In: Resetting the Kitchen Table: Food Security, Culture, Health and Resilience in Coastal Communities
Editors: C.C. Parrish, N.J.Turner and S.M.Solberg, pp. 51-74 2008 Nova Science Publishers, Inc.

Chapter 4

LIFE IN THE FAST FOOD CHAIN: OÙ SONT LES POISSONS D'ANTAN?

Nigel Haggan[1], Cameron Ainsworth[1], Tony Pitcher[1], U. Rashid Sumaila[2] and Johanna Heymans[1]
[1]Fisheries Centre, The University of British Columbia
[2]Fisheries Economics Unit, Fisheries Centre,
The University of British Columbia

ABSTRACT

This chapter reviews the decline in high trophic level or 'table' fish on Canada's Pacific coast in the context of global depletion, the potential extinction of marine species and the economic and social drivers of overfishing. Impacts on Aboriginal and other coastal communities are identified. Whole ecosystem (*Ecosim*) models of northern British Columbia as it was in the 1750s and present-day are used to determine the sustainable food production potential of both past and present systems under different exploitation scenarios. The food production potential of the 2000 and 1750s ecosystems was assessed under four twenty-five-year simulation scenarios. Results indicate that the 1750s system could have sustainably generated over twenty times the current annual food production in northern British Columbia's capture fisheries, while meeting UN food security criteria including cultural appropriateness. The present-day system could sustainably produce six times the fisheries yields extracted today if the fleet was adjusted to meet UN criteria for responsible fishing, and fisheries were conducted optimally to make best use of the existing resources.

One hundred-year simulations of the present day (2000) system incorporating natural climate and ocean regime variability indicate that the existing BC fishing fleet poses a significantly higher risk of seriously depleting and extirpating many species than an alternate fleet structured largely upon UN criteria for responsible fishing.

The chapter concludes with a review of the strengths and weaknesses of Marine Protected Areas and other conservation measures in achieving ecosystem restoration. We draft candidate fishing strategies for northern British Columbia that would increase food production; first, in terms of total available protein, and second, in terms of high-quality tablefish production.

INTRODUCTION

The Whale that wanders round the Pole
Is not a table fish.
You cannot bake or boil him whole
Nor serve him in a dish;

But you may cut his blubber up
And melt it down for oil.
And so replace the colza bean
(A product of the soil).

These facts should all be noted down,
And ruminated on,
By every boy in Oxford town
Who wants to be a Don (Belloc 1896).

What is a "table fish"? Why is a whale not one of them? Which "facts" do the poet exhort every aspiring "Don," or high trophic level scholar, to "ruminate on" or consider?

A "table fish" is, as the name implies, something that one would be proud to serve at a dining table, Atlantic salmon (*Salmo salar*), Pacific salmon (*Oncorhynchus* spp.), halibut (*Hippoglossus stenolepis*), lingcod (*Ophiodon elongatus*), red snapper (*Sebastes ruberrimus*), Atlantic cod (*Gadus morhua*) and so forth. The sense of pride and cultural identity wrapped up in the ability to catch and serve fish and a whole range of seafood is well conveyed by Tirone *et al*. (Chapter 10, this volume). This pride is often expressed by cooking and serving large fish whole, hence Belloc's exclusion of the whale from the canon of table fish.

> Whales and coastal food security
>
> Whales and other marine mammals are vitally important as food for Inuit and other circumpolar communities and were traditionally hunted by coastal tribes in the Pacific Northwest (Monks 2001 and references therein; Brody 1994). This hunt has been revived in recent years by the Makah people in Washington, although not without controversy. The Haida, Nuu-chah-nulth and possibly other First Nations in BC assert, but have not yet exercised, an Aboriginal right to hunt whales. See Reeves (2002) for a global review of Aboriginal whaling

The Haida people of the Pacific Northwest consider Chinook salmon (*Oncorhynchus tshawytscha*), as "rich food" which was "essential for maintaining the dignity of the family by possession and distribution at potlatches" (Boas 1916 in Jones 1999). Smoked halibut cheeks, called *Xang* in Haida were said to be a special food of chiefs (Jones 1999). The "facts" to be considered are that whalers traveled the globe, at great risk and hardship, to hunt something that was not used for food, at least not by English and American[1] whalers, and could well be replaced by an agricultural product. Why so? It was highly profitable. Lives were lost, but fortunes were made. Whales everywhere were driven to the brink of extinction. Whaling is the classic example of Colin Clark's dispiriting insight that dollars grow faster than long-lived marine species, so it makes economic sense to catch them all and put the money into something that gives a higher rate of return (Clark 1973).

[1] But see 'Stubbs Supper' - Chapter 64 of Moby Dick (Melville 1851).

Mining The Provident Sea[2]

> . . . the cod fishery, the herring fishery, the pilchard fishery, and probably all the great sea fisheries are inexhaustible; that is to say that nothing we do seriously affects the numbers of fish. And any attempt to regulate these fisheries seems consequently, from the nature of the case, to be useless (Huxley 1883).

Just eighty-five years later, Jack Davis, Canada's then Minister of Fisheries, compared the fishery to a copper mine, in which the best ore is taken first before the miner turns to progressively larger volumes of lower grade ore until the mine is exhausted: "Mr. Davis then turned to the sea and explained that life there is built on the same type of pyramid, at the top is the whale and below it such species as the salmon and the tuna. As the base broadens out it contains fish successively smaller but in greater number until, at the bottom, is the limitless mass of plankton which supports the whole pyramid." The Whale, the Minister said, has been virtually wiped out and the tuna and the salmon will be the next to go as man works his way down the pyramid to the plankton (*North Island Gazette* 1968, in Meggs 1991). This process, now known as "fishing down the food web" has been shown to be taking place in Canada and globally (Pauly *et al*. 1998, 2001).

> What problem?
>
> Apart from a handful of fisheries and social scientists and NGOs, the public is blissfully unaware of the extent of depletion. A 2001 survey found that British Columbians believe 16% of their waters to be 'no-take' marine protected areas (Strategic Communications Inc. 2001). Atlantic Canadians believe that 20% of their waters are fully protected (Edge Research 2002). In fact, less than 0.1% is fully protected. Canada's markets are full of fish, increasingly of distant origin, but this is not widely known.
>
> The live fish markets of Hong Kong are bursting with a multitude of species, flown in from increasingly depleted coral reefs in Indonesia and New Guinea, but the only fisheries supported by Hong Kong waters are for prawns, and small, high-turnover pelagic species harvested for agriculture and aquaculture feed. Problems in the westcoast fishery are cast in the language of allocation, not conservation.

Overfishing is now accepted as the major cause of the depletion and changes to marine ecosystem structure (Hilborn *et al*. 2003; Hall 1999; Christensen *et al*. 2003). The extent of recent fishery depletions and collapses is even more serious than many had thought (e.g., large fish, Myers and Worm 2003; table fish biomass, Christensen *et al*. 2003; whales, Roman and Palumbi 2003; sharks, Baum *et al*. 2002, Schindler *et al*. 2002; turtles, Hays *et al*. 2003).

Even exceedingly productive species such as hake (*Merluccius* spp.), deemed to be capable of sustaining intensive and prolonged fisheries (Pitcher and Alheit 1995), have been depleted to the point of closure, provoking a 1999 protest by industrial fishers in Chile that included a port blockade by one hundred fishing vessels and a march on the Chilean Congress (*Reuters* 1999). In a June 2005 interview, Cosme Caracciolo, President of the association of Chilean artisanal fishermen, stated that artisanal fishers have been virtually excluded from

[2] See Cushing (1987).

fisheries for jack mackerel (*Trachurus murphyi*) and two species of hake (Soto 2004), both of which go to fishmeal to supply explosive growth in Chilean salmon aquaculture.

Small, highly-productive species, collectively known as ‘forage fish’ are pivotal in the marine food web as they transport energy from plankton to higher trophic levels. Figure 4.1 shows some of the ecosystem connections to capelin (*Mallotus villosus*) in the Newfoundland and Labrador ecosystem as modelled by Bundy *et al.* (2000).

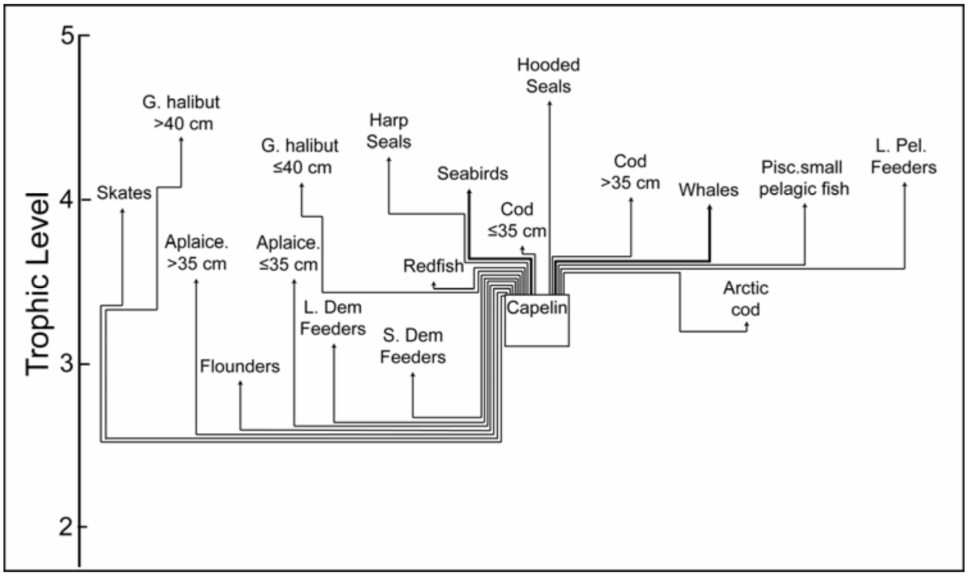

Figure 4.1. Simplified ecosystem model showing pivotal role of capelin (*Mallotus villosus*) in Newfoundland and Labrador (areas 2J3KL). Groups not connected to capelin removed from original figure. Alida Bundy, Fisheries and Oceans, Canada, unpublished data. See also Bundy *et al.* (2000)

Forage fish have long been converted to fishmeal used in pig and chicken feed. Salmon farming now accounts for some 50% of forage fish use in Europe[3]. Fishmeal is used extensively for salmon aquaculture in North America and Chile and for shrimp feed in the Far East (IFFO n.d.; Miller 2003). While some small pelagic species such as horse mackerel and sandlance are unpalatable, others such as herring, capelin, sardines, and anchovies, are eminently suitable for human consumption. Eulachons (*Thaleichthys pacificus*) are of extremely high cultural and economic importance to Aboriginal people in the Pacific Northwest (Drake and Wilson 1991), and are particularly high in lipids which contain healthful omega-3 fatty acids (Turner *et al*. Chapter 1, this volume).

Role of Sport Fisheries

Sport fisheries are sometimes perceived, and inevitably portrayed, as a minor part of catch, but a major contributor to the economy. Unrecorded and unregulated sport fish catch is a matter of serious, ongoing concern among Aboriginal and commercial fishers in the Pacific

[3] Now, after collapse of North Sea herring (ICES 1995) mainly sandlance (*Ammodytes* spp.), as yet unexploited in BC.

Northwest (Pitcher *et al*. 2002a and references therein). In fact, sport fishing accounts for 12% of global catch of table fish (Cooke and Cowx 2004) an average of 25% in the US and in excess of commercial catch of several species (Coleman *et al*. 2004). Other adverse effects of sport fisheries include depleting refugia too small to be targeted by commercial fisheries and so depriving Aboriginal people of a vital 'last resort' for food and cultural purposes on a coast where commercial long-lining has depleted the accessible grounds (Figure 4.2). Aboriginal people often regard sport fishing, particularly 'catch and release fisheries' as 'playing with food' which is unethical (Jones and Williams-Davidson 2000). The search for 'trophy' fish, involving catch and release of smaller specimens is both "disrespectful to the fish" and is a form of perverse genetic selection that reduces average size over time. Sportfishing in marine protected areas is particularly adverse as it defeats the major objective of developing a population of large, old, fecund spawners (Birkeland and Dayton 2005, and references therein).

Figure 4.2. Heiltsuk Nation members Pam and Bessie Brown protesting sportfishing expansion in the central coast. Photo: Janet Shaw

Life in the Fast Food Chain

In the ecological sense, life in the fast food chain relates to the replacement of long-lived high trophic level fish with short-lived species (Pauly *et al*. 1998). This situation is at its most extreme in places like the South China Sea (Cheung and Pitcher 2004; Cheung and Sadovy

2004), but also happens in Canada (Pauly *et al*. 2001). Intensive commercial and sport fisheries with unlimited access to the ocean also reduce the average age and size of fish caught over time (Law 2000). This is problematic, as many fish live to a great age. Table 4.1 shows the maximum ages, size and weight for salmon and other important table fish from the west and east coasts of Canada. Fish of this age and size would have been rare at any time, but are virtually unknown today.

Recent research indicates that reproductive success is more closely related to fish age than size (Berkeley *et al*. 2004), and that the number of *effective* spawners may be orders of magnitude lower than the total number of females in a population (Hauser *et al*. 2002). This underscores the need for extreme caution when setting catch rates for long-lived species. The failure of single species science and management, and the fleet structures that have evolved in response demands an ecosystem approach to restoration. Setting restoration targets requires an exploration of what the ecosystem is capable of producing on a sustained basis. In the social sense, life in the fast food chain relates to the nutritional content, cultural appropriateness and preferences aspects of the World Summit Food Security definition.

Table 4.1. Maximum known age, weight, and size for some Canadian table fish

Common Name	Scientific name	Years	Kg	Cm
Atlantic cod	*Gadus morhua*	25	96	200
Blackcod	*Anoplopoma fimbria*	94	57	120
Pacific Halibut	*Hippoglossus stenolepis*	55	363	267
Lingcod	*Ophiodon elongatus*	33	59.1	152
Red snapper	*Sebastes ruberrimus*	121	17.8	104
Pacific Herring	*Clupea pallasii*	19	1	46
Rougheye rockfish	*Sebastes aleutianus*	205	0.9	97
Pac. Ocean perch	*Sebastes alutus*	98	1.4	51
Copper rockfish	*Sebastes caurinus*	50	2.74	58
Atlantic Salmon	*Salmo salar*	13	46.8	150
Pacific Salmon	*Oncorhynchus*			
Chinook	*O. tshawytscha*	9	61.4	150
Sockeye	*O. nerka*	7	7.71	84
Coho	*O. kisutch*	5	15.2	108
Chum	*O. keta*	6	15.9	100
Pink	*O. gorbuscha*	3	6.8	76
Steelhead	*O. mykiss*	11	25.4	120

Sources: FishBase, www.fishbase.org and Alaska Dept. of Fish and Game, http://tagotoweb.adfg.state.ak.us/ADU/maxagetable.asp

Issues include the accelerated growth of farmed species from chickens to salmon (Volpe, Chapter 5, this volume), but likely the most significant factor is the increasing rate at which we live our lives and the attention span of small children and youth exposed to cartoons larded with advertising messages of instant gratification. The 'junk food giants' have an increasing presence in North American schools and universities. In 1995, The University of British Columbia signed a ten-year sole-source contract for US$6.8 million with the Coca Cola Company, becoming the first, but by no means the last Canadian university to do so (Thomas 2005). Parents and educators are beginning to resist the presence of junk food in schools and politicians are starting to heed. The UK announced a ban on junk food in schools from September 2006, in large part due to a TV campaign and petition by celebrity chef Jamie Oliver to involve school children in the design and preparation of healthy meals (Naughton 2005). In Canada, junk food has been banned in Ontario schools (Alphonso 2004). British Columbia Education Minister Shirley Bond plans to eliminate junk food over the next four years (Bond 2005).

The advertising pressures are of particular concern to Aboriginal communities, *viz* the ease of pulling food off the supermarket or convenience store shelf compared to the very limited time young people get to spend with elders and family on the land, and the weeks it takes to catch, dry, and prepare traditional foods such as seaweed and eulachon grease (Turner 2005). The cultural and dietary value of eulachons has been noted before, however many Aboriginal children now prefer tomato ketchup (pers. comm. Faren Brown-Walkus, Heiltsuk Nation, age thirteen). The prevalence of junk food and sugary drinks is a major cause of obesity-related disease in Aboriginal communities and the general population (Parrish *et al*. Chapter 13, this volume; Wong 2004; Turner and Ommer 2004).

Ecological, Economic, and Cognitive Drivers of Overfishing

Pitcher (2001) identified ecological, economic, and cognitive processes, or "ratchets" that drive depletion. The ecological and economic ratchets are inextricably linked. As large fish get scarce, fishers buy bigger, more powerful vessels, fishing gear, and high-tech electronics. The capital tied up in Pacific vessels, licences, and quotas is around US$2 billion (Ecotrust 2004; Nelson 2004). Increasing corporate concentration and the need to service this capital is a major economic driver of overfishing (Clark 1973).

Global subsidies of US$20 billion *per annum* (Milazzo 1998) keep fleets active long after fishing has ceased to be economically viable. Even so-called 'green' subsidies such as vessel buybacks have been shown to be counterproductive (Munro and Sumaila 2002). In Canada, subsidies to fishing have been estimated as at least equal to the catch and employment value (Pitcher *et al*. 2002b and references therein). Estimated overall figures for government subsidies to fishing in Canada range from a 'zero sum game,' where public money equals the value of the catch (100% subsidy, Dr Mary Gregory, Department of Fisheries and Oceans, Ottawa, pers. comm. 1999) to 150% (Roy 1998) to 170% subsidies in Newfoundland prior to the collapse (Schrank *et al*. 1987).

The cognitive ratchet, or "shifting baseline syndrome" where successive generations perceive the abundance and relative size of fish that existed in their early days as what there ought to be, is subtle and hard to reverse (Pauly 1995). Throughout human evolution, the ocean has been a metaphor for all that is mysterious, abundant, and inexhaustible (Haggan 2000), so, while it is easy, however sad, to contemplate the extinction of the giant panda, it is difficult to comprehend depletion and extinction risk in the ocean.

What is happening in the ocean parallels the extinction of large land animals as people spread over the face of the earth (Diamond 1997), a fate also suffered by large marine species such as Steller's sea cow (*Hydrodamalis gigas*) (Pitcher 2004c). Reduced access to marine protein also contributes to depletion of smaller land animals through increased pressure on 'bushmeat' (Robinson and Bennett 1999; Brashares *et al*. 2004). The significant difference is that the first wave of terrestrial extinctions took place over millennia, the second wave over a few hundred years of the age of exploration. It is only in the last one hundred years that we have developed the technology to catch all the fish in the sea, and deployed it so successfully that, depending on species, large fish hover between one tenth and one hundredth of their pre-industrial fishery abundance.

First Nations and Food Security

First Nations in the Pacific Northwest traditionally fished across the food web, taking a complete range of resource from whales (Monks 2001) to salmon, to shellfish, to seaweed (Turner *et al*. Chapter 1, this volume). The high level of social complexity and cultural richness attained by Pacific Northwest tribes has previously been attributed to the variety and year round availability of abundant resources. Recent research indicates that First Nations were not mere passive beneficiaries of this abundance (Anderson 2005; Deur and Turner 2005). Aboriginal people developed the technology to intercept entire salmon runs between 3,000 and 4,000 years ago, yet, according to pre-contact fishing and consumption levels, were able to sustain, enhance, and manage salmon populations to sustain catches equal to or greater than the present commercial fishery (Jones 2002; Haggan *et al*. 2006), now deemed "unsustainable" (McRae and Pearse 2004).

The sustainable First Nation fisheries would however, have differed significantly from those of the present day in species enhanced and capture technology. Dried salmon was essential for winter food and trade. Chum and Pink salmon keep better than the richer sockeye, Chinook, and coho, so would have been required in large numbers. Most traditional fisheries were 'terminal,' i.e. targeted stocks returning to their stream of origin, as distinct from today's 'interception' fisheries that target migrating stocks in saltwater with the inevitable consequence of overfishing weaker populations (Glavin 1996). The Pacific Northwest may have been a wilderness 4,000 years ago but the 'inexhaustible' resources described by early explorers and settlers were the result of conscious effort. Much can be learned by studying pre-contact management and enhancement methods (Wright 2004; Haggan *et al*. 2006; Turner 2005). The pre-contact Beothuk and Inuit people of Newfoundland and Labrador also relied heavily on the marine ecosystem (Marshall 1996) and their diet consisted of 65% marine derived food, predominantly seals, salmon, and birds (Heymans 2003). West coast First Nations have been severely impacted through disappearance of food sources readily available for thousands of years (Turner *et al*., Chapter 1; Ommer *et al*., Chapter 8, this volume). Some traditional resources can still be accessed, but often with increased effort, cost, and risk to life through, for example, having to go further out to sea in small boats in adverse weather conditions (Richardson and Green 1989).

MODELLING FOOD SECURITY AND EXTINCTION RISK

The Back to the Future Project

The collaborative Back to the Future approach engages natural and social scientists and the maritime community in constructing models of present and past ecosystems (Haggan 2000; Pitcher 1998b, 2000, 2004a, 2005; Ainsworth and Pitcher 2005a). The objective is to build support for whole ecosystem restoration goals that relate to benchmarks of past abundance, diversity, and trophic structure rather than present scarcity. The Back to the Future component of the *Coasts Under Stress* project (Ommer and team, 2007) used *Ecopath* (Christensen and Pauly 1992) to model the Newfoundland and southern Labrador[4] ecosystem for the 1450s, 1900s, 1985, and 1995 (Pitcher *et al*. 2002c; Heymans and Pitcher 2004) and the northern BC ecosystem for the 1750s, 1900s, 1950s, and 2000 (Ainsworth *et al*. 2002). The northern BC models aggregate ecosystem components into fifty-three 'functional groups' of species having similar diets. *Ecopath* models represent a 'snapshot' of an ecosystem at a particular time. Figure 4.3 represents the proportional decline in biomass from the 1750s to the present day in northern BC from four *Ecopath* models.

Ecosim (Walters *et al*. 1997) allows us to ask 'what if' questions on the effect of combinations of fishing rates, management, and conservation measures over time periods from twenty-five to one hundred years. *Ecosim* was used to compare the food production capacity of the 1750s and 2000 ecosystems as modelled by Ainsworth *et al.* (2002). For all food security comparisons, the 2000 and 1750 models were subjected to twenty-five years of simulated fishing.

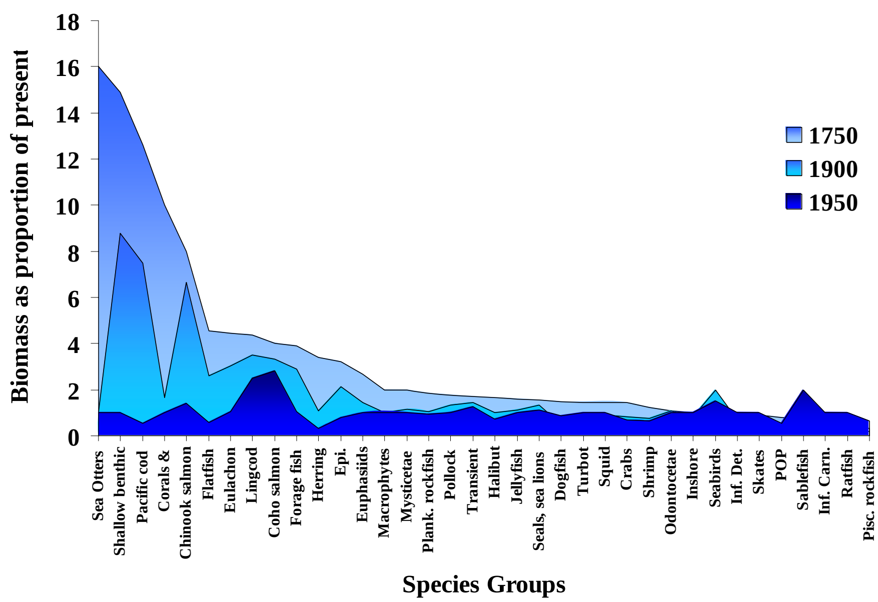

Figure 4.3. 1750s, 1900s, and 1950s Northern BC biomass as a proportion of 2000 biomass. As modelled by Ainsworth *et al.* (2002)

[4] DFO statistical areas 2J3KLNO.

Optimal fishing mortalities were estimated by *Ecosim* using the policy search routine of Christensen and Walters (2004)[5]. The optimal plans describe the gear and effort configurations that will yield the maximum amount of protein in tonnes per year. The optimization settings do not consider catch composition; i.e., all species groups are assumed to be of equal desirability and/or nutritional value. Later, we discuss the implications of this assumption in terms of UN food security preference and cultural-appropriateness criteria.

Protein yield was assessed using vessels and fishing gear in current use in northern BC and an alternate configuration, or *Lost Valley*[6] scenario, a metaphor for a pristine ecosystem, untouched by human fishing (Pitcher *et al*. 2002d, Pitcher 2004b). Simulated fisheries are used to determine the productive potential of the pristine system or Lost Valley. Fishing gears used in Lost Valley simulations are derived largely from the UN Code of Conduct for Responsible Fishing (FAO 1995) which Canada played a lead role in developing. The Lost Valley has been used in numerous simulations for northern BC (Pitcher and Ainsworth 2008; Ainsworth and Pitcher 2008; Pitcher *et al*. 2005; Ainsworth and Pitcher 2005b), and elsewhere (Newfoundland: Pitcher *et al*. 2002d; Hong Kong: Pitcher *et al*. 2002e).

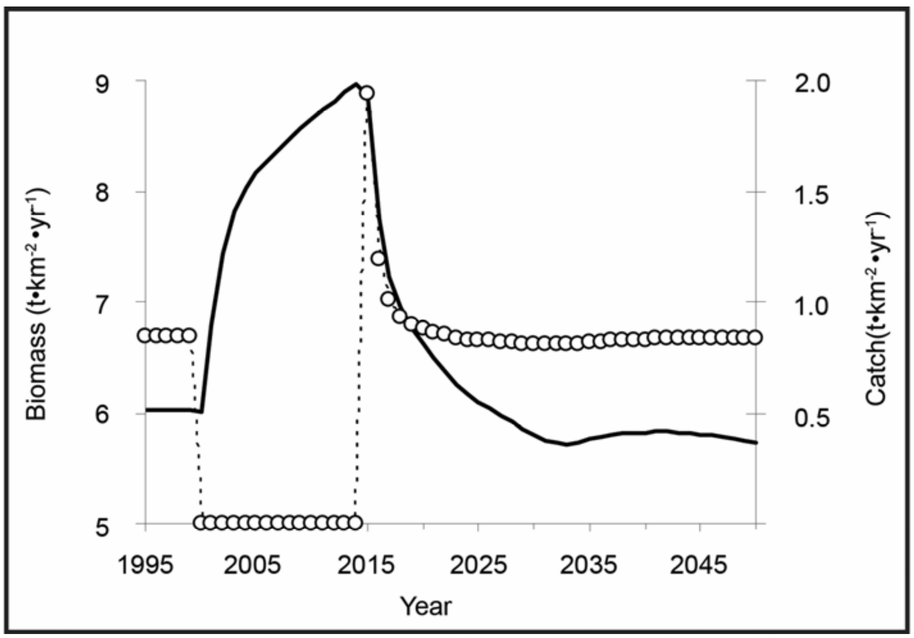

Figure 4.4. Tablefish biomass (solid line) and catch (open circles) projected over fifty years under restoration scenario for 2000 ecosystem. Fishing ceases (2000–14) allowing tablefish biomass to rebuild. Fishing resumes in 2015 using present-day fishing mortalities. The restored biomass is lost in only three to four years

[5] As the policy search routine has no explicit option to maximize catch, a simplified economic analysis was used to determine optimal fishing rates for food production where all fishery products have equal value, regardless of species caught or fishing gear used. By default, the economic optimization maximizes net present value, but by setting a discount rate near zero, the policy search routine can be made to maximize equilibrium level harvests.

[6] The reference is to a fictional scenario where explorers find themselves in a 'Lost World' where creatures from time past live untouched by human influence (Doyle 1912).

The Lost Valley scenario would be recognizable by today's fishers as it retains many of the fishing gears currently in use. It differs in that it reduces the number of juvenile fish groups caught and reduces bycatch to levels practically achievable through gear modification. It also assumes that bottom trawls for groundfish and shrimp have been modified, within realistic limits, to prevent damage to corals, sponges, and other seabed structure (Ardron 2005). The level of fishing effort is a key consideration in the scenarios, and is critically important for ecosystem restoration. Figure 4.4 shows the results of a simple rebuilding plan for the 2000 ecosystem. The beneficial effect of a fourteen-year program to rebuild the ecosystem by shutting off all fishing would be negated in only three to four years of renewed fishing at current fishing levels. This realization is at the root of our exploration of alternate gear and effort configurations in northern BC.

RESULTS

Current Gear–Protein Maximization Scenario

The *Current Gear–Protein Maximization* scenario uses the seventeen major fishing gears used by the northern BC fishing fleet to exploit twenty-five of the fifty-three functional groups in the year 2000 model. This scenario predicts that after twenty-five years of simulated fishing, the 2000 ecosystem could sustain more than four times the current landings. In this case, the ecosystem will have been restructured through selective manipulation and cultivation of species to provide increased levels of catch, even though for most fisheries the optimal fishing effort will be lower than today's levels.

Applied to the 1750s model, the Current Gear–Protein Maximization scenario was able to sustain catches greater than nine times the current level, although fishing effort per gear was adjusted optimally. Fleet configuration, catch composition, bycatch, and discard rates were entered in the same proportion as in today's fisheries[7]. This is for illustrative purposes only, as Figure 4.4 indicates today's fishing effort level would be inappropriate, even in the much more abundant ecosystem of the 1750s.

Current Gear–Economic Maximization Scenario

The *Economic Maximization* scenario considers prices for species, the cost of fishing and discount rate. The Economic max scenario increases landings to 3.7 times the current production rate in the 2000 model and 7.5 times for the 1750s. While this is less than the protein maximization scenario, it improves the quality of catch and so reflects consumer

[7] Some functional groups have increased in productivity since pre-contact as a consequence of exploitation, since older, less productive individuals are removed from the population. This and other factors, caused current catches, when transposed directly, to throw the 1750 model out of balance. Therefore, the absolute level of fishing effort was reduced by an equal proportion across all functional groups, to about 10% of its overall original value as seen in the 2000 model. This adjustment will not affect the results of the policy optimization; it is only a modelling convenience. Since the policy search was free to vary relative fishing mortalities from year zero of the simulation, the initial (reduced) catch was immediately discarded in favour of an optimal gear deployment solution.

preference (e.g. more table fish, less small fish or invertebrates); in terms of total protein production, the economic maximum still provides a great improvement over current BC fisheries.

Ecological Limit Scenario

In the real world, few fishing gears are entirely selective in the species they catch. Total fishing mortality comprises: catch of target species; 'bycatch' of other commercial species for which the fishers are not licensed; 'discards' of small, immature, and non-commercial species; and species that may be damaged by gear, or have their behaviour altered in a way that makes them more accessible to predators. Atlantic cod have been subject to a moratorium since 1992, but bycatch levels of cod in other fisheries are such that they are unlikely to recover (Rosenberg *et al*. 2005).

Mortality of non-target species further reduces the productive potential of the ecosystem, for example, when structure-building organisms such as corals and sponges are removed (Ardron 2005). In an ecosystem context, simultaneous capture of multiple species has other, often-overlooked effects on the productive capacity of the ecosystem through complex foodweb interactions (see also Figure 4.1).

Gear that catches multiple species also limits our ability to manipulate the ecosystem. We cannot easily choose to rebuild one weak species, while increasing catch on a sympatric species using unselective gear. If we could remove the distortions imposed by licensing and regulatory systems and the limitation imposed by the technology of fishing, we would uncover the true ecological limit of production. This limit could be used as a benchmark to evaluate the effectiveness and compatibility of a given suite of fishing gears.

> Ecological or Social Risk?
>
> Restricting catch to protect weaker stocks and 'non-commercial' species is always contentious. In 2004, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended listing the Cultus and Sakinaw sockeye salmon under Canada's Species at Risk Act. The Environment Minister overruled the recommendation on the basis that these populations were 'a fraction of 1%' of total BC sockeye and that their protection would incur 'unacceptably high social and economic costs' (Canada 2004).

The *Ecological Limit* scenario establishes a theoretical ecological limit on food production for both the 2000 and 1750 ecosystems in the absence of technological or regulatory constraints. Each species is assigned to a dedicated anonymous fishing gear to determine a hypothetical "ecologically sustainable yield" obtainable if fisheries were 100% 'clean,' i.e. had no bycatch or discards. Hence, the policy search routine is able to independently vary fishing mortality among species, and sculpt the ecosystem into a configuration that satisfies our objective (Ainsworth *et al*. 2004). The Ecological Limit scenario is constrained in that it has access only to the functional groups that are exploited by present-day BC fisheries.

The Ecological Limit scenario increases landings to six times the current production rate for the 2000 model and eleven times for 1750. This scenario allows us to set an upper limit to productivity as determined by the ecology of the system.

The two following scenarios investigate the hypothesis that increasing the variety of species landed will augment total food production from the ecosystem. We expect this to be achieved by two means. First and simply, there is some potential to increase fisheries landings—particularly on invertebrates and deep-water forage fish (which are made available by contemporary fishing technology) and seals, which were once of considerable importance in the diet of First Nations in northern British Columbia (Monks 2001, and references therein). These populations could sustain new fisheries and contribute to overall food production. Secondly, as more ecosystems become subject to direct population control by fishing, it becomes easier to manipulate the ecosystem into a desired configuration, in this case maximum protein production.

Lost Valley Scenario

The Lost Valley differs from Current Gear scenarios in that it revives efficient and selective Aboriginal fishing technologies such as traps, weirs, and fishwheels. Another significant difference is that it expands the number of functional groups exploited from twenty-five to thirty. The 'new' groups include those that are of traditional importance to First Nations, such as marine mammals and invertebrates. The Lost Valley scenario also includes some emerging and potential fisheries such as live rockfish (*Sebastes* spp.), squid, and jellyfish. This configuration is somewhat idealized, containing only minimal bycatch and discards, but species catch compositions are realistic for each fishing gear modeled. It therefore represents the level of food production that may be realistically achievable through regulation and gear modification.

Increasing the number of functional groups fished to thirty allows the Lost Valley scenario to augment current food production by eight times in the 2000 ecosystem, and twenty-six times in the pre-contact ecosystem. This is achieved by the sustainable exploitation of large invertebrate populations (primarily bivalves, sea urchins, and sea cucumbers) whose cumulative biomasses in the 1750s were estimated to be as much as four times the present-day levels (Ainsworth *et al*. 2002).

Lost Valley Broad Scenario

To understand the relationship between available food production and the range of target species, we have expanded the Lost Valley scenario to include some additional target species. The *Lost Valley Broad* scenario includes fisheries for baleen whales (which is of consequence only in the 1750 comparisons), additional species of forage fish and toothed whales[8]. This scenario exploits thirty-four functional groups.

With more functional groups subject to exploitation, fewer ecosystem components are beyond the direct control of the policy search. The Lost Valley Broad scenario improves food production by approximately eight times current levels in the 2000 system and twenty-eight

[8] Orca, dolphins and porpoises. Note that the Lost Valley Broad scenario is designed to explore how much protein the ecosystem could produce, not to recommend fisheries on these or other species. Orcas are of very high cultural significance for BC Aboriginal people, so are unlikely to have been hunted.

times in the 1750 system. However, this is only a marginal improvement in food production over the previous Lost Valley scenario which already exploits a large proportion of ecosystem components.

IMPLICATIONS FOR TABLE FISH

Up to a certain point, increasing the number of species approaches fishing *across* the food web by maintaining trophic relationships in a proportional sense, as opposed to fishing *down* (Pauly *et al*. 2001, 1998). Past that point, extreme protein production scenarios, such as the Lost Valley and Lost Valley Broad, increase the production of low trophic level species like invertebrates at the expense of table fish. Figure 4.5 shows the results of optimizing for protein production. After twenty five years of manipulation, the 2000 ecosystem could sustain much greater catch rates than are currently realized by BC fisheries. The 1750 ecosystem would have been able to sustain greater catch rates still than the 2000 ecosystem. Fisheries for table fish continue to some extent in these extreme food production scenarios, but cannot hope to match the quantity of protein from invertebrates due to limits imposed by the carrying capacity of the ecosystem.

Sustainable Catches after Twenty-Five Years

Table 4.2 presents sustainable catch rates after twenty-five years of simulated fishing for the five scenarios as multiples of current annual catch. With reduced effort, the current BC fleet structure is able to manipulate the ecosystem to support much greater catch rates than are currently enjoyed once the priority for protein production is factored into the long-term policy agenda. The ecological limit on protein production from currently-targeted species is revealed by the Ecological Limit scenario. Increasing the number of species, as in the Lost Valley and Lost Valley Broad scenarios, generates a marked increase in food production over current levels. Regardless of scenario, the pre-European contact ecosystem vastly outperforms the present-day ecosystem, indicating that sustainable production potential has been lost.

Table 4.2. Potential protein production rates for five fishing scenarios in northern BC

Scenario	# of groups fished	Protein production rate after 25 years relative to current BC fisheries	
		1750 model	2000 model
Current Gear (protein max)	25	9.1	4.1
Current Gear (economic max)	25	7.5	3.7
Ecological Limit	25	11	5.7
Lost Valley	30	26	8.0
Lost Valley Broad	34	28	8.4

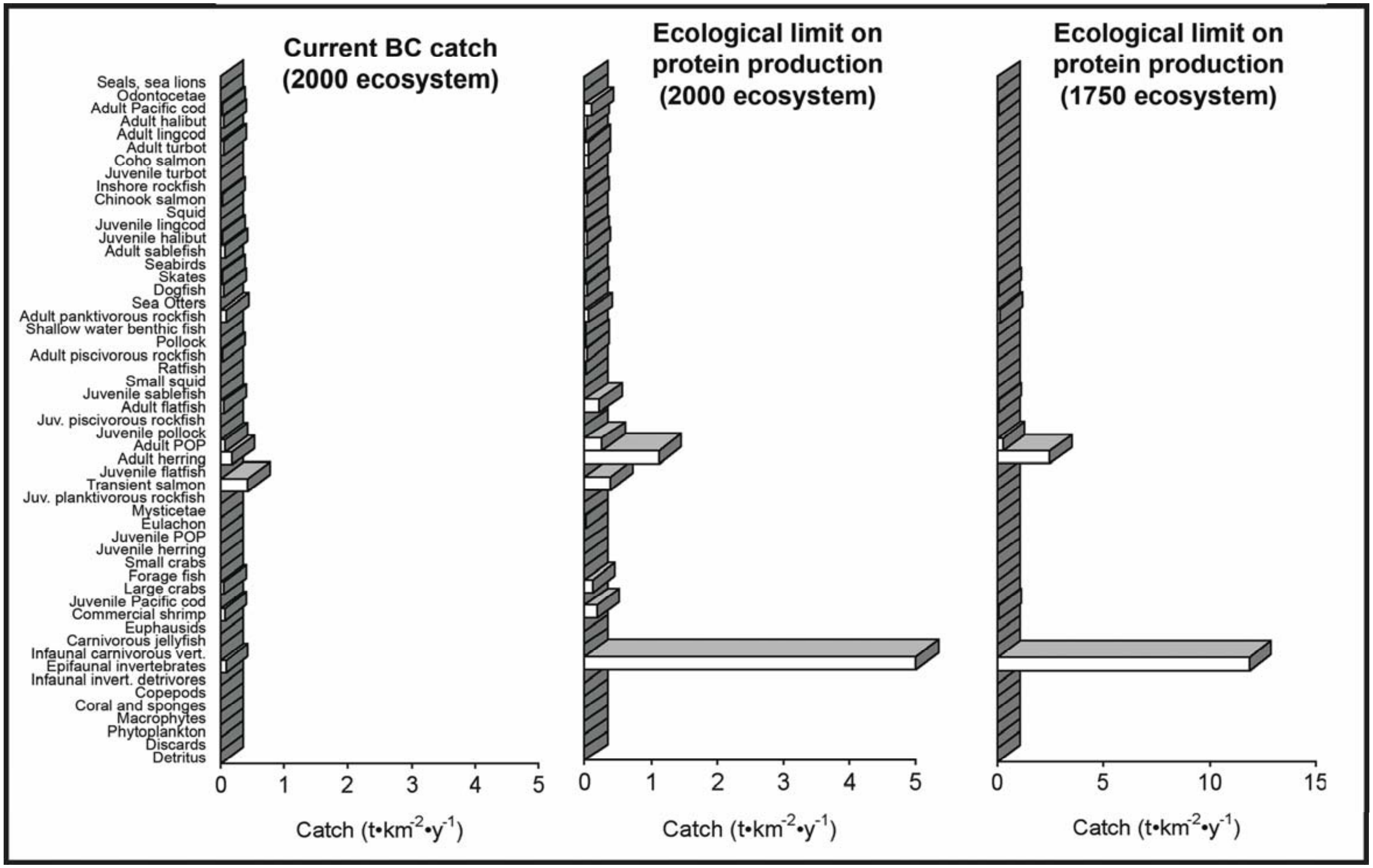

Figure 4.5. Catch by functional group. The 2000 ecosystem could be manipulated to sustain greater catch rates than are currently realized by today's fisheries. The 1750 ecosystem was capable of producing much more. Protein production is maximized using large invertebrate fisheries

Figure 4.6 summarizes the sustainable fishing capacity of the 2000 and 1750s ecosystems under different extraction scenarios. Bar graphs show the equilibrium (end-state) rate of production in terms of annual catch for pelagic or surface-living fish, demersal or bottom-dwelling fish and invertebrate functional groups. As a baseline for comparison with the theoretical optima, the year 2000 food production in northern BC shown in the left-most bar in Figure 4.6a is derived directly from catch statistics (see Ainsworth *et al*. 2002 for data sources).

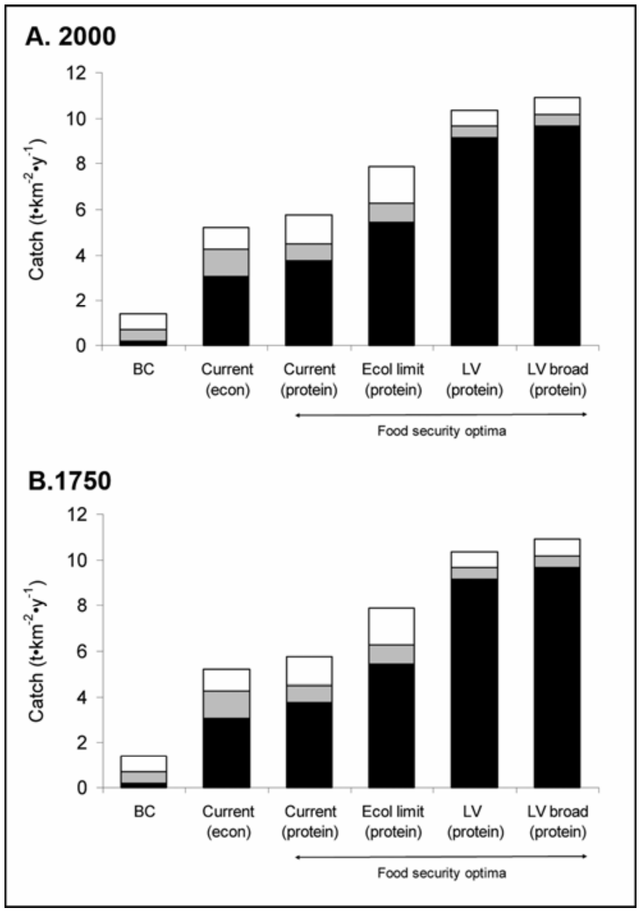

Figure 4.6. Optimal equilibrium catches for 2000 (A) and 1750 (B) after twenty-five years. Black bars show invertebrates; grey bars show demersal fish; white bars show pelagic fish. Scenarios left to right: 'BC' shows real-world catch in northern British Columbia in 2000; current gear types optimized for economic performance; current gear types optimized for protein production; Ecological limit on protein production from currently targeted species; LV (Lost valley) pursues additional fish species; LV broad pursues additional fish and invertebrate fisheries

The economic objective (Econ) shows the equilibrium catch level when fishing is optimized for maximum economic return over twenty-five years, as opposed to catch with the food security optima, also optimized over twenty-five years. Value is a fair representation of "*preference*," in the UN food security definition to the extent that it reflects what customers are prepared to offer.

It does not, however, reflect all species used by First Nations or all that could be exploited. Although the point of the economic optimization is not strictly to increase catch, there is still a great improvement over current landings since economic return is linked to catch volume. The four right-most bars in Figure 4.6a and b show food production under the different modelling scenarios.

Whole-Ecosystem Manipulation

Figure 4.7 shows evidence of whole ecosystem manipulations by the optimal fishing policies in order to support a larger sustainable catch.

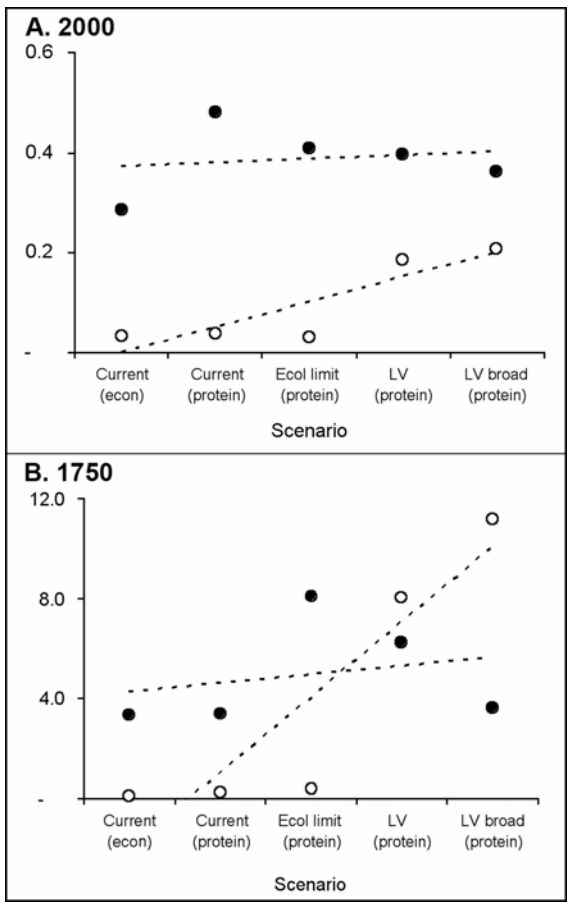

Figure 4.7. Changes in ecosystem structure (average change per functional group) after twenty-five years for 2000 (A) and 1750 (B) ecosystems. Closed circles show changes in exploited functional groups; open circles show changes in unexploited groups. From left to right, increased catch influences the ecosystem more heavily. As ecosystem manipulation increases, unexploited groups are altered from their original condition by more than exploited groups, suggesting that they are manipulated to support higher catch rates. The 1750 ecosystem has a greater potential for manipulation than 2000, both in terms of an absolute change from the initial condition, and in the relative contribution of non-exploited groups towards supporting greater catches. Scenarios left to right: Current gear types optimized for economic performance; current gear types optimized for protein production; Ecological limit on protein

production from currently targeted species; LV (Lost Valley) pursues additional fish species; LV broad pursues additional fish and invertebrate fisheries

Relative biomass changes from the initial ecosystem condition (as a result of optimal fishing scenarios) are compared between functional groups which are subject to fishing, and those which are not. After twenty five years, non-exploited groups have changed from their original condition by more than those subject to fishing, indicating that the non-exploited groups have been maneuvered to support the additional food production through trophic interactions. This may be viewed as a type of 'ecosystem service.'

From left to right in Figure 4.7, as the fishing strategy becomes more comprehensive, as in the Ecological Limit scenario, or with a greater breadth of target species as with the Lost Valley and Lost Valley Broad scenarios), two things occur. The sustainable catch increases (see Figure 4.5), and the ecosystem biomass equilibrium are manipulated further from its original condition. Results suggest that the 1750 ecosystem has a greater potential for manipulation than 2000, both in terms of an absolute change from the initial condition and in the relative contribution of non-exploited groups towards supporting the fished groups.

EXTINCTION RISK POSED BY CURRENT FLEET *VS* ALTERNATE STRATEGIES

> One man stood before the microphone, his face grey with fatigue and anxiety, and said in a breaking voice: "Let's face it: we've caught them all" (Storey 1993, in Ommer 1994).

The words of a fisher at a post-mortem on the collapse of the Atlantic cod, one of the great fish stocks once deemed inexhaustible (Byron 1812–18; Huxley 1883) signal the dawn of awareness that we can drive fish populations to the verge of biological extinction. This realization is also recent in the scientific community (Pitcher 1998a, 2004c; Carlton *et al*. 1999; Cheung and Pitcher 2004).

The depletion/extirpation risk posed by the Current Gear *vs* the Lost Valley scenarios was determined by driving the 2000 model for one hundred years with a random selection of primary production multipliers derived from an annual climate reconstruction series from 1638–1988 (Gedalof and Smith 2001). Figure 4.8 thus simulates the combined effect of fishing and *natural regime variability* over 350 years ending 1988.

Figure 4.8a shows that euphausiids, copepods, and squid are at significant risk of 80% depletion under either configuration. Lingcod are also at high risk, but substantially less in the Lost Valley scenario. The risk of extinction shown in Figure 4.8b is negligible or substantially less for the Lost Valley configuration than for the Current Gear scenario. The results indicate that fishing the present day ecosystem with fully sustainable and responsible fisheries considerably reduces the risk of extinction and extirpation in the face of past natural climate variability. Climate change may increase natural variability in the future, but has already been shown to have the effect of moving the spawning area of fish northwards, as for small demersal fish in the North Sea (Perry *et al*. 2005) and herring in the Strait of Georgia (Dr Tom Therriault, Fisheries and Oceans Canada, pers. comm.). A relatively small rise in ocean temperature could make BC waters unsuitable for sockeye salmon (Welch *et al*. 1998) with devastating effect on Aboriginal people and the commercial fishery.

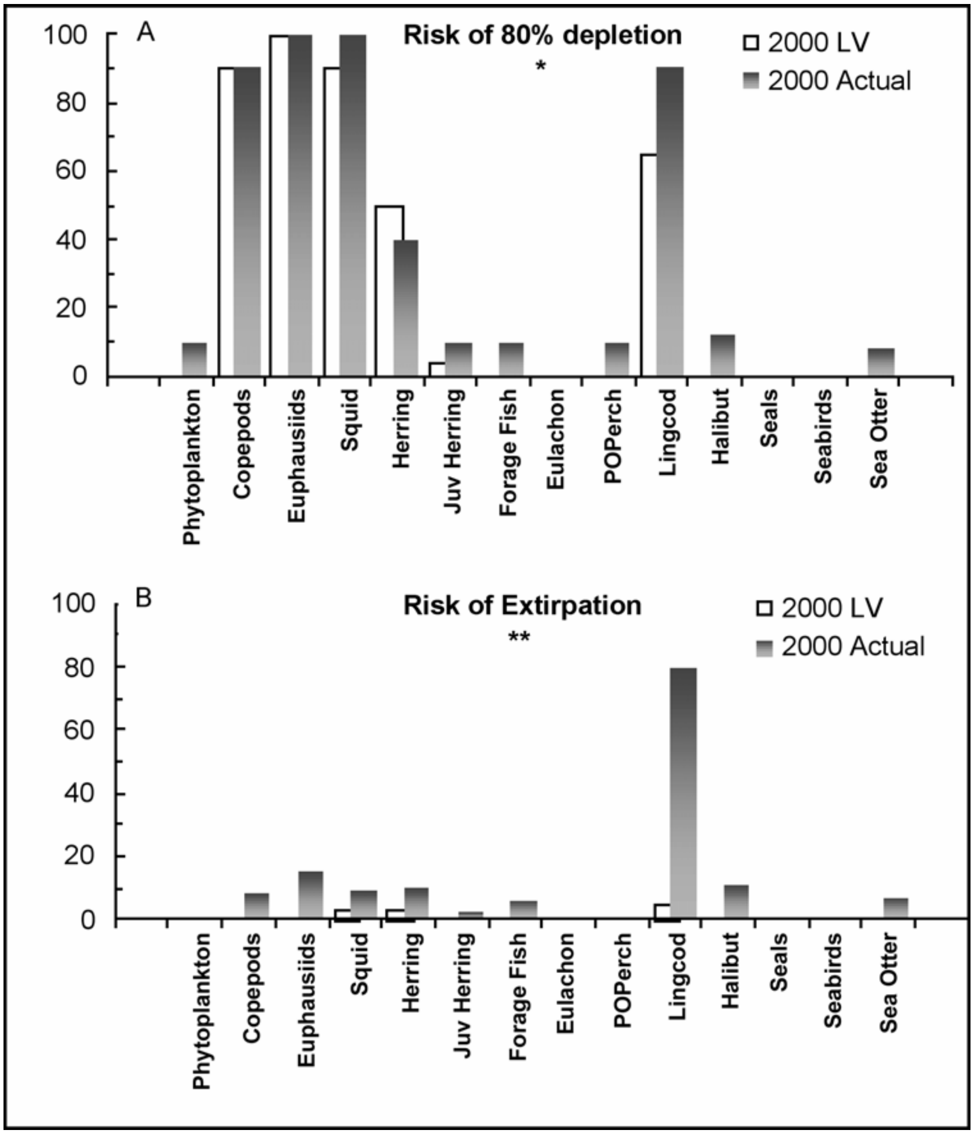

Figure 4.8. Risk of 80% depletion (A) and extirpation (B) in the year 2000 northern BC ecosystem with climate variation and model parameter uncertainty after one hundred years of fishing with the 'Actual' (present-day) and Lost Valley (LV) fisheries. Risks are estimated from one hundred Monte Carlo simulations with all principal model parameters allowed to vary within a 40% range. Risks are compared using the Wilcoxon paired signed ranks test: * = significant at the 5% level; ** = significant at the 1% level

RESTORATION—IMPEDIMENTS AND INCENTIVES

However discomforting as an audit of our management performance, the past models show significant potential for restoration (Figure 4.3; Table 4.2). The downside is that achieving the benefits would require a sharp reduction in catch, with short- to medium-term costs to industry. Single species assessment and management is problematic because it creates divisions within fisheries science and management that are reflected in the structure of government and industry (Finlayson 1994). Hence, the current BC fleet configuration is a product of 150 years of perverse evolutionary pressures, most notably reduction in number of species *per* fishing licence, leading to a proliferation of vessels, licences, and quota valued, at ~US$2 billion (Ecotrust 2004; Nelson 2004). Escalating costs of fishing and buyback or 'fleet rationalization' plans entrain loss of licences by small vessels with devastating effects on coastal communities and small-scale fishers (Gislason *et al*. 1996).

Individual fishers and their families have heavy, often multi-generational, investments in knowledge and skills, vessels, fishing gear, and social relationships ranging from collegial industry associations to struggles with management (Newell and Ommer 1999, and references therein). This investment relates almost exclusively to the narrow range of species fished. The need to protect these economic, cultural, and social investments escalates as fish stocks are depleted, perpetuating scientific, management, and industry structures that are extremely resistant to change (Finlayson 1994). Increased specialization leads to reduced ecosystem knowledge and higher competition.

On the incentive side, simulated rebuilding to 1950s biomass levels shows that moderate restoration trajectories can give a positive return equal to or greater than bank interest at 5% (Ainsworth and Pitcher 2008). A new method of quantifying benefits to future generations through intergenerational discounting (Ainsworth and Sumaila 2005; Sumaila 2004; Sumaila and Walters 2005) adds significantly to net present value and strengthens the argument for reinvestment in 'natural capital.'

The first step is to involve the entire maritime community, First Nations, commercial and sport fishers, conservation organizations, managers, and policy-makers in developing management and restoration strategies that increase their collective understanding of the ecosystem. Second, is for government to open the door to radically different approaches that encourage all concerned to harness their creative energy to making it happen.

Can Biodiversity, Table Fish, and Fishers Co-exist?

Tradeoff analysis of restored systems (Ainsworth and Pitcher 2008) shows that maximizing for economic return has a catastrophic effect on abundance, biodiversity, and trophic structure (and indeed seabed structure) in marine ecosystems. This is, in fact, the experiment we have performed over the past one hundred years, driving high trophic level species down to between 10% and 1% of their 1900 biomass globally and on both coasts of Canada. Reduction in fisheries and indeed forestry jobs and revenue is a major driver of the search for 'alternatives' such as farmed salmon and oil and gas. Maximizing for social benefits also has a negative effect on ecological values, while maximizing for biodiversity and ecosystem integrity provides unacceptably low economic and social returns (Ainsworth and Pitcher 2008). Is there any solution that would be a win for biodiversity, table fish, and fishers?

Marine Protected Areas and Fisheries Management

Marine protected areas (MPAs) are increasingly advocated as a way to offset the depletion of marine ecosystems. They are highly effective for the protection of sessile and territorial species, but much less so for moderately migratory species such as cod. Guénette *et al.* (2000) showed that 80% total closure of the east coast fishery would have delayed, but not prevented the cod collapse, while only 20% closure, plus fishing restrictions on migration corridors, would have been effective in averting the collapse. Taken individually, the benefit of MPAs is limited and offset by the contention caused, but a network of MPAs providing protection for inshore areas of high "conservation utility" (Ardron 2002), key oceanic habitat (Worm *et al*. 2003), and migration corridors (Guénette *et al*. 2000), would go a long way to meeting biodiversity criteria, preventing depletion and extinction and providing spillover benefits to fishers and ecotourism operators and many other ecosystem values (Sumaila *et al*., in press). Involvement of the maritime community in the design of such a network is essential to agreement on utility, location, and compliance.

The Role of Quotas

Individual transferable quotas (ITQs) are often advocated as another cure-all for whatever ails fisheries and marine systems. McRae and Pearse (2004) recommend that BC salmon licences be converted to quotas that can be traded on the market. Transferable quotas have two major downsides. Firstly, they lend themselves to concentration in the hands of wealthy individuals and corporations, effectively alienating access to fisheries from Aboriginal and coastal communities, with serious social and cultural consequences including the loss of traditional and local ecological knowledge vital to our understanding of ecosystem function (Coward *et al*. 2000). Secondly, ITQ holders are only interested in the species they catch, i.e., have no incentive to protect aspects of the system that provide broader cultural, social, ecological, and ecosystem service benefits (Sumaila and Bawumia 2000).

Community quotas, defined as the permanent vesting of access rights in coastal communities, do have the potential to re-link human communities to the ecosystems that called them into being and sustained them for thousands of years in the case of First Nations and hundreds of years for east coast fishing communities (Haggan and Brown 2002).

Policy Implications

The policy implications of ecosystem restoration and greater access for Aboriginal and other communities whose long-term survival depends on ecosystem health include:

- Potential to satisfy Canadian legislative requirements to manage for the benefit of future as well as present generations (Fisheries Act, Oceans Act, Marine Conservation Areas Act) and live up to Canada's obligations as a signatory to the Convention on Biological Diversity;

- Applying intergenerational discounting (Sumaila and Walters 2005) would go a long way towards meeting the First Nation's ethic of seventh-generational thinking;
- Improved conservation and increased food security on both coasts;
- More fish for the settlement of treaties with First Nations and more viable coastal economies with reduced government transfer payments (Haggan and Brown 2002);
- Retention and growth in practice and intergenerational transfer of traditional and local knowledge (Berkes 1999; Berkes and Turner 2006; Garibaldi and Turner 2004; Turner 2003; Turner and Berkes 2006; Turner *et al*. 2000) with significant benefit to resource management;
- Increased availability of culturally-appropriate and nutritionally-superior foods from local sources, coupled with increased awareness of the health hazards of junk food, as is happening in UK and Canadian schools, would materially contribute to health in coastal communities (Wong 2004); and,
- Strengthen cultural and social activities based on the marine ecosystem and environment.

CONCLUSION

Humans have a surprising ability to change marine ecosystem structure. Evidence suggests that the west coast ecosystem had been manipulated to produce very large surpluses of salmon, invertebrate and terrestrial species long before European contact (Haggan *et al*. 2006; Turner 2005). Benchmarks of abundance, biodiversity, and trophic structure established by collaborative modelling of past ecosystems indicate substantial potential for restoration (Figure 4.3).

The implications for food security are intriguing. Scenarios that maximize the amount of edible protein divert primary production from table fish to species that do not meet the cultural preferences of Aboriginal and other coastal communities or satisfy the desire of most people to be able to serve and consume large fish such as salmon and cod. These scenarios do not satisfy UN food security stipulations, that food be, "*personally acceptable and culturally appropriate . . . produced in ways that are environmentally sound and socially just.*" The criteria of "ecosystem justice" (Brunk and Dunham 2000) are not satisfied, nor are the 'existence' and other values of long-lived, high trophic level species maintained (Sumaila *et al*., in press).

Somewhat surprisingly, the 'Current Gear–Economic Maximization' scenario that adjusts fishing effort to maximize economic return; came closest to matching UN food security criteria. This is because market price reflects preference for table fish, though we note that not all species traditionally-harvested or valued by Aboriginal people were included in the model.

The Ecological Limit scenario sets a theoretical upper limit on the amount of protein that could be produced by 100% clean fisheries, i.e. with no bycatch, discards or habitat damage. There is significant potential for fishers and other maritime community interests to use this type of scenario to explore alternate ways to catch or otherwise use ecosystem goods and services sustainably. Creating the enabling conditions requires a commitment by government to 'open up' the entire structure of fisheries science and management and to deal effectively and fairly with the ~US$2 billion in vessels, gear, and quota (Ecotrust 2004, Nelson 2004).

In conclusion, ecosystem restoration requires a systemic approach that engages all concerned in the design of MPA networks that protect critical habitat *and* maximize fishery benefits, regulations to protect migratory species and some form of area licensing that provides guaranteed access to communities with a long term interest in ecosystem health and diversity as the key to their own survival. This requires nothing less than a complete overhaul of fisheries science and management matched by government willingness to actively encourage fishers in ways to use their skill to exploit a range of species. Experience with the Back to the Future project indicates that the fishers are willing.

References

Ainsworth, C., and T. J. Pitcher. 2008. Back to the future in northern British Columbia: Evaluating historic marine ecosystems and optimal restorable biomass as restoration goals for the future. Pages 317-329 *in* J. Nielsen, J. J. Dodson, K. Friedland, T. R. Hamon, J. Musick, and E. Verspoor, editors. Reconciling fisheries with conservation: Proceedings of the fourth world fisheries congress. American Fisheries Society, Bethesda.

Ainsworth, C., J. J. Heymans, and T. J. Pitcher. 2004. Policy search methods for back-to-the-future. Pages 48-63 *in* T. J. Pitcher, editor. Back to the future: Advances in methodology for modelling and evaluating past ecosystems as future policy goals. Fisheries Centre Research Reports 12(1), Vancouver.

Ainsworth, C., J. J. Heymans, T. J. Pitcher, and M. Vasconcellos editors. 2002. Ecosystem models of northern British Columbia for the time periods 2000, 1950, 1900 and 1750. Fisheries Centre Research Reports 10(4), Vancouver.

Ainsworth, C., and T. J. Pitcher. 2005. Evaluating marine ecosystem restoration goals for Northern British Columbia. Pages 419-438 *in* G. H. Kruse, V. F. Gallucci, D. E. Hay, R. I. Perry, R. M. Peterman, T. C. Shirley, P. Spencer, B. Wilson, and D. Woodby, editors. 21st Lowell Wakefield fisheries symposium. University of Alaska Sea Grant, Anchorage, [URL:http://www.uaf.edu/seagrant].

Ainsworth, C., and U. R. Sumaila. 2005. Intergenerational valuation of fisheries resources can justify long-term conservation: A case study in atlantic cod. Canadian Journal of Fisheries and Aquatic Sciences 62(5):1104-1110.

Alphonso, C. 2004. Ontario Bans Junk Food from School Machines. The Globe and Mail (October 21):A9, Toronto.

Anderson, M. K. 2005. Tending the wild: Native American knowledge and the management of California's natural resources. University of California Press, Berkeley.

Ardron, J. A. 2005. Protecting British Columbia's corals and sponges from bottom trawling. Living Oceans Society, Sointula, BC.

Ardron, J. A. 2002. A recipe for determining benthic complexity: An indicator of species richness. Pages 169-176 *in* J. Breman, editor. Marine geography: GIS for the oceans and seas. ESRI Press, Redlands.

Baum, J. K., R. A. Myers, D. G. Kehler, B. Worm, S. J. Harley, and P. A. Doherty. 2003. Collapse and conservation of shark populations in the northwest Atlantic. Science 299(5605):389-392.

Belloc, H. 1896. The bad child's book of beasts. Alden, Oxford. Reissued 1965 by Alfred A. Knopf, New York.

Berkeley, S. A., C. Chapman, and S. M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. Ecology 85(5):1258-

1264.
Berkes, F. 1999. Sacred ecology: Traditional ecological knowledge and resource management. Taylor & Francis, Philadelphia, PA.
Berkes, F., and N. J. Turner. 2006. Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. Human Ecology 34(4):479-494.
Birkeland, C., and P. K. Dayton. 2005. The importance in fishery management of leaving the big ones. Trends in Ecology & Evolution 20(7):356-358.
Boas, F. 1916. Tsimshian mythology. , Bureau of American Anthropology for the years 1909-1910 edition. Government Printing Office, Washington, DC.
Bond, S. 2005. Message from the minister and accountability statement, 2005–2008 service plan update: Http://www.bcbudget.gov.bc.ca/sp/educ
Brashares, J. S., P. Arcese, M. K. Sam, P. B. Coppolillo, A. R. E. Sinclair, and A. Balmford. 2004. Bushmeat hunting, wildlife declines, and fish supply in West Africa. Science 306(5699):1180-1183.
Brunk, C., and S. Dunham. 2000. Ecosystem justice in the Canadian fisheries. Pages 9-33 *in* H. G. Coward, R. E. Ommer, and T. J. Pitcher, editors. Just fish: Ethics and Canadian marine fisheries. ISER Books, St. John's.
Bundy, A., G. R. Lilly, and P. A. Shelton. Canadian Technical Report of Fisheries and Aquatic Science. A mass balance model of the newfoundland-labrador shelf. Fisheries and Oceans, Canada.
Byron, G. G. 1812-18. *Childe Harolde's Pilgrimage*. Reissued 2004 edition. Kessinger, Whitefish, Montana.
Canada, 2004. Canada Gazette.... (October 23) Part One.
Carlton, J. T., J. B. Geller, M. L. Reaka-Kudla, and E. A. Norse. 1999. Historical extinctions in the sea. Annual Review of Ecology and Systematics 30:515-538.
Cheung, W. W-L. and T. J. Pitcher. 2004. An index expressing risk of local extinction for use with dynamic ecosystem simulation models. Fisheries Centre Research Reports, 12(1), Vancouver.
Cheung, W. W., and Y. Sadovy. 2004. Retrospective evaluation of data-limited fisheries: A case from Hong Kong. Reviews in Fish Biology and Fisheries 14:181-206.
Cheung, W.W-L., R. Watson, and T. Pitcher, 2002. Policy simulation of fisheries in the Hong Kong marine ecosystem. UBC Fisheries Centre Report 10(2), Vancouver.
Christensen, V., and D. Pauly. 1992. ECOPATH II - A system for balancing steady-state ecosystem models and calculating network characteristics. Ecological Modeling 61:169-185.
Christensen, V., and C. J. Walters. 2004. Trade-offs in ecosystem-scale optimization of fisheries management policies. Bulletin of Marine Science 74(3):549-562.
Christensen, V., S. Guenette, J. J. Heymans, C. J. Walters, R. Watson, D. Zeller, and D. Pauly. 2003. Hundred-year decline of north Atlantic predatory fishes. Fish and Fisheries 4(1):1-24.
Clark, C. W. 1973. The economics of overexploitation. Science 181(4100):630-634.
Coleman, F. C., W. F. Figueira, J. S. Ueland, and L. B. Crowder. 2004. The impact of United States recreational fisheries on marine fish populations. Science 305(5692):1958-1960.
Cooke, S. J., and I. G. Cowx. The role of recreational fishing in global fish crises. Bioscience 54(9):857-859.
Coward, H. G., R. E. Ommer, and T. J. Pitcher editors. 2000. Just fish: Ethics and Canadian marine fisheries. ISER Press, St. John's, Nfld.
Cushing, D. H. 1988. The provident sea. Cambridge University Press, New York.
Deur, D., and N. J. Turner. 2005. Keeping it living: Traditions of plant use and cultivation on the northwest coast of North America. UBC Press, Vancouver, BC.

Diamond, J. M. 2005. Guns, germs, and steel: The fates of human societies. W.W. Norton, New York.

Doyle, A. C. 1912. The lost world, Reissued 2004 by Barnes and Noble.

Drake, A., and L. Wilson. 1991. Eulachon: A fish to cure humanity. UBE Museum of Anthropology Note No. 32:37.

Ecotrust. 2004. Catch 22: Conservation, communities and the privatization of BC fisheries. Ecotrust Vancouver and Portland.

Edge Research Inc. 2002. Public opinion poll on fully protected marine areas in New England and Atlantic Canada. http://www.clf.org/hot/20020216.htm.

FAO. 1995. Code of conduct for responsible fisheries, Food and Agriculture Organization of the United Nations, Rome.

Finlayson, A. C. 1994. Fishing for truth: A sociological analysis of northern cod stock assessments from 1977 to 1990. ISER Press, St. John's, Newfoundland.

Garibaldi, A., and N. J. Turner. 2004. Cultural keystone species: Implications for ecological conservation and restoration. Ecology and Society 9(3):1.

Gedalof, Z., and D. J. Smith. 2001. Interdecadal climate variability and regime-scale shifts in Pacific North America. Geophys.Res.Lett 28(8):1515–1518.

Gislason, G., E. Lam, and M. Mohan. 1996. Fishing for answers: Coastal communities and the BC salmon fishery.

Glavin, T. 1996. Dead reckoning: Confronting the crisis in pacific fisheries. Douglas & McIntyre, Toronto / Greystone Books, Vancouver.

Haggan, N. 2000. Back to the future and creative justice: Recalling and restoring forgotten abundance in Canada's marine ecosystems. Pages 83-99 *in* H. G. Coward, R. E. Ommer, and T. J. Pitcher, editors. Just fish: Ethics in the Canadian coastal fisheries. ISER Books, St. John's.

Haggan, N., and P. Brown. 2002. Aboriginal fisheries issues: The west coast of Canada as a case study. Fisheries Centre Research Reports, Report 10(8), Vancouver.

Haggan, N., N. J. Turner, J. Carpenter, J. T. Jones, C. Menzies, and Q. Mackie. 2006. 12,000+ years of change: Linking traditional and modern ecosystem science in the Pacific Northwest. UBC Fisheries Centre Working Papers, Report 2006-02, Vancouver.

Hall, S. J. 1999. The effects of fishing on marine ecosystems and fisheries. Blackwell Publishing, Oxford.

Hauser, L., G. J. Adcock, P. J. Smith, J. H. Bernal Ramírez, and G. R. Carvalho. 2002. Loss of microsatellite diversity and low effective population size in an overexploited population of New Zealand snapper (*Pagrus auratus*). Proceedings of the National Academy of Sciences of the United States of America 99(18):11742.

Hays, G. C., A. C. Broderick, B. J. Godley, P. Luschi, and W. J. Nichols. 2003. Satellite telemetry suggests high levels of fishing-induced mortality in marine turtles. Marine Ecology Progress Series 262:305-309.

Heymans, J. J. 2003. A revised model for Newfoundland and southern Labrador (2J3KLNO) for the time period 1985–1987. Fisheries Centre Research Reports 11(5), Vancouver.

Hilborn, R., T. A. Branch, B. Ernst, A. Magnusson, C. V. Minte-Vera, M. D. Scheuerell, and J. L. Valero. 2003. State of the world's fisheries. Annual Review of Environment and Resources 28(1):359-399.

Huxley, T. H. 1883. Inaugural address, international fisheries exhibition, London. Pages 1-22 *in* Ecosystem principles advisory panel, 1998, ecosystems-based fisheries management: A report to congress by the Ecosystems Principles Advisory Panel, Seattle.

ICES. 1995. Herring assessment working group for the area south of 62^{0}N. International Council for the Exploration of the Sea, Report ICES C.M. 1995/Assess: 13, Copenhagen.

IFFO. International fishmeal and fish oil organisation: Http://www.iffo.net/default.asp?fname=1&sWebIdiomas=1&url=253, .

Jones, J. T. 2002. "We looked after all the salmon streams." traditional Heiltsuk cultural stewardship of salmon and salmon streams: A preliminary assessment. MSc. School of Environmental Studies, University of Victoria, Victoria, BC.

Jones, R. R. 1999. Haida names and utilization of common fish and marine mammals. *in* N. Haggan, and A. Beattie, editors. Back to the future: A re-construction of the Hecate Strait ecosystem as it might have been in the early 1900s. Fisheries Centre Research Reports 7(3), Vancouver.

Jones, R. R., and T. Williams-Davidson. 2000. Applying Haida ethics in today's fishery. Pages 100-117 *in* H. G. Coward, R. E. Ommer, and T. J. Pitcher, editors. Just fish: Ethics and Canadian marine fisheries. ISER Books, St. John's.

Law, R. 2000. Fishing, selection, and phenotypic evolution. ICES Journal of Marine Science 57(3):659.

Marshall, I. 1996. A history and ethnography of the Beothuk. McGill–Queen's University Press, Montreal.

McRae, D. M., and H. Pearse. 2004. Towards a sustainable fishery on Canada's pacific coast. Treaties and Transition. Federal-Provincial, Post Treaty Fisheries Joint Task Group, Vancouver.

Meggs, G. 1991. The decline of the BC fishery. Douglas and McIntyre, Vancouver /Toronto.

Melville, H. Moby dick or, the whale. Harper and Brothers, New York.

Milazzo, M. 1998. Subsidies in world fisheries: A reexamination. World Bank Publications, Washington, DC.

Miller, P. 2003. Thailand: Profile of the world's largest farmed shrimp producer. The Blues of a Revolution: The Damaging Impacts of Shrimp Farming. Pages 63-120 in I. de la Torre and D. Barnhizer, editors, The blues of a revolution, ISA Net/APEX, Seattle.

Monks, G. G. 2001. Quit blubbering: An examination of Nuu'chah'nulth (nootkan) whale butchery. International Journal of Osteoarchaeology 11(1-2):136-149.

Munro, G., and U. R. Sumaila. 2002. The impact of subsidies upon fisheries management and sustainability: The case of the north Atlantic. Fish and Fisheries 3(4):233-250.

Myers, R.A. and Worm, B. (2003) Rapid worldwide depletion of predatory fish communities. Nature 423:280-283

Naughton, P. Junk foods to be banned in British schools. London Times (September 28, 2005):March 25, 2008.

Nelson, S. 2004. Commercial fishing license, quota and vessel values. Prepared for Fisheries and Oceans Canada. Nelson Bros. Fisheries, Vancouver.

Newell, D., and R. E. Ommer. 1999. Fishing places, fishing people: Traditions and issues in Canadian small-scale fisheries. University of Toronto Press, Toronto.

Ommer, R. E. 1994. One hundred years of fishery crisis in Newfoundland. Acadensis 23:5-20.

Ommer, R.E. and the Coasts Under Stress Team. 2007. Coasts under stress: Understanding restructuring and social-ecological health in coastal communities. McGill-Queens University Press, Montreal.

Ommer, R. E., N. J. Turner, M. MacDonald, and P. R. Sinclair. 2007. Food security and the informal economy. *in* C. C. Parrish, N. J. Turner, and S. Solberg, editors. Resetting the kitchen table: Food security, culture, health and resilience in coastal communities. Nova Science Publishers, Inc., New York.

Parrish, C. C., N. J. Turner, and Ommer, Rosemary E. Solberg, Shirley M. 2007. What food security in coastal communities really means. *in* C. C. Parrish, S. Solberg, and N. J. Turner, editors. Resetting the kitchen table: Food security, culture, health and resilience

in coastal communities. Nova Science Publishers, Hauppauge, NY.
Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10:430.
Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres Jr. 1998. Fishing down marine food webs. Science 279(5352):860.
Pauly, D., M. L. Palomares, R. Froese, P. Sa-a, M. Vakily, D. Preikshot, and S. Wallace. 2001. Fishing down Canadian aquatic food webs. Can.J.Fish.Aquat.Sci. 58(1):51-62.
Perry, A. L., P. J. Low, J. R. Ellis, and J. D. Reynolds. 2005. Climate change and distribution shifts in marine fishes. Science 308(5730):1912-1915.
Pitcher, T. J. 2004. The problem of extinctions. Pages 21-28 *in* T. J. Pitcher, editor. Back to the future: Advances in methodology for modelling and evaluating past ecosystems as future policy goals. Fisheries Centre Research Reports 12(1), Vancouver.
Pitcher, T. J. 2001. Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. Ecological Applications 11(2):601-617.
Pitcher, T. J. 1998. A cover story: Fisheries may drive stocks to extinction. Reviews in Fish Biology and Fisheries 8(3):367-370.
Pitcher, T. J., and C. Ainsworth. 2008. Back-to-the-future: A candidate ecosystem-based solution to the fisheries problem. Pages 365-383 *in* J. Nielsen, J. J. Dodson, K. Friedland, T. R. Hamon, J. Musick, and E. Verspoor, editors. Reconciling fisheries with conservation: Proceedings of the 4th world fisheries congress. American Fisheries Society, Bethesda.
Pitcher, T. J., C. Ainsworth, E. A. Buchary, W. W. Cheung, R. Forrest, N. Haggan, H. Lozano, T. Morato, and L. Morissette. 2005. Strategic management of marine ecosystems using whole-ecosystem simulation modelling: The 'Back-to-the-future' policy approach. Pages 199-258 *in* E. Levner, I. Linkov, and J. Proth, editors. The strategic management of marine ecosystems. Springer, NATO Science Series: IV: Earth and Environmental Sciences.
Pitcher, T. J., and J. Alheit. 1995. What makes a hake? A review of the critical biological features that sustain global hake fisheries. Pages 1–14 *in* J. Alheit, and T. J. Pitcher, editors. Hake: Fisheries ecology and markets. Chapman & Hall, London.
Pitcher, T. J., E. A. Buchary, and U. R. Sumaila. 2002b. A synopsis of Canadian fisheries, Available: http:/www.fisheries.ubc.ca/publications/reports/Canada-syn.pdf.
Pitcher, T. J., J. J. Heymans, C. Ainsworth, E. A. Buchary, U. R. Sumaila, and V. Christensen. 2002d. Opening the lost valley: Implementing A 'Back to future' restoration policy for marine ecosystems and their fisheries. *in* E. E. Knudsen, D. D. MacDonald, and J. K. Muirhead, editors. Fish in the future? perspectives on fisheries sustainability. American Fisheries Society, Bethesda.
Pitcher, T. J., J. J. Heymans, and M. Vasconcellos editors. 2002c. Ecosystem models of Newfoundland for the time periods 1995, 1985, 1900 and 1450. Fisheries Centre Research Reports, 10(5), Vancouver.
Pitcher, T. J., M. Power, and L. Wood editors. 2002a. Restoring the past to salvage the future: Report on a community participation workshop in Prince Rupert, BC. Fisheries Centre Research Reports 10(7), Vancouver.
Pitcher, T. J., J. J. Heymans, C. Ainsworth, E. A. Buchary, U. R. Sumaila, and V. Christensen. 2004. Opening the lost valley: Implementing a "back to the future" restoration policy for marine ecosystems and their fisheries. American Fisheries Society, Bethesda.
Pitcher, T. J., E. A. Buchary, and P. Trujillo editors. 2002e. Spatial simulations of Hong Kong's marine ecosystem: Ecological and economic forecasting of marine protected areas with human-made reefs. Fisheries Centre Research Reports 10(3), Vancouver.

Reeves, R. R. 2002. The origins and character of 'aboriginal subsistence' whaling: A global review. Mammal Review 32(2):71-106.
Reuters. 1999. Argentinean hake ban and protest, Available: http://segate.sunet.se/cgi-bin/wa?A2=ind9906&L=fish-sci&F=&S=&P=5056.
Richardson, M., and B. Green. 1989. The fisheries co-management initiative in haida gwaii. Pages 249-261 *in* E. Pinkerton, editor. Cooperative management of local fisheries: New directions for improved management and community development. University of British Columbia Press, Vancouver.
Robinson, J. G., and E. L. Bennett editors. 2000. Hunting for sustainability in tropical forests. Columbia University Press, New York.
Roman, J., and S. R. Palumbi. 2003. Whales before whaling in the north Atlantic. Science 301(5632):508-510.
Rosenberg, A., M. Mooney-Seuss, and C. Ninnes. 2005. Bycatch on the high seas: A review of the effectiveness of the Northwest Atlantic Fisheries Organization. Prepared for World Wildlife Fund Canada by: MRAG Americas, Ltd., Tampa, Florida.
Roy, N. 1998. The Newfoundland fishery: A descriptive analysis. Marine Resource Economics 13(3):197-213.
Schindler, D. E., T. E. Essington, J. F. Kitchell, C. Boggs, and R. Hilborn. 2002. Sharks and tunas: Fisheries impacts on predators with contrasting life histories. Ecological Applications 12(3):735-748.
Schrank, W., B. Skoda, N. Roy, and E. Tsoa. 1987. Canadian government financial involvement in a marine fishery: The case of Newfoundland, 1972/73-1980-81. Ocean Development and International Law 18(5):533-584.
Soto, H. 2004. "Colapso pesquero" adiós a la merluza y al jurel. Punto Final, Chile (569, June 11-24).
Strategic Communications Inc. 2001. BC-wide marine protected areas poll. October 10-13, 2001. Online at: Http://www.cpawsbc.org/press/20011122.php.
Sumaila, U. R., J. Alder, G. Ishimura, W. W. L. Cheung, L. Dropkin, S. Hopkins, S. Sullivan, and A. Kitchingman. In press. Values from marine ecosystems of the United States. UBC Fisheries Centre Research Reports, Vancouver.
Sumaila, U. R., and M. Bawumia. 2000. Ecosystem justice and the marketplace. Pages 140-153 *in* H. G. Coward, R. E. Ommer, and T. J. Pitcher, editors. Just fish: Ethics and Canadian marine fisheries. ISER Books, St. John's.
Sumaila, U. R., and C. J. Walters. 2005. Intergenerational discounting: A new intuitive approach. Ecological Economics 52:135-142.
Sumaila, U. R. 2004. Intergenerational cost-benefit analysis and marine ecosystem restoration. Fish and Fisheries 5(4):329-343.
Thomas, M. 2005. Are Universities Hooked on Coca Cola?... The Ubyssey, February 1, Vancouver.
Tirone, S., B. Shepard, N. J. Turner, L. Jackson, A. Marshall, and C. Donovan. 2007. Celebrating and connecting with food. *in* C. C. Parrish, N. J. Turner, and S. Solberg, editors. Resetting the kitchen table: Food security, culture, health and resilience in coastal communities. Nova Science Publishers, Inc., New York.
Turner, N. J. 2005. The earth's blanket: Traditional teachings for sustainable living. University of Washington Press, Seattle.
Turner, N. J. 2003. “Passing on the news”: Women’s work, traditional knowledge and plant resource management in indigenous societies of NW N. America. Pages 133-149 *in* P. Howard, editor. Women and plants: Case studies on gender relations in local plant genetic resource management. Zed Books, UK.
Turner, N. J., and F. Berkes. 2006. Coming to understanding: Developing conservation

through incremental learning in the Pacific Northwest. Human Ecology 34(4):495-513.

Turner, N. J., M. B. Ignace, and R. Ignace. 2000. Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. Ecological Applications 10(5):1275-1287.

Turner, N. J., and Ommer, R. E. 2004. "Our food is our medicine": Traditional plant foods, traditional ecological knowledge and health in a changing environment. Proceedings of the First Nations Nutrition and Health Conference Proceedings Arbokem Inc. Vancouver:22-39.

Turner, N. J., C. C. Parrish, and S. Solberg. 2007. Introduction—Food security in coastal communities in the context of restructuring: *Coasts under stress*. *in* C. C. Parrish, N. J. Turner, and S. Solberg, editors. Resetting the kitchen table: Food security, culture, health and resilience in coastal communities. Nova Science Publishers, Inc., New York.

Volpe, J. 2007. "Salmon sovereignty" and the dilemma of intensive Atlantic salmon aquaculture development in British Columbia. *in* C. C. Parrish, N. J. Turner, and S. Solberg, editors. Resetting the kitchen table: Food security, culture, health and resilience in coastal communities. Nova Science Publishers, New York.

Walters, C. J., 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.

Welch, D. W., Y. Ishida, K. Nagawasa, and J. P. Eveson. 1998. Thermal limits on the ocean distribution of steelhead trout (*Oncorhynchus mykiss*). North Pacific Anadromous Fish Commission Bulletin 1:396-404.

Wong, A. 2004. First Nations' nutrition and health conference proceedings, Arbokem Inc. Vancouver.

Worm, B., H. K. Lotze, and R. A. Myers. 2003. Predator diversity hotspots in the blue ocean. Proceedings of the National Academy of Sciences of the United States of America 100(17):9884.

Wright, R. 2004. A short history of progress. House of Anansi Press, Toronto.