	sti'moon	1764
Pygmy salmon (*Oncorhynchus nerka*)	ts'üwaas	1980
Pygmy sockeye salmon (*Oncorhynchus nerka*)	ts'üwaasmmüsoo	1981
Sockeye salmon - red salmon (*Oncorhynchus nerka*)	Müsoo	1456
Sockeye - male in red phase (*Oncorhynchus nerka*)	Gyi'aȽ	582
Flounder - may refer to several members of the family Pleuronectidae	Daxs	203
Golden shiner minnow (*Notemigonus crysoleucas*)	t'axt'oosk	
Grey cod - probably referring to the Pacific cod (*Gadus macrocephalus*)	K'awts	
Hake (*Merluccius productus*)	Balaas	134
Ling cod (*Ophiodon elongatus*)	Wa'tuk	2071
Oolachan – candlefish (*Thaleichthys pacificus*)	Haalmmoot, haldm'oot, \`wah	644; 707; 2045
Pacific halibut (*Hippoglossus stenolepsis*)	Txaw	1896
Pacific herring (*Clupea harengus pallasi*)	skah, tskah	1725; 1941

Rainbow trout/ Steelhead trout (*Oncorhynchus mykiss*)	meliit	
ratfish - angel fish, chimaera (*Hydrolagus colliei*)	Guumaa	502
Red snapper - red cod (*Sebastes ruberrimus*)	ts'mhon	
Shark - blue and hammerhead (*Prionace glauca* and *Sphyrna lewini*)	ksaa	
Skate, ray - could be the big skate (*Raja binoculata*) or the longnose skate (*R. rhina*)	gandah, k'andah	388; 878
Starry flounder (*Platichthys stellatus*)	kbidaxs, xbidaxs	900; 2136
Tommy cod (*Microgadus proximus*)	K'awts	
Wolf eel – Dunn (1978) notes "not *Anarchichas lupus* but a local common name for the eel". (*A. lupus* is the Atlantic wolf eel). Dunn *may* mean that the Sm'algyax word does *not* refer to the wolf eel, but to some other fish).	gyibawmts'm'aks	
Eel - it is unclear which species of eel this word refers to, but probably the Pacific wolf eel, *Anarrhichthys ocellatus.*	lo'k, lo'ox	184; 1192

Fish-related terms

Anal fin	geesk	461
Dorsal fin	nee'k	
Caudal fin	Na'tsiks	1517
Soft dorsal fin	Haas	
Pectoral fin	ts'muuhoon, waayt	1965; 2041
Ventral fin	waayt	2041
Dried fish	Gnsmhoon, luunüksmhoon	471
Dried fish belly	k'ak'wiikws	
Dried fish nose	gagok, nagaoxt	325, 1482
Half-dried salmon	Ksits'al	972
Female fish	Laanmhoon	1071
Fish- an old one	Dzalee	246
Fish brains	Gagox	325.2
Fish eggs	Laan	1070
Fish heart	Goopn	

Fish scales	Siksxan	1669
Fish slime	YeŁ	2232
Fish sperm	loo	1185
herring eggs	Xs'waanx	2190
Male fish	Loomhoon	1188
Roe	laan	1070
Salmon for smoking	ts'aal	1900
Salmon - split open and dried	Dzigaws	257
Salmon stomach	k'wiinti	1013

Marine plants

Alaria algae (*Alaria* spp.)	Dayts	207
Dried sea weed	p'I'iŁosk	1598
Enteromorpha algae (*Enteromorpha* spp.)	Ła'ask	1273
Fucus algae (*Fucus gardneri*)	p'aatsah	1587
Gigartina algae (*Gigartina* spp.)	Gadzakeew	316
Grinnella algae (*Grinnella* spp.)	Gyoos	637
Kelp- the kelp forests of the Pacific northwest are made up of giant kelp (*Macrocystis integrifolia*) and bull kelp (*Nereocystis luetkeana*)	mok	1436
Phosphorescent algae	adaaŁn, biwaatk	27; 161

Invertebrates

Abalone (*Haliotis kamtschatkana*)	Bilhaa	159
Barnacles - a species of either genus *Semibalanus* or *Balanus*	ts'maay	1948
Black katy chiton - sea prune, possibly referring to the black chiton (*Katharina tunicata*)	Yaanst	221
Butter clam (*Saxidomus gigantea*)	sam'k	1645
Clam - members of the class Bivalvia	ts'a'a	1898
Clam siphon	Gants'iit	405
Crab - most likely referring to the Dungeness crab (*Cancer magister*), but may also include the red rock crab (*C. productus*)	Galmoos	361

Crow chiton - hairy *Mopalia* (*Mopalia hindsii*)	Yensagawgaw	
Giant Pacific octopus (*Octopus dofleini*)	Xbihats'al	2137
Devil fish – local common name for octopus (*Octopus dofleini*)	Hats'al	777; 2137
Giant squid (*Dosidicus gigas*)	Xbihats'al	
Horse clam (*Tresus capax*)	Loon	189
Isopods - referring to order Isopoda (Crustacean) with approximately 10,000 species	sts'oolalop	767
Metridium anemone - member of the class Anthozoa	Masxayloop	
Mussel - most likely the blue mussel (*Mytilus edulis*)	Gyels	571
Oyster - Pacific oyster (*Crassostrea gigas*)	Hagwn	678
Sand dollar - sea urchin (*Strongylocentrotus droebachiensis*)	asuun	107
Scallop – could be the spiny scallop (*Chlamys hastata*), rock scallop (*Crassadoma gigantea*), pink scallop (*C. rubida*), or the weathervane scallop (*Patinopectea caurinus*)	k'aȽ'an, 'nȽgabuus	874; 1547
Sea anemone – members of the class *Anthozoa*	Daga'aw	186
Sea cucumber - members of the class Holothuroidea	Gyenti	
Sea urchin - describes three species – *Arbacia punctulata, Strongylocentrotus franciscanus,* and *Echinometra lucunter*	Dzügwiits	
Shipworm (*Bankia setacea*)	GyiwaȽgn	
Spider crab	k'almoosgmlaxsga'niis	873
Starfish - members of the class Asteroidea	Gamaats	370

Birds

Black duck - referring to either the white-winged scoter (*Melanitta fusca*) or the surf scoter (*M. perspicillata*)	Amgyiik	79
Bufflehead (*Bucephala albeola*)	Waal'k	
Common scoter - also known as black scoter (*Melanitta nigra*)	Ahoo	43
Coot - probably the American coot (*Fulica americana*)	Amgyiik	79

Cormorant - three species of cormorants are present in Hecate Strait: the double crested cormorant (*Phalacrocorax auritusi*), pelagic cormorant (*P. pelagicus*), and Brandt's cormorant (*P. penicillatus*)	hawts	
Duck	ann'aneex	92
Eagle - most likely the bald eagle (*Haliaeetus leucocephalus*)	Xsgyiik	
Goose - probably Canada goose (*Branta canadensis*)	ha'a, Łi'win	641; 1329
Harlequin duck (*Histrionicus histrionicus*)	K'agaa	861
Kingfisher - probably the Belted kingfisher (*Ceryle alcyon*)	ts'iyoolgy	1940
Mallard duck (*Anas platyrhynchos*)	na'na	1508
Sandhill crane (*Grus canadensis*)	k̲'a̲sk̲oos	886
Sandpiper - could be referring to any of the members of the genus *Calidris*	ts'iiŁ	
Sawbill duck - could refer to the Common merganser (*Mergus merganser*) or the red breasted merganser (*M. serrator*)	Łgümiik	1314
Sea gull - there are five species of gulls found in Hecate Strait: the mew gull (*Larus canus*), glaucus gull (*L. hyperboreus*), herring gull (*L. argentatus*), glaucus winged gull (*L. glaucescens*), and Thayer's gull (*L. thayeri*)	G̲agoom	326
Sparrow - referring to members of the family Emberizidae	Güsgüüts	
Tree duck - golden eyed sea duck, viz. Common goldeneye (*Bucephala clangula*) and Barrows goldeneye (*B. islandica*)	ts'as	
Western black oyster catcher (*Haematopus bachmani*)	GyedmŁ	567
Wood duck - same as Tree duck	ts'as	1923
Wren - referring to members of the family Troglodytidae	güsgüüts, ts'a̲pts'ap, waaxs	500; 1922; 2040

Mammals

Blackfish - Killer whale (*Orcinus orca*)	`NaaxŁ	

Dolphin, porpoise – may refer to Pacific white sided dolphin (*Lagenorhynchus obliquidens*), Dall's porpoise (*Phocoenoides dalli*) or Harbour porpoise (*Phocoena phocoena*)	dziiw	
Grizzly bear (*Ursus arctos*)	Midiik	
Polar bear (*Ursus maritimus*)	Moksgm'ol	1439
River otter, Land otter (*Lutra canadensis*)	Watsa	
Sea otter (*Enhydra lutris*)	PŁoon	1603
Sea lion - probably referring to Steller sea lions (*Eumetopias jubatus*)	t'iibm	1845
Baby seal	k'a'ootk	880
Elephant seal (*Mirounga angustirostris*)	Badzit'ool	132
Fur seal (*Callorhinus ursinus*)	k'oon	938
Harbour seal (*Phoca vitulina*)	Uula	2003
Hooded seal (*Cystophora cristata*)	Badzit'ool	132
Snout of a bull hooded seal	t'ool	1872
Pregnant seal	WiniiŁk	
Seal fur	k'oon	938
Sea monster	hagwilo'ox, hala'lox	677; 704
Shore animal	Amgyeek	78
Walrus - may be referring to *Odobenus rosmarus*	t'iibm	1845
Whale	Łbuun	1295

General Fishing Terms

Catch fish, catch fish with a net	aadmhon, 'mak,	5; 1384
Catch salmon when they are red and in freshwater	xgüüs	2146
Coast Tsimshian language	sm'algyax	1727
Nass-Gitksan language	gaalmx, gyaanmx	284; 560
Cut salmon for smoking	ts'aal	1900
Fish-boiled whole	Tkadzemsk	1852
Fish basket	ts'ükts'alaa	1917
Fish trap	t'iin	1850
Fish trap-horseshoe rock trap	luulp	1253
Fish trap-weir trap	amsahoon, nisahoon	85; 1540

Fish weir	DzeeyeȽ, dziis	253; 261
Fisherman	aadit, huk'at	4; 816
Fishing ground (an owned place for fishing)	Nahoon	1489
Flood tide	Leeks'aaks	1135
High tide	ditxaks, wagagyik	220; 2043
Low tide	Wagagyik	2043
Zero-tide	Lugawsga'aaks	1203
Go ashore	DzagmdaawȽ	243
halibut boat	saxs uumtxaw	1653
halibut hook	nuu, t'a'awil, yügah	1568; 1822; 2240
Harpoon barb/point	naatsk	
Harpoon shaft	Sgank'yiin	1674
herring rake	K'yideh	1050
Hunt on the water	woo	2100
Ocean floor	s'yaan	1812
Offshore wind	Uksbaask	1989
Onshore wind	Dzogmbaask	269
Oolachan grease	Smk'awtsi	1738
Oolachan net	T'agaaȽ	1823
Open ocean	gyaaks	559
Oyster cutter	GyedmȽ	567
River	k'ala'aks	867
Nass river	Klusms	907
Head of a river	Magoon	1378
Salt water	moon	1445
Sand bar	Laxhuu	1110
Scoop net	bana	136
Sea shell	NȽts'iik	1549
Seine	ga'aat	
Seine boat	saxs labagayt se'kya	1652
Squall	gatgyetgabaask, sba'ala	422; 2132
Troll	magon, umhon	1377; 1998

Discussion

This list of Tsimshian terms is not exhaustive, at least in part due to the method in which the dictionary was constructed. As a linguist, Dunn may not have been able to gather words for species he was unfamiliar with. Thus, the list of Tsimshian terms contains relatively few words for some groups, such as marine invertebrates and plants. Furthermore, a few of the words are used to describe several species belonging to the same class or genera. For example, there is only one word to describe sea cucumbers despite the occurrence of 34 species in the waters from southern Alaska to southern British Columbia (Lambert 1997).

Variability in the use of common names may also have presented a problem for this list of Tsimshian words. Local populations tend to give local names to organisms (see also Jones, this vol.). For instance, the Tsimshian now describe the species *Oncorhynchus nerka* by a variety of English common names: sockeye salmon, red salmon, blueback salmon, and pygmy salmon. With so many common names occurring within a relatively small geographical area, it may have been confusing as to which species was actually being referred to. Lumping of different species into one common name also appears to have been a problem. Thus, Tsimshian uses the same word for squid and octopus, and for both sea lion and walrus. For all intents and purposes, these species may have been perceived as being the same in terms of function, i.e., it is the 'cephalopod' that is perceived. It is hard to believe that people who relied heavily on nature's resources would not be able to distinguish two different species.

What is not surprising about the list of words is the large number of species for which there are names. The early Coast Tsimshian people relied heavily on the sea for resources. The majority of species listed in the dictionary are those that were commonly caught for food and ceremonial purposes, or those that were economically exploited. Thus, it is not surprising that many words exist for activities and species belonging to the marine ecosystem. The natural cycle of species available for exploitation throughout the year dictated the timing of the activities for the people. Traditional foods such as fish, shellfish, herring, Oolachan, and seaweed that are harvested locally and consumed in the household still comprise the majority of the diet for the people (Inglis *et al.* 1990). Traditional harvesting sites are still being used to gather these marine and river resources.

The Tsimshian's close relationship with the land and sea is prevalent in our mythology where animals are able to transform themselves into human form and vice versa. From this belief came a deep respect for human interactions with animals. A reciprocal relationship, where other organisms are treated respectfully, developed so that both humans and animals can benefit. For instance, if the remains of animals were not treated properly, the human form of the animal, which has returned to its hidden village, will suffer (Miller and Eastman 1984). Similar rules for fish have also been described by Boas (1916) who states that the Tsimshian believed that it was necessary to drink water after eating fish so that the fish can be revived again and go home gladly. Men would also have to go through a ritual in which they purified themselves before going fishing or hunting. The ritual included fasting, bathing, drinking the juice of the root of the devil's club (*Oplopanax horridus*), and sexual continence. This purification was seen as necessary because an unclean person was thought to offend animals that would then refuse to allow themselves to be caught.

Tsimshian people have inhabited the northern coast of British Columbia for thousands of years. Therefore, the language contains words that describe all aspects of the local environment. The language is somewhat biased in the sense that the local abundance and diversity of organisms influenced the development of the language. This local bias is a benefit for scientists that wish to study historical ecosystems where published data may be non-existent. Bridging the language barrier between scientists and First Nations will lead to the cross-referencing of TEK and science.

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References

Boas, F. 1916. Tsimshian Mythology. *In*: W. LaBarre (ed). 1970. Landmarks in Anthropology: a series of reprints cultural anthropology. Johnson Reprint Corporation, 1037 pp.

Danko, J.P. 1998. Fish Related Terms From the Saanich Language. p. 29-33. *In:* D. Pauly, T. Pitcher and D. Preikshot (eds.) Back to the Future: Reconstructing the Strait of Georgia ecosystem. Fisheries Center Research Reports, Vol. 6(5).

Dunn, J.A. 1978. A Practical Dictionary of the Coast Tsimshian Language. National Museums of Canada, Ottawa. Canadian Ethnology Service Paper No. 42.

Froese, R. and D. Pauly (Editors). 1998. Fishbase 98: concepts, design and data sources. ICLARM, Manila, Philippines. 293 p.

Haplin, M.M. and M. Seguin 1990. Tsimshian Peoples: Southern Tsimshian, Coast Tsimshian, Nishga, and Gitksan.P.267-284. *In*: W. Suttles (ed.) Handbook of North American Indians Volume 7: Northwest Coast. Smithsonian Institution.

Hart, J.L. 1973. Pacific Fishes of Canada. Fish. Res. Board Can. Bull. 180. 740 p.

Inglis, G.B., D.R. Hudson, B.R. Rigsby and B. Rigsby, 1990. Tsimshian of British Columbia Since 1900. p. 285-293. *In* W. Suttles (ed.) Handbook of North American Indians Volume 7: Northwest Coast. Smithsonian Institution.

Lambert, P. 1997. Sea Cucumbers of British Columbia, Southeast Alaska and Puget Sound. Royal British Columbia Museum Handbook. UBC Press, Vancouver. 166 p.

Miller, J. and Eastman, C.M. (Editors). 1984. The Tsimshian and Their Neighbors of the North Pacific Coast. University of Washington Press, 343 p.

Pauly, D., T. Pitcher, and D. Preikshot (Editors). 1998. Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Center Research Reports, Vol. 6(5).

Preikshot, D., and J. Leer 1998. An Annotated List of Alutiiq Words Relevant to Modeling the Prince William Sound Ecosystem. p. 92-108. *In*: Okey, T.A., and D. Pauly (eds.). Trophic Mass-Balance Model of Alaska's Prince William Sound Ecosystem, for the Post-Spill Period 1994-1996. Fisheries Center Research Reports. 6(4).

Seguin, M. 1985. Interpretive Contexts for Traditional and Current Coast Tsimshian Feasts. National Museums of Canada. Canadian Ethnology Service Paper No. 98.

Haida Names and Utilization of Common Fish and Marine Mammals

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Haida Gwaii

Abstract

Names can be an important source of embedded cultural and biological information about species. This paper provides a list of Haida names and a brief summary of Haida knowledge about common fish and marine mammals from a variety of sources. The two main dialects of Haida from the Haida Gwaii region (British Columbia, Canada) are considered: the Skidegate dialect, and the Masset dialect. Where available, notes on the method of catch and preparation are included, as is the cultural significance of some species.

Introduction

The preparation of this paper was fraught with difficulties. Information on historical Haida resource use is scattered throughout the published and unpublished literature and is neither extensive nor complete. Despite this, some valuable accounts do exist. In particular, two researchers recorded information from Haida elders in the 1970s. These accounts are (1) unpublished work on the Skidegate Haida by David W. Ellis, who relied on Solomon Wilson as his primary source[1]; and (2) Margaret Blackman's (1979) work with several Massett elders including Florence Davidson, Percy Brown, William Russ Sr., Emma Matthews and Amanda Edgars.

Unfortunately, early investigators did not focus on Haida usage of natural resources, although there are some notable exceptions. George M. Dawson provided some information on the more important food resources used by the Haida in the 1880s (Dawson 1880). John R. Swanton's ethnographic studies provided limited information on Haida resource use (Swanton 1905a), but the Haida oral history that he recorded provides insight into the traditional use of many species. Other potential sources of information from archives exist, such as C.F. Newcombe's field notes from the 1880s; however these have not yet been reviewed.

Another difficulty in preparing this paper was providing a consistent transcription of Haida words. Linguists have developed a variety of systems to write Haida (e.g., Enrico 1991). Haida has three main dialects – Skidegate, Masset and Alaska – in which words may be similar but differences are common (see Figure 1, in Watkinson, this vol., for approximate locations). A dictionary has been developed for Alaskan Haida (Swanton 1905a) and one is currently in development for Skidegate Haida (see footnote 2). The spelling of Skidegate words was provided by the Skidegate Haida Immersion School[2]. Some characteristics of the Skidegate writing system are:

Underlined characters (_) refer to a glotallized consonant;

A single quotation mark (') refers to an explosive sound;

The number **7** refers to a glottal stop.

A variety of sounds do not occur in English, including t', k', k̲, g̲, tl, tl', dl, x and x̲. The spelling of Masset Haida words is from Blackman (1979) which used a modified version of the international phonetic alphabet. She notes that she is not trained as a linguist, thus her rendition of Haida words may in some cases be phonetically incorrect. Unless otherwise noted, Skidegate terms were obtained from Ellis and Wilson (see footnote 1) and Masset words were obtained from Blackman (1979).

Some mention of the Haida system for control and management of resource harvesting areas is important. Rivers and

[1] Recording by Solomon Wilson and David W. Ellis, copies stored at the Canadian Museum of Civilization, Ottawa, and the Queen Charlotte Islands Museum, Skidegate. 30 minutes. October 21, 1974.

[2] Skidegate Haida Immersion School, School District #50, Queen Charlotte City, Haida Gwai. Spelling and translation of Skidegate words provided on January 8th, 1999.

streams were owned by Haida families (Blackman 1979, Dawson 1880, Swanton 1905a). Blackman (1979) recorded the ownership of streams by northern Haida lineages as recalled by Haida elders in the 1970s. Lineages also controlled other resource sites, such as berrypicking grounds and beaches for beachcombing whales. The author was told a story by Henry Geddes of Massett indicating lineage control of green sea urchin beds. Furthermore, at least some sites in the open ocean may have been lineage property, for example Swanton (1905a) remarked that "The halibut fishing grounds were all named and were owned by certain families". This account contrasts with Blackman (1979), who reported being told by Massett Haida that halibut fishing grounds were open to anyone with a boat and fishing line.

Description by Animal Group or Species

Descriptions are organized with the Haida name and dialect in the first column (Note that (S) = Skidegate dialect and (M) = Massett), followed by the meaning of the Haida word (if known), a description of the fishing technology and utilization of the species or group.

The dictionary

Fish

chiina (S) *chin (M)*	Solomon Wilson said *chiina* refers to fish from both fresh and saltwater that are found near the surface and are believed to "breathe air". Masset sources said *chin* was a general name for salmon (Blackman 1979).
sk'aagii (S) *sk'aga (M)*	Chum salmon (*Oncorhynchus keta*). Chum salmon were the most important salmon species to the early Haida because of their abundance, ready accessibility and preservative qualities (Jones and Lefaux-Valentine 1991; Blackman 1979). Chum, pink and coho were captured in the streams when they returned to spawn using traps made of boulders or saplings, nets, spears or gaffs (see footnote 1, Jones and Lefaux-Valentine 1991; Blackman 1979; Dawson 1880; Swanton 1905a; Acheson and Zacharius 1985; Stewart 1977; Langdon 1977). Food preparation was similar for most salmon species with the fillets, heads and roe generally being utilized (Jones and Lefaux-Valentine 1991). A single, wide fillet was usually prepared by splitting the fish along the backbone and leaving the belly intact. Thin slices were trimmed from the sides of the fillet that were dried separately and called *ts'ilgi (S)* or *tch'ilts (M)*. In the old days, fillets were preserved by a process of cold-smoking and drying in a smokehouse for approximately 10 days. Chum fillets were tied in bundles of 40 and could be kept in bent-wood cedar storage boxes for up to a year. The backbones were also smoke-dried. Heads were eaten fresh after boiling or aged in intertidal pits lined with seaweed and covered with rocks. Before eating, fillets could be rinsed in water and barbecued over an open fire or soaked in salt water and then boiled. Fresh eggs could be eaten raw or boiled with seaweed. Sometimes eggs were lightly smoked and roasted over a fire. 'Stink eggs' were prepared by placing the eggs in a bent-wood cedar box lined with skunk

cabbage leaves and covered with black mud and left until they became clear. Eggs could also be smoked, then pounded and stored in a container. Eggs were also fermented in a seal stomach that was hung in the house by the smoke hole until very dry. Glue could be made by chewing chum salmon skin and storing the liquid in a small container.

ts'iit'aan (*S*)

Pink salmon (*O. gorbuscha*). Pink salmon were not utilized as much as chum due to their earlier run timing, smaller size and a higher fat content that decreased shelf life (Jones and Lefaux-Valentine 1991). Fillets were often sun-dried because the runs returned in August when the weather was generally drier. Fillets were also half-smoked but would only keep only about four months. Fresh, bright pinks are still frequently used in *jum*, or fish stew. The small heads, tails and backbones were generally not utilized.

tyaayii (*S*)
t'aiya (*M*)

Coho salmon (*O. kisutch*). 'Jacks' or small precocious males that return to spawn were referred to as *ts'iidu* (*S*). The last run of coho in November was referred to as *Gaayda dahlgyang* which means 'needlefish in belly of coho' (see footnote 2). Coho returning in January or February were referred to as *ts'iing k'ii ga* which means 'sharp tooth' (see footnote 2). At Copper River, coho were taken using spears with a detachable barb that was attached by a line to the middle of the shaft (Jones and Lefaux-Valentine 1991). Coho were one of the most abundant salmon species at Cape Ball and were of special importance to the Haida of that area. Fresh coho were an esteemed food (Jones and Lefaux-Valentine 1991). Coho fillets and *ts'ilgi* would only keep about three months, because of the high fat content. Coho eggs were separated, soaked in freshwater until hard and white, and then pounded to a soft butter-like consistency. They were not considered suitable to make stink eggs. Milt from male coho were sometimes added to *jum* (fish stew).

taaxiid or *sgwaagaan* (*S*)
swagan (*M*)

Sockeye salmon (*O. nerka*). *Taxiid* referred to sockeye which return to local rivers, Copper River and Mathers Creek, in the spring (April to July). *Sgwaagaan* refers to common sockeye which are caught in the summer. *Taaxiid*, also known locally as 'blueback' were the first fresh salmon of the season and fishing rights in streams were carefully guarded. It was said that a trap owned by Chief Skidegate on the Copper River would catch one of the salmon species or steelhead all but ten days of the year (Jones and Lefaux-Valentine 1991). At one time gillnets made from fireweed fibre were used to catch sockeye on the Copper River (Jones and Lefaux-Valentine 1991). Sockeye were preserved and stored in boxes for the winter. Fresh sockeye heads, backbone and roe were commonly cooked by boiling. The roe was sometimes smoked. Sockeye *ts'ilgii* are a highly prized delicacy. Most Haida Gwaii sockeye streams are fished with gillnets and the Haida Fisheries Program develops annual management plans in consultation with Canada's Department of

Fisheries and Oceans (DFO), operates a counting fence and fish trap on the Copper River, samples smolts and participates in lake hydroacoustic assessments to assess fry numbers.

taagun (*S*)
t'aown (*M*)

Chinook salmon (*O. tsawytscha*). *Taagun gaaw gaada* (*S*) refers to 'white spring' and *taagun gaaw sg'iida* (*S*) refers to 'red spring'. The Haida utilized both migrating chinook found in tidal waters and a local stock on the Yakoun River. Haida use of chinook salmon prior to development of the commercial fishery at the turn of the century is not well documented. Trolling by other northern Indian groups, involved moving a baited hook of wood, bone and twine through the water so as to lure a salmon to strike. Ethnographic accounts of the gear and methods are available for the Tlingit (south-east Alaska) and the Nuu-chah-nulth (west coast of Vancouver Island). More recent accounts were provided for the Alaskan Haida (Langdon 1977, p. 186). Archaeological excavations at Kiusta in Haida Gwaii resulted in finds of bone barbs likely used for fish hooks and salmon vertebrae up to 18 mm in diameter, corresponding to chinook salmon between 30 and 40 pounds in midden deposits dated between 4,380 and 10,435 years of age (N. Gessler, Director of Kiusta excavations, pers. comm.). "Chinook salmon come and hit my heart", a Haida expression used when they are seen jumping, originates from the Haida creation stories where raven lures a chinook salmon into his canoe (see footnote 1, Jones and Lefaux-Valentine 1991, Enrico 1991). Another Haida story described a fisher who catches and sells a large quantity of chinook salmon for a feast (Swanton 1905b). Among the Tsimshian, and likely also the Haida, fresh chinook was considered 'rich food' which was essential for maintaining the dignity of the family by possession and distribution at potlatches (Boas 1916).

Chinook salmon were utilized fresh and half-smoked. The heads as well as the eggs were cooked by boiling. The fillets were either sun-dried or lightly smoked and had to be used soon afterwards because of the high fat content and limited shelf life. The Haida were one of the first to become involved in the commercial troll fishery for chinook salmon that began in the late 1800s (Forrester and Forrester 1975).

taatl'aad (*S*)
tatlat (*M*)

Trout (general). The Skidegate term included *t'ak'al* (rainbow and cutthroat trout) and *sidu* ("sea trout" found in saltwater), but not steelhead (Jones and Lefaux-Valentine 1991). Trout were caught in fish traps and were also fished with a noose (Enrico 1991, p.161). Dragonfly larvae or *sk'aadaasgwaal* were used as bait for catching trout and *maaluu* (see footnote 2).

maaluu (*S*)

This term refers to both freshwater salmon and trout fry (see footnote 1).

taayingaa (*S*)

Steelhead trout (*O. mykiss*). Steelhead were taken in fish traps,

taiyung (*M*)	and were frequently the only catch taken in the Copper River (Jones and Lefaux-Valentine 1991). Steelhead were considered closely related to red snapper because the bones of both fish were so tough (Jones and Lefaux-Valentine 1991, Blackman 1979).
sk'aahlaa (*S*)	This was the general name for bottomfish or those fish that "don't breathe air" (see footnote 1).
k'aaxada a7wga (*S*)	This was the general name for a large shark. The literal meaning is "dogfish mother". Stranded or moribund sharks were utilized for oil from their liver (Dawson 1880).
7uwii guuga (*S*)	Soupfin shark (*Galeorhinus zyopterus*). Soupfin shark were fished commercially for their liver and vitamin oils in the mid to late 1940s.
sliina nang gyuugings (*S*)	Sixgill shark (*Hexanchus griseus*). The literal meaning is "wearing gut ear rings."
k'aaxada (*S*) *q'ad* (*M*)	Spiny dogfish (*Squalus acanthias*). Utilized for oil from their livers which was sold to white traders (Dawson 1880). Also, the dogfish was the crest of the *Yaaku 7laanas* (Middle town people) and *Kyanuusilee* ([tom]cod people), two Haida Raven lineages (Swanton 1905a).
ts'iidga (*S*) *ch'iida* (*M*)	Skate (*Raja sp.*) Not eaten (Blackman 1979). A crest of the *Git7ins* of Tsiits, a Haida eagle lineage (Swanton 1905a).
k'aa 7un (*S*)	Ratfish (*Hydrolagus colliei*)
7iinang (*S*) *iinang* (*M*)	Herring (*Clupea harengus pallasi*). When used as an adjective, the Haida name means "plentiful". Also, it may be a compound word derived from *ii* (to have sexual intercourse) and *nang* (play). Traditionally it was caught using a herring rake, a light pole six to eight feet in length with sharpened nails driven through one end, and used for halibut bait. Nets were also used at one time (Gessler, N., Director of Kiusta excavations, pers. comm., also see Enrico 1991, p.173). Herring eggs or *k'aaw* were harvested on kelp and hemlock branches (Enrico 1991, p.84). It was sometimes picked from other substrate such as eelgrass and eaten on the spot. If weather permitted, *k'aaw* was sun-dried on a gravel beach. If dried indoors, drying was slower and the product was poorer quality. Dried fronds were tied into bundles of about ten and stored in bent-wood boxes. Dried *k'aaw* was susceptible to insect damage and turned brown and lost flavour. It was eaten dried or soaked in fresh water, then dipped in boiling water or fried. It is often eaten with eulachon oil or *hum* (*S*).
kiina (*S*) *qaian* (*M*	Surf smelt (*Hypomesus pretiosus pretiosus,* see footnote 1). Reported to be taken using a rake (Blackman 1979). The literal meeting in Skidegate Haida is "heavy" (Skidegate Haida Immersion School).

gaaydaa (*S*)	Capelin (*Mallotus villosus*) or sand lance (*Ammodytes hexapterus*)
saaw (*S*)	Eulachon (*Thaleichthys pacificus*) or Pacific sardine (*Sardinops sagax*). Dried and smoked eulachon and eulachon grease or *hum* (*S*) were obtained in trade with the Coast Tsimshian.
st'aaydaay (*S*)	Pacific cod (*Gadus macrocephalus*). The literal meaning was "chin whiskers" (see footnote 2).
gaadaa (*S*)	Shiner perch (*Cymatogaster aggregata*). The literal meaning is "white" (see footnote 2).
7uusduu (*S*) *k'aay kuul kyaadsiid* (*S*)	Striped perch (*Embiotoca lateralis*). Pile perch (*Rhacochilus vacca*). The Haida name means "searchers of the bottom of the kelp" (see footnote 1).
st'aaxaam (*S*)	Wolf eel (*Anarrhichthys ocellatus*). Also refers generally to any blenny (see footnote 1)
sgan (*S*) *s'aan* (*M*)	Yelloweye rockfish (*Sebastes ruberrimus*). Haida usage of rockfish was considerable, particularly of yelloweye rockfish (Jones and Lefaux-Valentine 1991). Rrockfish were caught using light kelp lines or spears. Rockfish were allowed to age for several days before they were scaled, cut into chunks and boiled. rockfish were eaten fresh and not usually preserved (see footnote 1). However, lingcod have been said to be dried and traded with halibut to Mainland First Nations. The head was also cooked by boiling and eaten. *Sgan Gwaii* (*S*) (or Anthony Island), which means Yelloweye Island, is well known for the abundance of this rockfish. It was said that yelloweye could be taken by the people of Skedans in the lee of Skedans Islands in any time of weather. They were also fished outside the sealion rocks at North Island and in Masset Inlet. The eggs were boiled and had a similar consistency to porridge.
k'itsgalang or x'asaa (*S*) *qaja* (*M*)	Black rockfish (*Sebastes melanops*). The name means "hard" and it is considered a really proud fish because it will not take just any kind of bait. They were caught on hooks similar to halibut hooks, but smaller. Found in kelp beds. Eaten fresh, not preserved. (Jones and Lefaux-Valentine 1991)
skun g'wiidsxuldan (*S*)	Quillback rockfish (*Sebastes maliger*).
xaadxadaay or taayii (*S*) *hat'* (*M*)	Copper rockfish (*Sebastes caurinus*). The name means "white" in Masset dialect (Blackman 1979)
k'aa (*S*)	Canary rockfish (*Sebastes pinniger*).
k'aalts'iida (*S*)	An unidentified rockfish. The literal meaning is "crow" (see footnote 2).
st'iiydiiy (*S*)	An unidentified rockfish (see footnote 1).
skil (*S*) *sqEl* (*M*)	Sablefish or black cod (*Anoplopoma fibria*). Immature sablefish are referred to as *sqiitl'aaga* (*S*). Haida use and fishing methods were recounted by Solomon Wilson and recorded by David W. Ellis (see footnote 1). Since sablefish live at great depth, their

capture by the early Haida required a great deal of technological skill as well as physical effort. Fishing was done in winter using 150 to 200 fathom kelp lines (see the halibut section for care and handling of lines). Special hooks were constructed from a spruce tree knot. A rock anchor was used. As fish were hooked, they knocked out the sticks holding the bait that could be counted on the surface. The lines broke easily if chafed on the gunwale of the canoe. Lines and hooks were individually owned and the crew shared the catch accordingly. The fish were gutted and the head and backbone removed. The stomach and gills were often saved and boiled with seaweed. After soaking overnight, the fish were boiled in bent-wood cedar box with hot rocks and the oil skimmed off. Oil was also extracted by wrapping the boiled meat in spruce root sacks and squeezing them between two boards. The boiled meat was also consumed. In the Englefield Bay area, blackcod were taken mainly for their oil, which was a valuable trade item not only with the mainland Indian tribes but also with Haida from other areas of Haida Gwaii who did not have access to sablefish. The eggs were also eaten and could be preserved by drying. In northern Haida Gwaii, sablefish were a preferred food that was sometimes caught and was sliced and smoked for winter use and highly valued for its oil (see footnote 1). Swan obtained samples of sablefish at Skidegate Village (Swan 1885). A saltery for sablefish was established in Englefield Bay for a short time about 1890.

kiijii (S) — Greenling (Hexagrammidae).

kits (M) — Probably whitespotted greenling. Fished off Tow Hill and *kits chai (M)*, the spawn, is found on seaweed in August. Neither the fish nor its spawn were preserved but were eaten fresh. (Blackman 1979).

skaynung (S)
sqoiinan (M) — lingcod (*Opiodon elongatus*) (see footnote 1, Jones and Lefaux-Valentine 1991; Blackman 1979). The nickname, *sgaagaay (S)*, means 'shaman dance' and refers to the way a shaman shakes his head when dancing (Skidegate Haida Immersion School). lingcod and inshore rockfish were taken with special spears and lines. People at Tanu village often speared lingcod and rockfish close to the local kelpbeds. lingcod eggs were reported eaten in Skidegate but not in Massett (see footnote 1; Jones and Lefaux-Valentine 1991).

hl'aama (S) — Bullhead or sculpin (Fam. Cottidae) Referred to by Ellis as bullhead (see footnote 1). It is a crest for several Haida eagle lineages (Swanton 1905a).

k'aal (S)
q'al (M) — Identified by Solomon Wilson as Buffalo sculpin (*Enophrys bison*) or Brown Irish Lord (*Hemilepidotus spinosus*) and described to David Ellis as "bullhead without horns" (see footnote 1). In Masset the term was described to Blackman as the name for several species of sculpin. Florence Davidson stated that they were not eaten, though Percy Brown noted that the

giant sculpins were taken with *hlskujiit* (*M*), a two or three pronged rake or fork. (Blackman 1979).

7wagwahlagaay — An unindentified sculpin. The literal meaning is "bullhead with horns" (see footnote 2).

k̲'aayaay (*S*) — An unidentified sculpin. The literal meaning is "old".

galdaa (*S*) — A large unidentified sculpin that Solomon Wilson described to David Ellis as "good to eat". (see footnote 1).

t'aal (*S*) — Small flounder.

t'al khlugwung (*M*) — Flounder; literally translated the name means "Stay around bottom by big, wide kelp". Taken with *hlkujida,* a long two or three timed fork. Also taken with small hooks. Not preserved, eaten fresh (Blackman 1979)

sg̲an t'aal (*S*) — Lemon sole (*Parophyrys vetulus*). Found in commercial abundance in Skidegate Inlet.

x̲aadlin (*S*) — Starry flounder (*Platichthys stellatus*).

x̲agu (*S and M*) — Pacific halibut (*Hippoglossus stenolepsis*). Information on halibut utilization and fishing technology are from Ellis (Jones and Lefaux-Valentine 1991) unless otherwise noted. halibut were an important staple food and trade item for the Haida, due to its' year-round availability, large size and good preservative qualities. halibut was also an important feast and potlatch food. Many Haida villages were located at exposed, seaward locations which gave ready access to halibut fishing grounds even during the winter. An old Haida saying "When the salmonberries are ripe, the halibut are in the kelp" reflects that halibut are more plentiful in shallow waters during the spring and summer months. halibut were caught using a special wooden halibut hook. The shape of the hook is remarkably similar to 'circle' hooks that were adopted by the commercial longline fishery in the early 1980s as more efficient than the J-shaped hook. In shallow water, fishing lines were made of cedar bark and spruce root while in deep water kelp was used. Kelp lines would last for many years but had to be properly cared for because they easily broke if they rubbed against the edge of a canoe. They had to be properly cured, coiled and stored and were soaked in seawater prior to use. Two hooks were often suspended from the same float, which would stand up when a fish was caught to alert the fishers. In Skidegate, halibut could be fished from the shore and one individual would attach the fishing line to a pole stuck in the ground with a rattle on top that would signal when a fish was caught[3]. An inflated seal stomach was often attached to the line in case a large fish was hooked. Locations where halibut could be caught were called *gyu* (both *S* and *M*) or halibut houses. Swanton indicated that "the halibut bands were all named and owned by certain families" (Swanton 1905a). halibut are large

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James Young, Skidegate. Interview with Russ Jones, August 1998 fish, sometimes often exceeding 50 kgs. Blackman noted that one or two men would generally go out in a medium-sized canoe to take halibut (Blackman 1979). Halibut were bled by cutting and breaking the vertebrae at the tail. Almost every part of the fish was utilized. The head was boiled fresh in *jum* (fish stew). The fish was filleted and fillets were sliced into thin strips that were sun-dried as *ts'ilgi* or sometimes partly smoked. Dried halibut was stored in bent-wood cedar boxes. Dried halibut was eaten after dipping in eulachon or sea mammal oil. The backbone was boiled fresh or preserved by sun-drying or smoking. The skin was usually lightly smoked and dried and eaten after being blistered over the fire. The cheeks, called *xang*, were often smoked and said to be a special food of chiefs. halibut eggs were added to *jum* or barbecued over a fire. Glue would be prepared by chewing the skin around the tail and storing the liquid in a container.

Marine mammals

k'aay (S)
q'ai (M)

Northern Sea lion. Taken at North Island on sea lion rocks known as *q'ai q'adle* ('sea lion island'), and also on the west coast outside the Haida village of Tian. (Blackman 1979). A crest of several Haida raven lineages.

kuu (S)
qo (M)

Sea Otter. Hunted from small canoes or *qothlu* meaning 'sea otter canoe'. Furs were made into capes and worn by high ranking Haida. Sea otter were hunted intensively and depleted in the early 1800s (Blackman 1979)

k'uuwan (S)
k'waan (M)

Northern Fur Seal. Hunted from early spring through summer when these seals migrated northward, passing through Haida Gwaii waters. Hunters "had to go way out to get it". Taken for its fur and for the meat which was brined and smoked dry (Blackman 1979). Fur seal were hunted during their migration and were depleted by about 1900 (Forrester and Forrester 1975).

xuud (S)
x'ot (M)

Harbour seal. Can be taken all year round, but were mainly hunted in wintertime. Seal meat was preserved by smoking and drying. *Xot t'o,* the seal oil, was eaten but not at feasts or potlatches (Blackman 1979).

skul (S)
sqwhul (M)

'Sea porpoise', probably the Dall's Porpoise (Blackman 1979). Percy Brown thought they were hunted with a bow and arrow. One Skidegate story tells about catching porpoise while fishing herring with nets (Enrico 1991, p. 173). The meat was boiled and eaten fresh. *Au sqwhul (M)*, described as an 'Inlet porpoise' (probably the Harbour Porpoise), was not hunted.

sgaana (M)
sqan (M)

Killer whale. Percy Brown identified a second type of *hotgal (M)* Killer whale, which goes up on the beach to die. It was not hunted or economically important. A crest of all the Haida raven lineages (Swanton 1905a).

kun (*S,M*)	Humpback whale. The literature records that the Haida utilized whales found on the beach but did not actively hunt them. However, Percy Brown indicated that humpback whale were taken from *klu inuwe* (a relatively small canoe also used for halibut fishing). The harpooner used a toggle-headed harpoon, *kittu,* made of hemlock. Acheson recorded a high proportion of whale bones at some village sites at the south end of Haida Gwaii that indicated active whaling (Acheson and Wigen 1996).

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The assistance of the Skidegate Haida Immersion School and the instructor, Diane Brown, in reviewing the spelling of words in the Skidegate dialect was much appreciated. Her work greatly enhanced the usefulness of this paper for Skidegate Haida speakers. David W. Ellis's summary of Haida fish use from his unpublished field notes and his tape recording of fish names with Solomon Wilson were invaluable references. Thanks also to Daniel Pauly of the Fisheries Centre, UBC for his encouragement in completing this work.

References

Acheson, S. and R.J. Wigen. 1996. Evidence for a prehistoric whaling tradition among the Haida. Circum-Pacific Prehistory Conference, Seattle. August 1989.

Acheson, S.R. and S. Zacharias. 1985. Kunghit Haida Culture History Project: Results of Phase 1: 1984 Archaeological Site Inventory Permit No. 1984-32.

Blackman, M. 1979. Northern Haida land and resource utilization. P. 43-55. In "Tales of the Queen Charlotte Islands" Regional Council of Senior Citizens of the Queen Charlotte Islands.

Boas, F. 1916. Tsimshian Mythology. *In:* 31st Annual Report of the Bureau of American Ethnology for the Years 1909-1910. Washington: Government Printing Office

Dawson, G.M. 1880. Report on the Queen Charlotte Islands, 1978. Geological Survey of Canada Report of Progress for 1878-79, Vol. 4. Reprinted by UBC Press, 1993.

Enrico, J. 1991. Skidegate Haida Myths and Histories. Collected by J.R. Swanton. Edited and translated by J. Enrico. 212 p.

Forrester, J.E. and A.D. Forrester. 1975. Fishing: British Columbia's Commercial Fishing History. Hancock House. Saanichton, BC. 224 p.

Jones, R.R. and W. Lefeaux-Valentine. 1991. Gwaii Haanas – South Moresby National Park Reserve, Review of Vertebrate Fishery Resources. Prepared for Canadian Parks Service. August 1991. 234 p.

Langdon, S. 1977. Technology, Ecology, and Economy: Fishing Systems in Southeast Alaska. Ph.D. Dissertation, Stanford University.

Stewart, H. 1977. Indian Fishing. J.J. Douglas, North Vancouver, BC. 181 p.

Swan, J. 1885. Report on blackcod of the North Pacific Ocean. Bull. U.S. Fish Comm. (15):225-234.

Swanton, J.R. 1905a. Haida texts and myths: Skidegate dialect. Bureau of American Ethnology Bulletin. Bulletin No. 54

Swanton, J.R. 1905b. Contributions to the Ethnology of the Haida. Publications of the Jesup North Pacific Expedition 5; Memoirs of the American Museum of Natural History, New York 8(1):1-300.

Estimating lingcod Biomass in Hecate Strait Using Stock Reduction Analysis

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Abstract

In this paper an age-structured model and historical catches from the commercial Hecate Strait lingcod fishery are used to reconstruct the present population size. A minimum of 7260 tonnes of lingcod must have been present in 1955 in order to sustain the observed catches between 1956 and 1995. The maximum likelihood estimate for the initial slope of the stock-recruitment curve is 2.3 times greater than the slope through the equilibrium recruitment point. The present lingcod stock in Hecate Strait is approximately 2990 t, or 41 % of the biomass present in 1955. There is no persistent contrast in the catch per unit effort (CPUE) time series, an indication that the fisheries catch statistics do not reflect changes in stock size. It was not possible to estimate an upper bound for the 1955 biomass because the relative abundance time series does not reflect any change in the stock size. Additional fishery-independent data are required to estimate past recruitment anomalies, and to avoid assuming proportionality between CPUE and stock size.

Introduction

Stock Reduction Analysis (SRA) is a method that uses a time series of historical catches to estimate the past stock size required to sustain the observed catches. The important population parameters of interest are the unfished biomass and the initial slope of the stock recruitment curve. Coupled with a time series of relative abundance data (such as CPUE data or survey data), SRA is a useful method for estimating the present day stock size (Kimura and Tagart 1982).

The process of reconstructing the lingcod stock in Hecate Strait is outlined in Fig. 1. The stock parameters contain information pertaining to the biology of lingcod, the size of the stock prior to the fishery, and the productivity of the stock (recruitment parameters). The historical removals are used to drive the dynamic annual changes in the age-structured model. The age-structured model incorporates all of the biology, reproduction, and annual harvest to predict a dynamic set of state variables (e.g., the number of fish in a given year). Using the dynamic state variables predicted by the age-structured model, the observation model generates a set of predicted observations.

A Bayesian approach as used to estimate two important population parameters, the unfished biomass and the initial slope of the stock-recruitment curve after the method

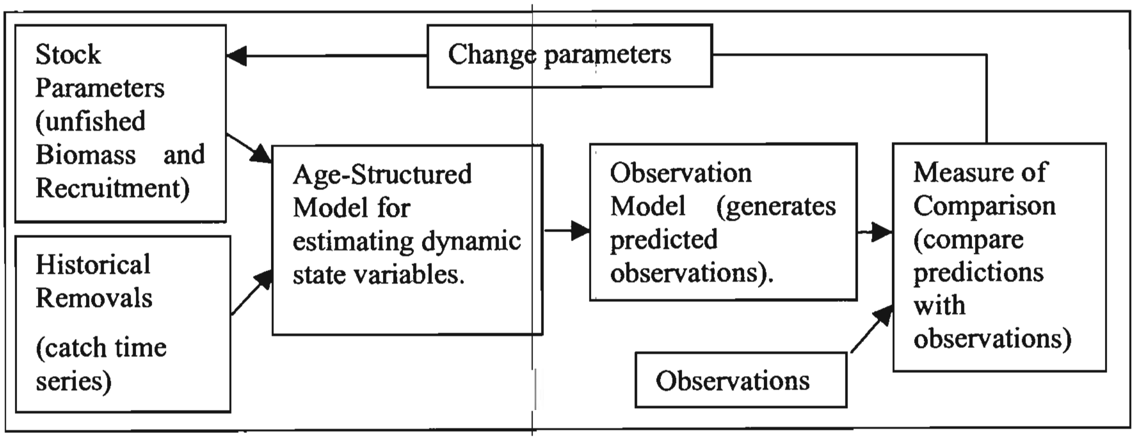

Figure1. A diagrammatic interpretation of SRA methods used to reconstruct the Hecate Strait lingcod biomass.

described by Walters and Ludwig (1994). In this context, Bayes' theorem is used to assign a probability distribution to a range of hypotheses about the size of the unfished biomass and the initial slope of the stock-recruitment curve. For each hypothesized parameter value the model generates a measure of credibility. The next step is to change the parameter values and generate a second measure of credibility, and the process is repeated until all possible parameter combinations are explored. Finally, all possible parameter values are compared in the form of a posterior distribution. The mean of the posterior distribution is the best estimate of the parameter value in question and the peak of the posterior distribution is the maximum likelihood estimate.

In this paper, the catch and catch per unit of effort data for the commercial lingcod fishery in Hecate Strait are used to estimate the biomass in 1956 before the start of the fishing season. In addition, estimates of the initial slope of the stock recruitment curve (a measure of the stock productivity) are provided, based on these data. Using the most likely estimates of the initial biomass and the slope of the stock recruitment curve, the observed catch time series can then be used to estimate the size of the present day stock.

The data

The catch time series in Fig. 2 shows the total landings from the commercial lingcod fishery in Hecate Strait (McFarlane and Leaman 1996). These are combined catch from the trawl fishery and a directed line fishery. CPUE is expressed in kilograms of lingcod caught per hour of fishing. The CPUE index is collected from interviews with commercial fishers. The number of interviews per year ranges from 1 to 69. In years with a high number of interviews, there is a better chance of capturing the true CPUE than in years with only one interview. Therefore, CPUE data were only used in years when there were more than five interviews. As a result of omitting a portion of the data set, the 40-year time series is reduced to 30 years of information about relative abundance (CPUE). An important point to keep in mind is that the relative abundance data are not independent of the fishery. Also, the only relative abundance data available from the literature, on this particular stock, are the commercial fishery CPUE data. Additional age structured data or fishery independent surveys for this stock could not be found.

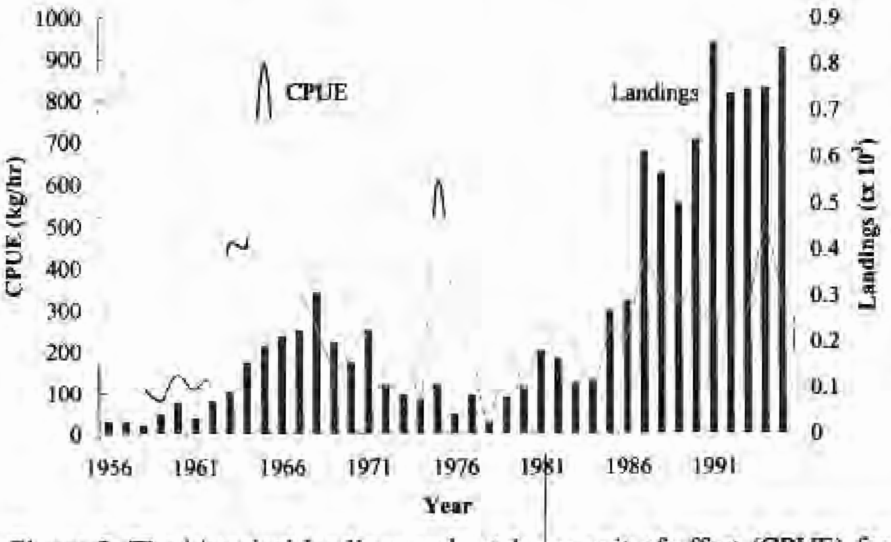

Figure 2. The historical landings and catch per unit of effort (CPUE) for the commercial lingcod fishery in the Hecate Strait from 1956 to 1995 (source: McFarlane and Leaman 1996). These data are used to estimate the historical biomass and the intial slope of the stock recruitment curve.

Stock parameters and the age structured model

The age-structured model uses the weight-at-age, vulnerability-at-age, and a constant survival rate to propagate biomass over time. The weight at age was estimated from a tagging study carried out on the West Coast of Vancouver Island (Smith and McFarlane 1990). Female lingcod are larger and grow faster than male lingcod (Cass *et al.* 1990). In this model, a 50:50 sex ratio is assumed, and the average weights at age for the two sexes are used. This implies that the sex ratio in the catch is also 50:50. The minimum legal size for lingcod is 65 cm, and prior to 1987 the minimum legal size was 58 cm. Therefore, the vulnerability at age changes during this 1956 to 1995 time series. According to the length-at-age estimates from Cass *et al.* (1990), the 50% age of recruitment to the fishery prior to 1987 is 4 years old, and 5 years old after 1987 (Figure 3). The natural survival rate was estimated from a tagging study in the Strait of Georgia. Smith and McFarlane (1990) estimated that the instantaneous natural mortality falls between 0.24 – 0.64, or 20% to 48% per year. To avoid over-estimating the population size, the most optimistic survival rate (80% per year) was used. This may seem counter-intuitive, but by over-estimating the natural survival rate, the model is less likely to over-estimate the relationship between the spawning stock size and the number of recruits produced. In other words, a long-lived population (low natural mortality rate) has a lower reproductive rate.

Two important elements in the age-structured model are the unfished biomass and the initial slope of the stock recruitment curve. When these two parameters are changed, the observation model generates a set of predicted observations and the predicted observations are compared to the real observation data (CPUE). There is no single correct solution to this simple system of non-linear equations. Either the unfished stock is very large and less productive, or the stock is small and very productive. Calculating the stock-recruitment curve parameters assumes that the stock was in a steady state before the fishery. Therefore, a stock with a high mortality rate must also have a high natural rate of recruitment in order to sustain a steady state. The form of the stock-recruitment relationship assumed was a Beverton-Holt type.

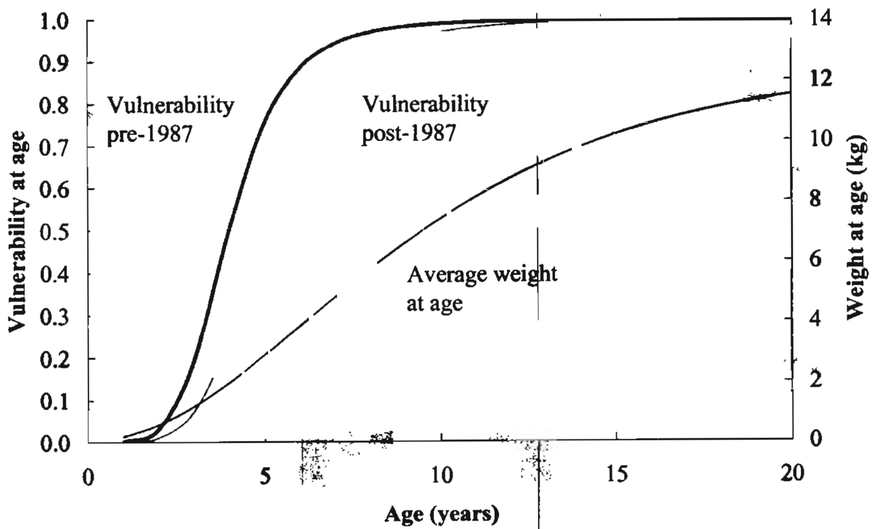

Figure 3. The average weight-at-age for male and female lingcod, estimated from West Coast Vancouver Island lingcod (Smith and McFarlane, 1990). Also, the graph illustrates the vulnerability-at-age schedule used in the stock reconstruction model.

Results and discussion

The relative abundance data (CPUE from the fishery, Figure 2) show no clear indication of the stock size changing over time. In this analysis, I assume that the catch rate (CPUE) is directly proportional to the stock size. In general, this is a very dangerous assumption to make and should be avoided if at all possible (Walters and Ludwig 1994; Hilborn and Walters 1992); however, the intent of this analysis is to provide a minimum estimate of the current lingcod biomass present in Hecate Strait. These results are not intended for assisting fisheries managers with policy decisions.

The marginal posterior distribution for the unfished biomass is shown in Fig. 4. Each point along the line in Fig. 4 can be interpreted as a measure of credibility or 'believability' about the estimated size of the unfished biomass in 1955. The minimum biomass estimate for 1955 that is required to sustain the observed catches (shown in Fig. 2) is 7260 t. Initial population sizes below this level result in extirpation before 1995, and we know from the observed catches that lingcod have not been extirpated from Hecate Strait. The posterior distribution does not have an upper bound (it is a so-called 'non-integrable' posterior). This, however, does not mean there is no upper limit to the population. The problem here is the lack of contrast in the relative abundance data and/or a violation in assuming proportionality between stock size and CPUE.

Recall that the stock-recruitment relationship is calculated under the assumption of a steady state population prior to the start of the fishery. If this assumption is correct, then the equilibrium recruitment must be equal to the total number of animals dying in a given year. The initial slope of the stock-recruitment curve defines how resilient the population is to exploitation. For example, a stock with a steep initial slope is more resilient to exploitation then a stock with a shallow initial slope. In other words, a steep slope implies that the same number of offspring will be produced at lower stock sizes.

The maximum likelihood estimate of the initial slope is 2.326, which corresponds to the peak of the posterior distribution shown in Fig. 5. The initial slope of the stock-recruitment curve is roughly 2.3 times greater than the slope of a strait line running through the origin and a point corresponding to the equilibrium recruitment and the unfished biomass. The initial slope of the recruitment curve and the unfished biomass are calculated simultaneously. Therefore, the recruitment slope is also estimated from the CPUE data in Fig. 2. Consequently, the slope of the recruitment curve is also calculated under the assumption of proportionality between CPUE and stock size.

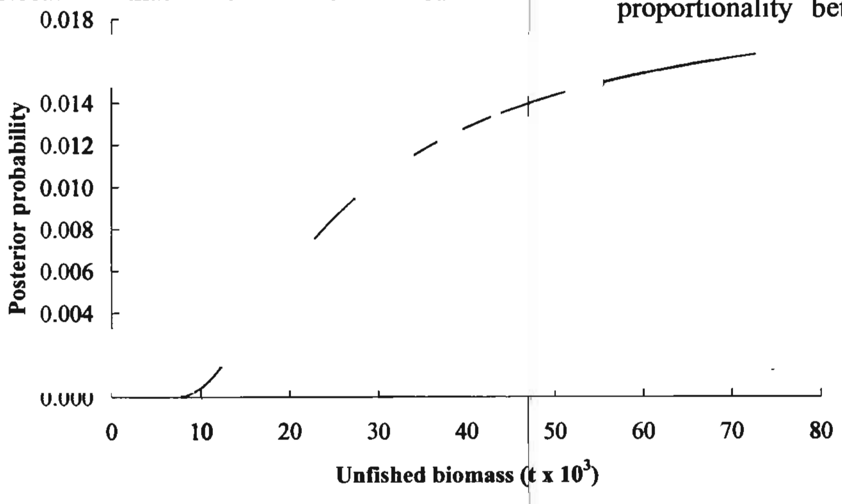

Figure 4. The marginal posterior probability distribution for the unfished lingcod biomass in Hecate Strait. The minimum biomass required to sustain the observed catches is 7260 tons (corresponding to the x-intercept).

Using the minimum estimate of the unfished biomass (7260 t) and a slope of 2.36 to initialize the model, the model we can then be run with the observed catches from 1956 to 1995. The result is a historical reconstruction of the stock, as shown in Fig. 6. The annual exploitation rate is equal to the observed catch in year *t* divided by the estimated biomass in year *t*. The

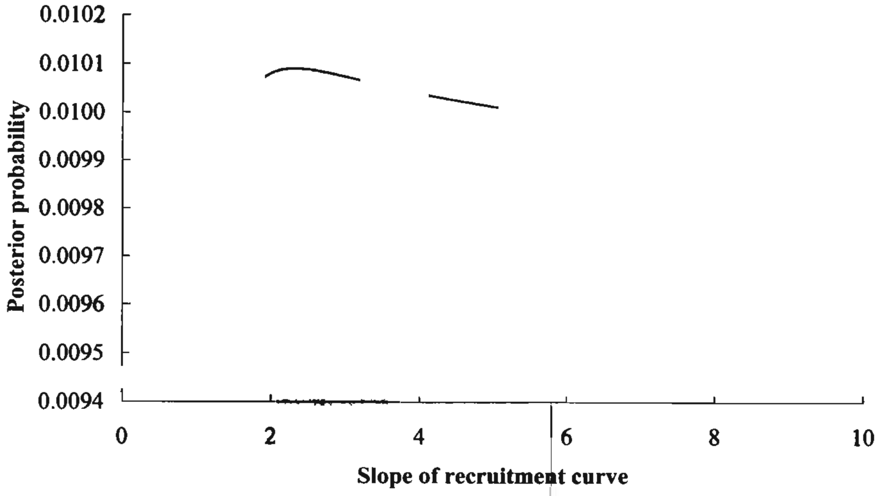

Figure 5. The marginal posterior probability distribution for the initial slope of the recruitment curve.

difference between the vulnerable biomass and the total biomass is a property of the fishing gear and the age of recruitment to the fishery (*i.e.* minimum size limits). In Fig. 6, prior to 1987 the vulnerable biomass consists of 4+ year old fish, and after 1987 the vulnerable biomass consists of 5+ year old fish. Note too, however, that the minimum size limit in the commercial fishery increased from 58 cm to 65 cm in 1988.

Over the time series shown in Fig. 6, the annual exploitation rate ranges from <0.01 to 0.45. During the late 1960s and early 1970s, there was an increase in the annual catches followed by a decrease (Fig. 2). As shown in Fig. 6, the lingcod population actually increased during the period of small catches in the 1970s. Using this deterministic approach, the estimate of total biomass in Hecate Strait is approximately 2990 t (41.2% of the unfished biomass). The estimated vulnerable biomass (the biomass available to harvest) is 1548 t, or 25.8% of the vulnerable biomass available in 1955. Note that this does not preclude the biomass in the early 1900s from being even higher, see below and the estimates provided by workshop participants (Beattie *et al.* this

The results shown in Fig. 6 do not actually reflect well the true population biomass in Hecate Strait. This analysis is supposed to be a worst case scenario (i.e., a minimum estimate of the 1955 biomass required to support the observed catches). Data on annual catches and catch rates are only available back to 1956. In reality, this fishery started before 1955, and the stock

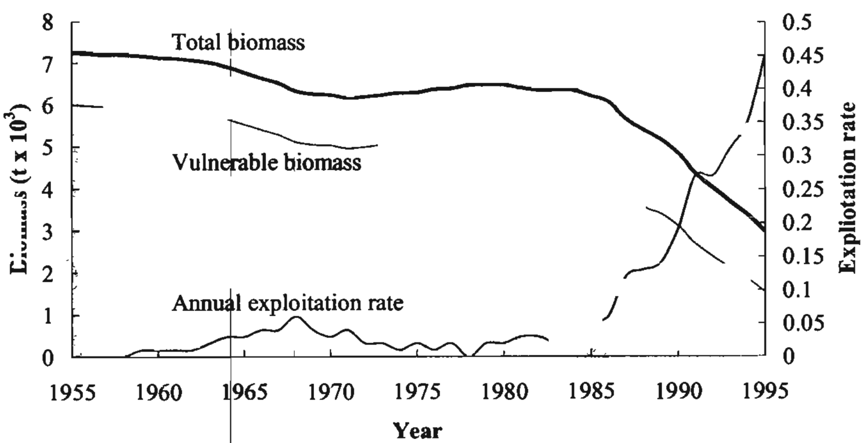

Figure 6. The reconstructed lingcod biomass in Hecate Strait. This stock was reconstructed using the observed catches (Figure 2) and an estimate of the pre-1956 biomass (7260 t) and a recruitment curve slope of 2.326.

had already been eroded from its unfished state. Therefore, calculating the stock recruitment relationship using a stock that is below its carrying capacity will result in under-estimating the initial slope of the stock recruitment curve. In other lingcod stocks, however, highly variable recruitment has been observed (McFarlane and Leaman 1996, Cass *et al.* 1990), so it is still possible that this approach is over-estimating the average annual recruitment.

A note on some problems, and their remedies

A major problem with this analysis is the use of CPUE data collected from the fishery. In most fisheries, CPUE data gathered from fisheries are biased (Hilborn and Walters 1992). Thus, the relationship between CPUE and stock size is not directly proportional, and may even be of an inverse nature, at least until very small stock sizes occur. Imagine how this lingcod fishery works: lingcod aggregate in small areas, fishers remove an aggregation; then they search for a new aggregation. As long as fishers remain fishing on aggregations, the catch rates will remain constant or even increase, until the last aggregation is removed. A simple remedy for this problem is the use of a fishery-independent sampling program. The focus of the sampling program would be to maximize the information about the stock, not maximize the catch.

The second major problem with this assessment is assuming a deterministic stock-recruitment relationship. In the absence of any age-structured data, however, there is no justification to assume anything but a deterministic relationship. As an alternative to collecting age-structured data, random recruitment anomalies could be incorporated into the analysis and Monte-Carlo simulations (i.e., run the model 10,000 times) could be used to calculate the posterior distributions for each parameter. The problem with this method, however, is the proportionality assumption between CPUE and stock size is still required. Random samples of the catch and aging of fin rays is a practicable solution for gathering age-structured information about the stock. In fact, this method is already in use for the Strait of Georgia and West Coast of Vancouver Island lingcod stocks (McFarlane and Leaman 1996). A simpler method, one that could be carried out by the users of the resource, is to gather length frequency data on the fish. Catch-at-length data can be transformed to catch-at-age data quite readily using simple computer programs.

Finally, a minor problem in dealing with stock reduction analysis is examining the trade-off between stock size and productivity. As mentioned previously, there is no single solution for the simple system of non-linear equations (Kimura and Tagart 1982, Kimura *et al.* 1984). In general, the observed data can be explained equally well by a small, highly productive stock, or a large, unproductive, stock. lingcod are not generally thought of as being highly productive. lingcod fisheries are typically supported for many years by a single, strong year-class (McFarlane and Leaman 1996, Cass *et al.* 1990). Again, catch-at-age data (or an equivalent) can be used to resolve the uncertainties about the productivity of the stock.

Acknowledgements

I would like to thank Dr. Daniel Pauly for his encouragement towards completing this paper, Scott Wallace and Alasdair Beattie for supplying the historical data, and of course, Dr. Carl Walters for the ongoing whippings.

References

Cass, A.J., R.J. Beamish, and G.A. McFarlane. 1990. lingcod (*Ophiodon elongatus*). Can. Spec. Publ. Fish. Aquat. Sci. 109, 40 p.

Hilborn, R., and C.J. Walters. 1992. Quantitative Fisheries Stock Assessment: choice, dynamics & uncertainty. Chapman & Hall. New York. 570 p.

Kimura, D. K., and J. V. Tagart, 1982. Stock reduction analysis, another solution to the catch equations. Can. J. Fish. Aquat. Sci 39: 1467-1472.

Kimura, D. K., J. W. I. Balsiger, and D. H. Ito, 1984. Generalized stock reduction analysis. Can. J. Fish. Aquat. Sci. Vol. 41: 1325-1333.

McFarlane, G.A., and B. L. Leaman. 1996. Offshore lingcod stock assessment and recommended yield options for 1997. Pacific Stock Assessment Review Committee. Department of Fisheries and Oceans.

Smith, B. D., G. A. McFarlane. 1990. Movements and mortality of tagged male and female lingcod in the Strait of Georgia, British Columbia. Trans. Amer. Fish. Soc. 119:813-824.

Walters, C. J. and D. Ludwig, 1994. Calculation of Bayes' Posterior Probability Distributions for key population parameters. Can. J. Fish. Aquat. Sci. 51: 713-722

Appendix I. List of Participants

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Appendix II. ECOPATH Outputs.

Table A. Basic estimates as supplied by the ECOPATH software for the present day model of the Hecate Strait. Values in bold characters were calculated by the software.

Group name	Trophic level	Biomass (Wet weight, (t km^{-2}))	Production/ Biomass (year^{-1})	Consumption/ Biomass (year^{-1})	Prod.uction / Consumption	Ecotrophic efficiency	Omnivory index
Transient orcas	**5.0**	0.002	0.200	12.130	**0.016**	-	**0.045**
Odontocetae	**4.1**	0.020	0.400	15.590	**0.026**	**0.607**	**0.059**
Pinnipeds	**4.1**	0.052	0.400	15.330	**0.026**	**0.875**	**0.155**
Lingcod	**4.0**	0.065	0.580	3.300	**0.176**	**0.508**	**0.281**
Pacific halibut	**3.9**	0.305	0.440	1.730	**0.254**	**0.201**	**0.181**
Sablefish, juvenile	**3.8**	1.500	0.600	6.600	**0.091**	**0.852**	**0.267**
Turbot	**3.7**	1.130	0.775	3.210	**0.241**	**0.969**	**0.533**
Sablefish, adult	**3.6**	0.200	0.080	3.730	**0.021**	**0.813**	**0.315**
Seabirds	**3.6**	0.016	0.100	112.000	**0.001**	-	**0.241**
Ratfish, skates	**3.4**	1.240	0.310	**1.240**	0.250	**0.996**	**0.215**
Pacific cod	**3.4**	**0.059**	1.200	4.000	**0.950**	0.950	**0.325**
Walleye pollock	**3.3**	0.357	0.800	4.760	**0.513**	**0.513**	**0.128**
Spiny dogfish	**3.2**	1.250	0.750	5.000	**0.813**	**0.813**	**0.119**
Rockfish, small benthic fish	**3.2**	**41.347**	0.170	3.440	**0.980**	0.980	**0.036**
Flatfish	**3.1**	2.831	0.775	3.210	**0.451**	**0.451**	**0.346**
Mysticetae	**3.1**	0.310	0.020	13.370	**0.196**	**0.196**	**0.012**
P. O. Perch	**3.1**	0.841	0.100	3.440	**0.950**	0.950	-
Salmon, juvenile	**3.1**	4.430	0.980	7.115	**0.116**	**0.116**	-
Herring, small pelagic fish	**3.1**	**2.959**	2.200	11.000	**0.980**	0.980	-
Carnivorous jellies	**3.0**	6.190	7.000	**23.333**	0.187	**0.187**	**0.163**
Crustaceans	**2.2**	15.000	1.600	**6.400**	0.757	0.757	**0.171**
Macrobenthos	**2.1**	40.000	1.913	**21.256**	0.564	0.564	**0.111**
Zooplankton	**2.1**	40.000	59.591	**297.955**	0.665	**0.665**	**0.111**
Phytoplankton	**1.0**	257.500	135.000	-	**0.323**	**0.323**	-
Detritus	**1.0**	7.000	-	-	**0.013**	**0.013**	**0.153**

Table B. Basic estimates as supplied by the ECOPATH software for the 100-year model of the Hecate Strait. Values in bold characters were calculated by the software.

Group name	Trophic level	Biomass (Wet weight, ($t \cdot km^{-2}$))	Production/ biomass ($year^{-1}$)	Consumption/ biomass ($year^{-1}$)	Production/ consumption	Ecotrophic efficiency	Omnivory index
Transient orcas	**5.1**	0.002	0.200	12.130	0.0160	**0.000**	**0.046**
Odontocetae	**4.1**	0.024	0.400	15.590	0.0260	**0.505**	**0.059**
Pinnipeds	**4.1**	0.052	0.400	15.330	0.0260	**0.875**	**0.119**
Lingcod	**4.0**	0.127	0.580	3.300	0.1760	**0.216**	**0.312**
Pacific halibut	**3.9**	0.305	0.440	1.730	0.2540	**0.000**	**0.192**
Sablefish, juvenile	**3.7**	1.950	0.600	6.600	0.0910	**0.650**	**0.263**
Sablefish, adult	**3.7**	0.130	0.080	3.730	0.0210	**0.000**	**0.258**
Turbot	**3.7**	1.130	0.775	3.210	0.2410	**0.315**	**0.516**
Seabirds	**3.6**	0.032	0.100	112.000	0.0010	**0.000**	**0.241**
Flatfish	**3.5**	3.680	0.775	3.210	0.2410	**0.968**	**0.301**
Ratfish, skates	**3.5**	1.240	0.310	1.240	0.2500	**0.944**	**0.306**
Pacific cod	**3.4**	0.051	1.200	4.000	0.3000	**0.548**	**0.331**
Walleye pollock	**3.3**	0.357	0.800	4.760	0.1680	**0.475**	**0.128**
Spiny dogfish	**3.2**	1.250	0.750	5.000	0.1500	**0.888**	**0.123**
Rockfish, small benthic fish	**3.2**	50.050	0.170	3.440	0.0490	0.980	**0.036**
Mysticetae	**3.1**	**0.310**	0.020	13.370	0.0010	**0.196**	**0.012**
P.O. Perch	**3.1**	0.478	0.100	3.440	0.0290	0.500	-
Herring, small pelagic fish	**3.1**	**4.925**	2.200	11.000	0.2000	**0.756**	-
Salmon, juvenile	**3.1**	**4.430**	0.980	7.115	0.1380	**0.152**	-
Carnivorous jelllies	**3.1**	**6.190**	7.000	23.333	0.3000	**0.193**	**0.163**
Crustaceans	**2.2**	**15.000**	1.600	6.400	0.2500	**0.874**	**0.171**
Macrobenthos	**2.1**	**40.000**	1.913	21.256	0.0900	**0.576**	**0.111**
Zooplankton	**2.1**	**40.000**	59.591	297.955	0.2000	**0.686**	**0.111**
Phytoplankton	**1.0**	**257.500**	135.000	-	-	**0.323**	-
Detritus	**1.0**	**7.000**	-	-	-	**0.013**	**0.154**

Table C. Diet composition for all groups used in the present day model. Values are identical for the 100-year model, except as noted in the text (see Beattie *et al.* this volume).

Prey / Predator	Transient Orcas	Odontocetae	Pinnipeds	Mysticetae	Seabirds	Spiny dogfish	Ratfish, skates	Pacific Halibut	Pacific Cod	Walleye Pollock	Sablefish, juvenile	Sablefish, adult	Herring, small pelagics	Carnivorous jellies	Crustaceans	Macrobenthos	Zooplankton	Salmon, juvenile	P.O.Perch	Flatfish	Rockfish, small benthics	Turbot	Lingcod
Transient Orcas	-	-	-		-		-	-	-		-	-	-		-	-	-	-	-	-	-	-	
Odontocetae	0.200	-	-		-		-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	
Pinnipeds	0.750	-	-		-		-	-	-		-	-		-	-	-	-	-	-	-	-	-	
Mysticetae	0.050	-	-		-		-	-	-		-	-		-	-	-	-	-	-	-	-	-	
Seabirds	-	-	-		-		-	-	-		-	-		-	-	-	-	-	-	-	-	-	
Spiny dogfish	-	0.602	0.278		0.016	0.050	-	-	-		-	-		-	-	-	-	-	-	-	-	-	0.038
Ratfish, skates	-	-	-		-	-	-	-	-		-	-		-	-	-	-	-	-	-	-	0.100	-
Pacific Halibut	-	-	-		-	-	-	-	-		-	-		-	-	-	-	-	-	-	-	-	-
Pacific Cod	-	0.023	0.013		-	-	-	-	-	-	-	0.030		-	-	-	-	-	-	-	-	-	-
Walleye Pollock	-	-	0.170		-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	
Sablefish, juvenile	-	-	0.027		-	-	-	-	0.020	-	-	0.020		-	-	-	-	-	-	-	-	0.200	-
Sablefish, adult	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Herring, small pelagics	-	[illegible]	0.	0.012		-	-	0.	0.250	0.150	0.410	0.400	-	-	-	-	-	-	-	-	-	-	0.289
Carnivorous jellies	-	-	-	-	0.005	0.050	-	-	-	-	0.040	0.030	-	0.051	-	-	-	-	-	-	-	-	-
Crustaceans	-	0.055	0.116	-	0.142	0.130		0.120	0.125	-	0.	0.410	-	-	0.040	-	-	-	0.081	0.390	0.048	0.200	0.151
Macrobenthos	-	-	-	0.092	0.001	0.050	0.400	0.100	0.149	0.600	-	-	-	050	0.120	-	-	0.526	0.025	0.310	0.007	0.400	-
Zooplankton	-	-	-	0.896	0.412	0.700	-	-	0.380	0.250	0.300	0.060	.000	[illegible]	-	0.100	0.100	0.474	0.894	-	0.910	0.050	0.115
Salmon, juvenile	-	-	-	-	-	-	-	-	-		0.050	-	-	-	-	-	-	-	-	-	-	-	0.038
Phytoplankton	-	-	-	-	-	-	-	-	-		-	-		-	-	0.600	0.900	-	-	-	-	-	-
P.O. Perch	-	-	0.030	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-	-	-
Flatfish	-	-	-	-	-	0.005	0.150	0.040	0.014		0.050	0.025		-	-	-	-	-	-	0.150	-	-	0.116
Rockfish, small benthics	-	-	0.070	-	-	0.010	0.150	-	0.012		0.010	0.025		-	-	-	-	-	-	0.150	0.035	-	0.115
Turbot	-	-	-	-	-	0.005	-	0.040	-		0.050	-		-	-	-	-	-	-	-	-	0.050	0.100
Lingcod	-	-	-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-	-	0.038
Detritus	-	-	-	-	-	-	-	-	0.050	-	-	-	-	0.099	0.840	0.300	-	-	-	-	-	-	-

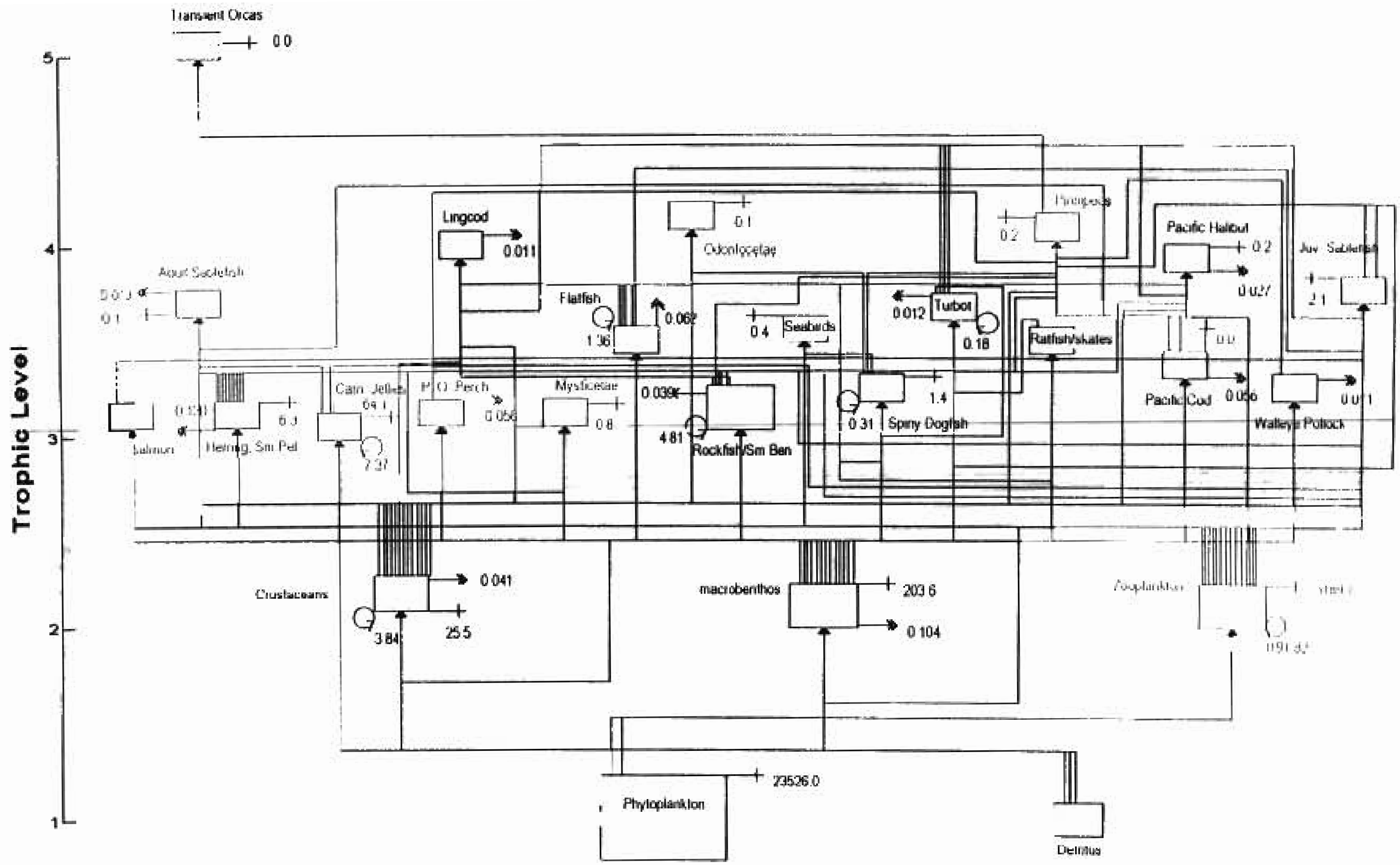

Figure A. A flow diagram of the present Hecate Strait Ecosystem as presented at the workshop held in Prince Rupert. Box size is proportional to the biomass of the functiuonal group, and boxes are centered at the trophic level calculated by the software. All production exits from the top of the box; consumption enters in the bottom of the box; minor flows between boxes not shown for simplicity. Double arrows indicate harvest, circles indicate cannabalism, and crosses indicate flows to detritus.

Appendix III. General Index

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multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1470.

Tyler, A.V. 1989. Hecate Strait Project: Results from four years of multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1675.

Venier, J. and J. Kelson, 1996. The demersal fish "box", p. 67. *In:* D. Pauly, D. and V. Christensen (eds.). Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1).

Venier, J. 1996. Pacific halibut, p. 43-45. *In:* D. Pauly, D. and V. Christensen (eds.). Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1).

Vermeer, K. and L. Rankin. 1984. Pelagic seabird populations in Hecate Strait and Queen Charlotte Sound: comparison with the west coast of the Queen Charlotte Islands. Can. Tech. Report. Hydrogr. Ocean Sci. No. 52. iii + 40 p.

Wada, Y. and J. Kelson, 1996. Seabirds of the southern B.C shelf. p. 55-57. *In:* D. Pauly, D. and V. Christensen (eds.). Mass-balance models of Northeastern Pacific ecosystems. Fish. Centre Res. Rep. 4(1): 37-62.

Walters, C. J., M. Stocker, A.V. Tyler, and S.J. Westrheim, 1986. Interaction between Pacific cod and Pacific herring in the Hecate Strait. p. 43-48. *In:* A.V. Tyler, A.V. (eds.) Hecate Strait project: results of the first two years of multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1470

Ware, D.M. and G.A. McFarlane 1989. Fisheries production domains in the Northeast Pacific Ocean, p. 359-379. *In:* R.J. Beamish and G.A. McFarlane (eds.). Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108.

Welch, D.W. and R.P. Foucher, 1986. Analysis of population regulation in Hecate Strait Pacific cod, p. 49. In: A.V. Tyler (ed.) Hecate Strait project: results of the first two years of multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1470

Zeiner, S.J. and P. Wolf 1993. Growth characteristics and estimates of age at maturity of two species of skates (*R. binocular* and *R. rhina*) from Monterey Bay, California. *In*: S. Branstetter (ed.), 1993. Conservation Biology of Elasmobranchs. NOAA Tec. Rep. NMFS 115.