Fisheries

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Fisheries

BACKGROUND

Coastal First Nations people have fished in British Columbian waters for many thousands of years and attach great cultural significance to the marine environment and its resources. Europeans have fished in BC since the 1800s, catching herring, salmon, halibut, and many other species of groundfish, pelagic fish, and invertebrates. The bounty of these fisheries depends on intact coast and marine ecosystems that support spawning, foraging, migration, growth, and reproduction of fish. It also depends on how well humans manage their direct impact on fish through harvesting. Healthy fish stocks and functioning marine ecosystems are important for many marine mammals, seabirds, eagles, bears, and a host of other species that depend at least partly on the marine fish and invertebrates for food.

Economically, the state of fisheries and marine ecosystems is an important issue for the many BC coastal communities that depend on fishing and fish processing. In 2004, commercial landings of all species in British Columbia totalled 265,000 tonnes and were valued at close to $390 million, while the wholesale value to the BC economy was almost $810 million (BCMOE/MAL 2005). Fishing is also a major form of recreation. In the last nationwide survey of recreational fishing in Canada, annual expenditure on recreational fishing in BC tidal waters (direct expenditure plus investments attributed wholly to fishing) was estimated to be almost $500 million (DFO Statistical Services Unit 2000).

Fisheries in British Columbia

The main species caught in BC’s coastal waters are Pacific salmon and steelhead trout (in freshwater); groundfish (fish that live on or near the bottom of the ocean); pelagic fish (schooling fish that live at or near the surface); and many species of invertebrates (animals without backbones, such as crabs, shrimp, clams, sea urchins, and squid). Depending on the species, there are commercial trawl fisheries, hook-and-line fisheries, longliners, dive and dig fisheries, troll, gillnet, seine, and trap fisheries. The largest commercial fishery in terms of landings is the groundfish trawl fishery, primarily for hake, halibut, rockfish, and sablefish. There are also recreational fisheries for many species. First Nations people harvest fish and invertebrates for food and ceremonial purposes, as well as actively participate in commercial fisheries.

The federal government has jurisdiction over the sea coast and inland fisheries, fishing in tidal or navigable non-tidal waters, and the power to protect the waters in which fish spawn or live. The provincial government regulates freshwater fisheries in the province and also has authority over fish once they are caught.

Managing Impacts of Fishing

Fish and other species differ widely in their ability to withstand harvest. Short-lived species with a high turnover rate (e.g., shrimp, squid, small pelagic fish) are generally able to sustain much higher rates of harvest than slow-growing species with low rates of reproduction (e.g., rockfishes). It is generally assumed that, for any population of fish, there is an optimum harvest rate. This is based on the assumption that the rate of growth for a population depends on population size and that, within certain limits, harvesting a proportion of a population is beneficial to the remaining individuals because it reduces the competition for resources.

Because fish are hard to observe directly, there is usually a great deal of uncertainty about the status of fish stocks and how they respond to harvesting. There is also uncertainty about the effect of environmental factors, such as climate, on fish stocks and how these factors interact with fisheries. Despite this uncertainty, fisheries scientists try to determine safe levels of harvest and convey this information to fisheries managers who are ultimately responsible for setting the allowable catch. Fisheries scientists study the population dynamics of fish stocks and the fishery's response to management so they can provide information that must be taken into account during management.

Measures used in managing BC groundfish, pelagic, and invertebrate fisheries range from simple to highly sophisticated stock assessment techniques. These measures include indices of recruitment, abundance, harvest rate, catch, and catch per effort. Even the best stock assessment techniques, however, cannot completely remove uncertainty in managing stocks. Many fisheries agencies around the world, including Canada, buffer against uncertainty by using precautionary management tactics such as limiting fishing effort (by restricting licences, days, or areas fished) or using cautious quotas.

Fishing has a negative impact when stocks are overfished, and can have other, indirect, impacts on ecosystems. Overfishing occurs when a fish stock (i.e., a discrete population of fish) is harvested at a higher rate than the rate at which it can grow. Immigration aside, the biomass of a fish population grows by recruitment (adding new juveniles) and by growth in size of individuals. Overfishing can affect one or both of these processes, by harvesting too many fish before they have had a chance to spawn or by harvesting fish before they have the opportunity to grow larger. Although some reduction in size or age of fish is normal when stocks are exploited, a large reduction in either or both factors is a concern.

Scientists are becoming increasingly aware that commercial fishing may have a wider impact on marine ecosystems than just on the species that are directly targeted. Fisheries can alter the structure of marine ecosystems and increase their instability and unpredictability by:

- selectively removing large, long-lived species that are less able to withstand high fishing mortalities than smaller, short-lived species;

- altering habitats by fishing gear such as bottom trawl nets;

- reducing predator pressure coming from large fish, which leads to greater abundance of small fish and squids (e.g., “fishing down marine foodwebs”; Pauly et al. 1998);
- causing trophic cascades, which occur when a reduction in the number of top predators allows populations of lower trophic-level fish to increase; in turn, they deplete their food supply of organisms still lower on the food chain (e.g., Pinnegar et al. 2000).

Monitoring to detect signs of overfishing (such as reduced abundance or smaller fish in the catch) is one of the main roles of fisheries management agencies. Although that is not an easy task, monitoring to detect impacts of fishing on ecosystems is an even more difficult problem. Establishing clear explanations for changes in the relative abundances of interacting species is complicated, partly due to the great complexity of food webs (May et al. 1979; Yodzis 1994).

Fisheries Indicators

Most indicators in this paper use data that were collected to manage commercial fisheries. Although this is not a review of the commercial fishing industry, fishery-based indicators are used partly as a proxy for the status of marine ecosystems and partly as a measure of direct human pressures, mainly from fishing, on those ecosystems. Indicators show overall status and in some cases trends, but do not show which of the many contributory factors have the most weight; such factors are complex, numerous, and vary with location and species. This is the reason for using a suite of indicators to detect changes in marine ecosystems—rather than relying on one indicator—to provide a broader picture of what is happening in the ocean (e.g., Rice 2000; Link et al. 2002; Hall and Mainprize 2004).

As with all state-of-environment reporting, undesirable results of indicators signal that more must be done to discover causes and take effective action to address influences that are under human control. A key response indicator in this paper addresses the latter point by attempting to quantify the effect of efforts to reduce the negative impacts of commercial fishing on non-target species.

Indicators were chosen to provide a broad, coast-wide assessment wherever possible. They are based on data available at the time of writing from websites and published research.

INDICATORS

1. Key Indicator: Proportion of salmonid populations that are classed as healthy, at moderate to high risk of extinction, or extinct

This is a status indicator. It address the question: What is the current status of British Columbia's salmon? Such an overall assessment of the status of salmon populations shows the net effect of:

- the overall state of terrestrial and oceanic ecosystems on which salmon depend, including impacts from human activity ranging from direct impacts on spawning streams to the global impacts of climate change;
- the direct impact of fishing and fisheries management practices; and
- naturally occurring factors and changes that are outside of human control.

This indicator infers the risk of extinction based on the trends in spawning salmon populations. It is intended to provide an overview by estimating the risk of extinction of a large number of salmon populations over the entire length of the northwest coast. The unit used in this indicator is a "spawning population" (a unique combination of species and stream). Note that this is not the same unit as a "stock" as defined for fisheries management purposes, which includes genetic relationships in defining a stock, a stock group, or conservation unit.

Salmon are anadromous, meaning that they spawn (breed and lay eggs) in freshwater but spend most of their adult life in the marine environment. Native anadromous salmon species found in British Columbia include chum (*Oncorhynchus keta*: ~1450 populations), coho (*O. kisutch*: ~2400 populations), sockeye (*O. nerka*: ~900 populations), pink (*O. gorbuscha*: ~2100 populations), chinook (*O. tshawytscha*: ~780 populations), and steelhead trout (*O. mykiss*: ~850 populations) (Riddell and Tautz 2003). It is estimated that there are more than 22,300 spawning populations of salmonids in North America (Waples et al. 2001), of which approximately 9080 are located in the BC/Yukon region (Slaney et al. 1996, excluding the Strait of Georgia).

Pacific salmon spawn in gravel beds in rivers, streams, or along lake shores. Depending on the species, juveniles may spend a few months to 3 years in freshwater or estuaries before migrating to the ocean. Salmon spend between 18 months and 5 years in the ocean, depending on the species, and may migrate extensively. A great deal remains unknown about these migration patterns (e.g., Eggers et al. 2003). At the end of the ocean stage, salmon return from the sea to spawn in the same streams from which they hatched. Most species die after spawning, although steelhead may spawn in successive years. Table 1 summarizes the life histories and diet of the seven species.

Table 1. Life cycle and food requirements of chum, chinook, sockeye, coho, and pink salmon and steelhead trout.

Species	Freshwater stage	Primary diet in ocean	Ocean stage	Total lifespan
Chum (keta)	Up to 6 months; fry migrate Feb.-June, immediately upon hatching, with most migrating April-May.	Mainly copepods; also crustaceans, squid, fish.	2-5 years; migrating adults present in coastal waters July-Oct.	2-7 years, with most living 3-5 years; adults die after spawning.
Coho (silver)	Juveniles overwinter in coastal streams and small lakes; remaining in freshwater 1-3 years.	Insects, copepods, other invertebrates and small fish.	1-2 years males; 2 years females.	3 years; adults die after spawning.
Sockeye	Juveniles overwinter in coastal watersheds and remain in lakes 1-3 years, migrating from streams in the spring; a few go directly to sea.	Plankton, krill, and small crustaceans.	1-4 years, returning to spawn in late summer and fall.	3-5 years; adults die after spawning.
Pink	Fry migrate from rivers and streams mid-April to mid-May; they spend the least time in fresh water of all species.	Mainly copepods, other plankton and crustaceans; also small fish.	18 months.	2 years; adults die after spawning.
Chinook (king or spring)	"Ocean-type" migrate late summer, 1-3 months after emergence; some overwinter and migrate the next year. "Stream-type" migrate during 2nd or 3rd spring.	Copepods and other invertebrates; small fish supply larger part of diet than for other species.	4-5 years; (2 or more for males; 3-4 for females).	3-6 years; adults die after spawning.
Steelhead	1-2 years in coastal streams; most hatch in early summer and migrate from rivers the next spring.	Fry eat bottom-dwelling invertebrates, fish eggs, plankton; also small fish and crustaceans.	1-4 years; "summer run" steelhead enter rivers spring-late summer, spawn the next spring. "Winter run" fish enter rivers late fall or winter, spawn in spring.	Adults can migrate and spawn repeatedly.

Threats to Salmon Populations

The following is a list of known and potential threats to BC salmonids; the type and impact of threats varies with the stock:

- Overexploitation: Smaller or less productive stocks mixed with larger or more productive stocks are vulnerable to overfishing. Failing to account for mixed stock structure in overexploited populations can lead to underestimation of optimum escapement and overestimation of safe harvest rates, and prevent recovery of less productive stocks (Hilborn 1985).
- Alteration of spawning and rearing habitat: Changes to spawning habitat can affect the survival of spawning adults, eggs, or juveniles. Alterations include construction of dams (Levin and Tolimieri 2001) and impacts from mining, gravel removal, water impoundment, and other human activities. Land clearing (i.e., for urban development, agriculture, logging) increases runoff, which increases nutrient levels, erosion, and sedimentation in streams and reduces the natural vegetation that shades streams and regulates the water temperature (e.g., Regetz 2003). (Note: Habitat alteration from human activities is not always detrimental, e.g., Walters 1975; Walters and Martell 2004.)
- Alteration of marine rearing habitat: Impacts from human activities include loss of estuarine area, impacts from log handling and booming, waste discharge and contaminants in effluents, development of marinas and aquaculture. The escape of Atlantic salmon (*Salmo salar*) from net pens used in BC's aquaculture industry has caused concern about the potential for competition with wild stocks (e.g., Neilsen 2003). Another area of controversy, currently under study by Fisheries and Oceans Canada, is the impact of sea lice (a small, parasitic crustacean) on the health of wild pink salmon and whether this is related to net-pen aquaculture in the Broughton Archipelago.
- Ocean conditions: Sea surface temperature, salinity, and ocean currents have been correlated with migration timing and pathways (e.g., Flynn and Hilborn 2004). Predation by marine mammals and competition for food with other species also affect marine survival. Another component of ocean conditions could be considered the exponential increase in released hatchery salmon into the ocean from all countries around the North Pacific. Nielsen (2003) estimates that introductions have exceeded 6 billion fish per year for the last decade (see next point).
- Hatchery programs: Beginning in 1977, the Canadian Salmonid Enhancement Program sought to improve stream conditions and double the catch of Pacific salmon and steelhead through stocking programs. In 1998, 429 million salmon were released from BC hatcheries and up to 80% of the coho caught in BC coastal waters were attributed to enhancement programs (Noakes et al. 2000). Concerns about the effect of hatchery fish on wild salmon populations have led to a re-evaluation of the impacts of hatchery production on natural populations (reviewed in Nielsen 2003). Such concerns include competition with wild salmon for resources, increased fishing pressure on wild stocks as the presence of hatchery fish attracts fishing effort, harvest

of eggs and fry from wild populations, increased predation or disease of wild stocks as predator and parasite populations increase in response to the abundance of hatchery salmon, and genetic change in wild stocks that interbreed with hatchery fish (reviewed in Gardner et al. 2004).

- Climate change: Strong correlations have been found between salmon productivity in BC and the decade-long oscillations in climate and ocean conditions called the Pacific Decadal Oscillation (PDO) (e.g., Mantua et al. 1997; Beamish et al. 1999). The type of changes seen in the warm phase of the PDO may presage the type of changes in store as the global climate changes. Changes in oceanic temperature and circulation patterns cause changes in production of the phytoplankton (single-celled algae) that form the base of the oceanic food chain, ultimately affecting the productivity of salmon in the ocean.

ENDANGERED SALMON

At the time of writing, three populations of salmon were listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC):

- Interior Fraser coho
- Sakinaw Lake sockeye
- Cultus Lake sockeye

The federal Minister of Environment decided not to add the Sakinaw and Cultus Lake populations to Schedule 1 of the Species at Risk Act (SARA), meaning that they have not been officially listed as Wildlife at Risk in Canada. Once a species is added to the list and protected officially under SARA, a recovery strategy must be developed. A decision on the status of the Interior Fraser coho is pending.

Methodology and Data

Riddell and Tautz (2003) reviewed the extinction risk of 6692 populations of Pacific salmon in North America as described in *Fisheries,* the American Fisheries Society's journal (Nehlsen et al. 1991; Baker et al. 1996; Huntingdon et al. 1996; Slaney et al. 1996). Riddell and Taut defined four categories of extinction risk using trends in spawning numbers or information available, following the definitions as defined by Nehlsen et al. (1991). The four risk categories are:

1. High risk of extinction: Populations whose spawning numbers are declining. Fewer than one adult fish returns to spawn for each parent spawner. This category includes populations with recent escapements under 200 spawners, in the absence of evidence that they were historically small. ("Escapement" refers to the number of mature salmon that escape capture by fisheries and other forms of mortality to return to their rivers of origin to spawn.)

2. Moderate risk of extinction: Populations whose spawning escapements appear stable after previously declining more than natural variation would account for, but that exceed 200 spawners.

3. Special concern: Populations for which:
   – Relatively minor disturbances could be a threat;
   – Insufficient information on population trend exists, but available information suggests they are depleted;
   – Relatively large ongoing release of non-native fish and the potential for interbreeding with the native population exists; or
   – The population is not presently at risk, but requires attention because of a unique character.
4. Extinct: Populations that were known to exist previously, but the native fish are known to no longer spawn in the original habitats.

Populations at risk are summarized by geographic region in Table 2 and Figure 1 and by species in Table 3 and Figure 2. Note that "Special Concern" and "Moderate Risk" categories were combined because numbers in these categories were low (Riddell and Tautz 2003).

Table 2. Proportion of assessed populations of Pacific salmon (chinook, coho, sockeye, chum, pink, steelhead) by risk category and geographic region.

Geographic region	No. of assessed populations	No to low risk of extinction (%)	Special concern to moderate risk (%)	High risk of extinction (%)	Extinct (%)
Pacific Northwest states[a]*	404	24.5	25	20.3	30.2
BC and Yukon[b]	5358	81.4	5.1	11.4	2.1
SE Alaska[c]	930	98.6	1.0	0.2	0.2

Source: Riddell and Tautz (2003).

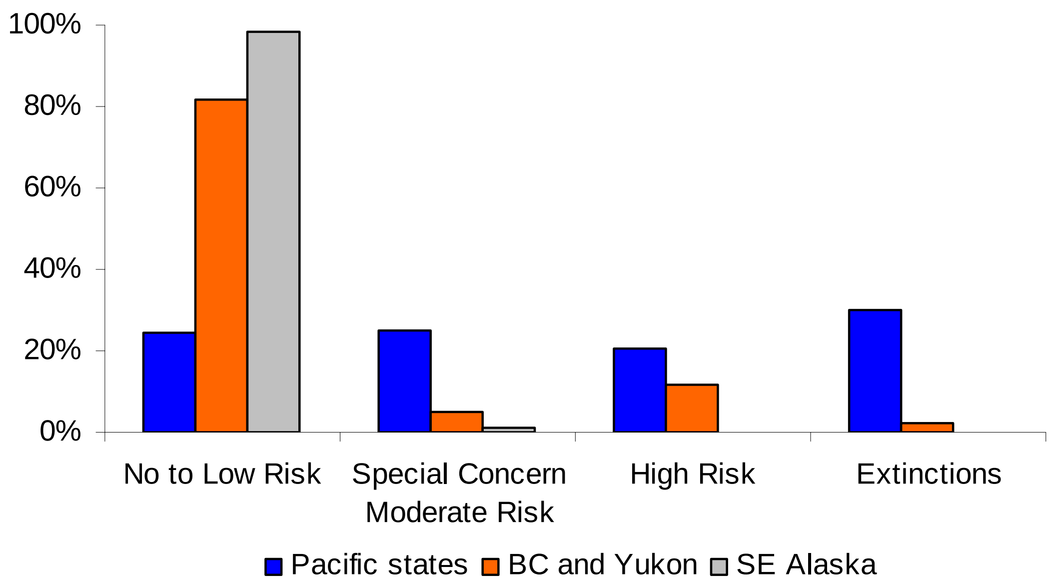
* Includes populations from Canadian parts of Strait of Georgia.

[a.] Nehlsen et al. 1991; Huntingdon et al. 1996.

[b] Slaney et al. 1996 (excludes populations from Canadian parts of Strait of Georgia).

[c.] Baker et al. 1996.

Figure 1. Proportion of assessed populations of Pacific salmon (chinook, coho, sockeye, chum, pink, steelhead) by risk category and geographic region.



Source: Riddell and Tautz (2003).

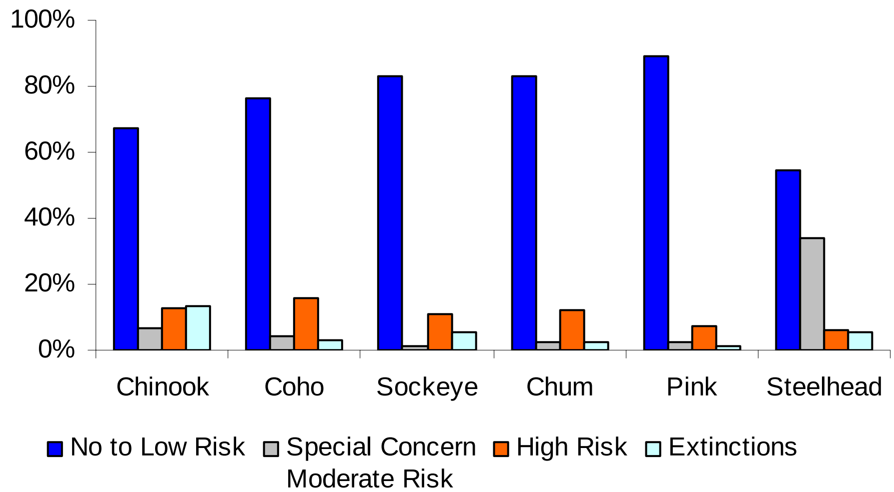
Table 3. Proportion of assessed populations of Pacific salmon by species and risk category.

	Chinook *n* = 587	Coho *n* = 1435	Sockeye *n* = 590	Chum *n* = 1240	Pink *n* = 2254	Steelhead *n* = 586
No to low risk	67.3	76.45	83.05	82.9	89.3	54.3
Spec/Moderate risk	6.8	4.32	1.02	2.6	2.2	34.1
High risk	12.8	16.03	10.68	12	7.4	6
Extinctions	13.1	3.2	5.25	2.5	1.1	5.6

Source: Riddell and Tautz (2003).

n = number of populations assessed.

Figure 2. Proportion of assessed populations of Pacific salmon by species and risk category.



Source: Riddell and Tautz (2003).

Comparison of BC populations with those of neighbouring jurisdictions shows that half (50.5%) of the populations in the Pacific Northwest states (US) are extinct or at high risk of extinction. This compares to 13.5% in British Columbia and the Yukon and only 0.4% in southeast Alaska.

Assessment of salmon populations relative to their risk of extinction based on the spawning escapement is a relatively coarse indicator and one that does not show early declines in populations. Although a quantitative analysis based on changes in total production (catch plus spawners) over time would be a better indicator of salmon status, catch data are not available for all spawning populations and further work is required to determine reference points for categorizing levels of concern.

Interpretation

Riddell and Tautz (2003) viewed these results as encouraging for Canadian Pacific salmon populations and as more optimistic than might have been expected. It should be noted, however, that a larger proportion of Canadian populations were at risk than those of southeastern Alaska, and populations from the Canadian part of the Strait of Georgia were excluded from the BC/Yukon part of the analysis and were included with the Pacific Northwest states. The Strait of Georgia is the most developed and heavily populated region in BC and the site of the Fraser River fisheries, BC's largest Pacific salmon fisheries.

The status of a particular salmon population reflects the net impact of fishery management practices as well as other factors (human caused and naturally occurring) that alter conditions in their freshwater and marine habitats. Factors affecting survival in the oceanic phase of salmon life cycles are not as well understood as those that affect their freshwater environments. Substantial resources have been allocated to researching and restoring freshwater salmon habitats, but relatively few resources have been directed toward understanding factors affecting marine survival of salmon.

One of the main issues affecting salmon populations and salmon biodiversity is that many small stocks are fished in mixed stock complexes. Walters (2003) maintains that the basic issue facing salmon managers is that there is no way to manage these complexes without putting at least some of the smaller populations at risk of extinction. Management of such stocks (e.g., by setting low harvest rates for the mixed stock fishery) involves consideration of the difficult trade-off between social and economic values of the harvest and the benefits of maintaining salmon biodiversity.

2. Secondary Indicator: Current outlook of managed salmon stocks in BC

This is a status indicator. It addresses the question: What is the status of commercially fished salmon stocks in BC?

Indicator 1 provided an overview of the risk of extinction of many of the salmon populations along the entire coast. This supplementary indicator provides the current outlook for the managed salmon stocks, by species, relative to an assessment of the target abundance of fish for each stock. Note that the unit used in this indicator, the "stock" as defined for fisheries management purposes, is a different unit than the salmon populations used in Indicator 1. Like the previous indicator, however, the outlook for each stock portrays the net effect of environmental factors as well as the effects of fishing and fisheries management.

Methodology and Data

The 2004 stock outlooks for managed BC salmon stocks were obtained from Fisheries and Oceans Canada (DFO 2003e). The Stock Assessment group of DFO assigns each stock group a status outlook that reflects the available quantitative and qualitative information on recent returns for each stock, as well as the expert opinion of fisheries managers on its status. The outlook is relative to the target abundance for that stock for fisheries planning; where stock targets have not been formally described, targets were either historical levels of abundance or were based on expert opinion (DFO 2003e).

Stock status outlook is rated according to where stock is (or is forecast to be) on a scale of 1 to 4:

1 = Stocks are less than 25% of target abundance or declining rapidly.

2 = Stocks are well below target or below target and declining.

3 = Stocks are within 25% of target and stable or increasing.

4 = Stocks are well above target abundance.

Some (23) stocks were assigned a range of outlook categories, reflecting the significant geographic variation in status within the stock group. Stocks given ratings of 1 or 1/2 were counted together, stocks rated as 2, 2/3, or 2/4 were counted together, and stocks rated as 3 or 3/4 were counted together.

The 2004 outlooks for a total of 87 managed stock groups (populations) of sockeye, chinook, chum, coho, and pink salmon are shown in Table 4.

Table 4. Number of BC managed salmon stocks rated in each status outlook category (1 to 4) and proportion of the total number of stocks in each category.

Species	No. stocks assessed	Stock outlook category			
		1, 1/2	2, 2/3, 2/4	3, 3/4	4
Sockeye	29	6	10	11	2
Chinook	23	1	7	9	6
Coho	18	0	8	8	2
Pink	6	0	4	1	1
Chum	11	4	4	2	1
Total	87	11	33	31	12
Proportion of total		12.6%	37.9%	35.6%	13.8%

Source: DFO (2003e).

Note: No data were available for one stock of coho and three stocks of pink salmon.

According to the stock outlooks for the 2004 year analysed for this indicator, 43 of the stock groups assessed, or about half (49%), were forecast to be in categories 3 and 4, meaning they are stable, increasing, or well above target—in other words, not of concern. Thirty-three stock groups (about 38%) were in category 2 or had part of the stock group rated in this category. This group consists of sensitive stocks that are well below target abundance or well below target and declining. Eleven stocks (about 13%) were rated in category 1—stocks that are expected to be of the greatest concern because they are at less than 25% of target abundance or are declining rapidly.

Interpretation

It is important to note that year-to-year variations in stock status occur as different year classes of salmon return. This analysis shows that about half of the stock groups were forecast for 2004 to be in categories 1 or 2 and half of the stocks were rated in category 3 or 4. Chum had the highest percentage of stocks in the two lower categories (8 of 11 stocks). Three of these stocks (the Taku and two Yukon stocks) are transboundary stocks that are caught in Alaskan and Canadian fisheries. Precautionary fishing practices in both countries appear to be resulting in improved escapement for these stocks (DFO 2003e). For the other species, poor marine survival (as juveniles or adults), leading to low numbers of returning spawners, has contributed to the depressed levels of many of the stocks listed in categories 1 or 2 (DFO 2003e).

Stocks that are forecast to be in categories 1 and 2 are considered to be “sensitive,” meaning that, where possible, fisheries would be planned to reduce impacts on these groups (DFO 2003e). Possible consequences for fisheries implied by the four outlook categories, are listed in Table 5.

Table 5. Fishery consequences implied by the stock outlook categories.

Stock outlook	Fishery consequence
1	Directed fisheries are unlikely and there may be a requirement to avoid indirect catch of the stock.
2	Directed fisheries are uncertain and likely to be small if permitted. Allocation policy will determine harvest opportunities.
3	Directed fisheries subject to allocation policy.
4	Directed fisheries subject to allocation policy.

Source: DFO (2003e).

Conservation requirements for stocks in categories 1 and 2 may limit fishing opportunities for stock groups for which there are no concerns. For example, restrictions on fisheries in several regions have been implemented to protect the endangered Cultus salmon stock (DFO 2004a).

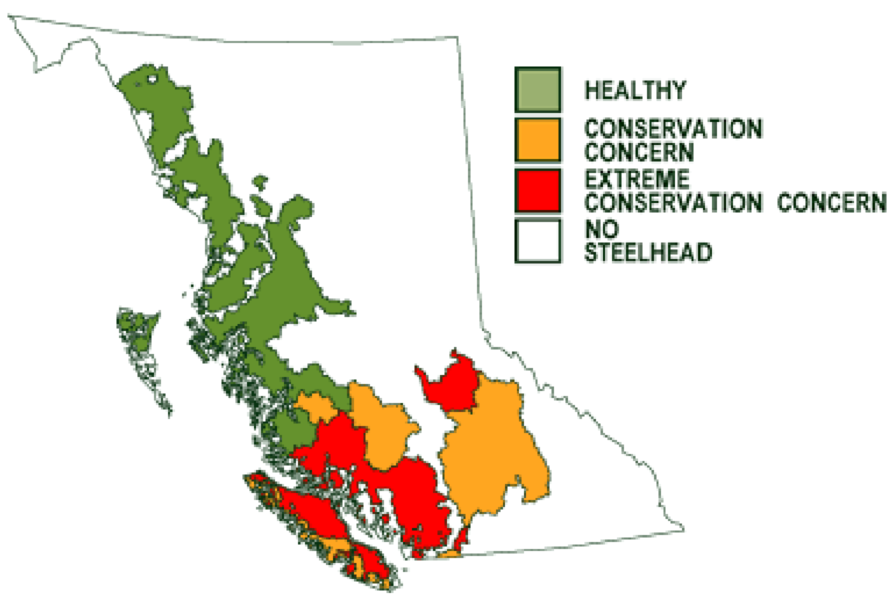
Supplementary Information: Conservation Status of Steelhead in the Lower Mainland

Steelhead (*Oncorhynchus mykiss*) are highly valued by recreational anglers and are important in First Nations ceremonial, social, and food fisheries. The Steelhead Recovery Plan (Lill 2002) classifies wild steelhead stocks relative to the capacity of a watershed to produce and sustain steelhead into the following categories:

- Special Concern (SC): Mostly small stocks in probable need of conservation but for which little or no stock assessment information is available.
- Routine Management Zone (RMZ): Stocks above 30% of habitat capacity in most years and not threatened in terms of genetic and environmental distinctiveness; can withstand modest catch and release fisheries.
- Conservation Concern (CC): Stocks estimated to be at 10–30% of habitat capacity. Limited catch-and-release angling may be possible for stocks in the upper part of this range.
- Extreme Conservation Concern (ECC): Stocks believed to be at 10% or less of habitat capacity and likely to become extinct if they are in decline for more than one or two generations.

The status of steelhead trout stocks over the whole province was reported in *Environmental Trends in British Columbia: 2002* (BCMWLAP 2002). About half of the stocks in BC that were assessed at that time were classed as healthy and about half were classified as either of Conservation Concern or of Extreme Conservation Concern. Most of the latter occurred in the Lower Mainland and Vancouver Island (Figure 3), where 93 to 95% of stocks were rated as being of Conservation Concern or Extreme Conservation Concern (Lill 2002). Most conservation efforts are being allocated in this region.

Figure 3. Assessed conservation risk to steelhead stocks in 2002.



Source: BCWLAP 2002.

In 2002, most of the steelhead stocks classified as of Conservation Concern or Extreme Conservation Concern occurred in the Greater Georgia Basin (BCMWLAP 2002). At that time, the wild steelhead stocks in 48 of the 58 highest priority watersheds were classified as in decline or at very low levels, with 51 of 55 (93%) winter-run and 21 of 22 (95%) summer-run stocks of Conservation Concern or Extreme Conservation Concern (Lill 2002).

Further research on the 2005 status of steelhead in the Fraser River watershed are shown in Table 6 (R. Ahrens, UBC Fisheries Centre, 2005. pers. comm.). These assessments are part of the Steelhead Recovery Plan, which is completing stock assessments for all priority watersheds (*www.bccf.com/steelhead/about-steelhead.htm*). The objectives of the recovery plan are to stabilize and restore wild steelhead stocks and habitats to healthy self-sustaining levels and to maintain or restore angling opportunities (Lill 2002).

In 2005, 30 watersheds were assessed using methods similar to those used in 2002 (Table 6), but the 2005 analysis did not use the category Special Concern (SC). Stocks for which there were too few data to complete the assessment but that showed a likely decreasing trend were placed in the Extreme Conservation Concern (ECC) category. Thus five stocks rated as SC in 2002 were assigned to ECC in 2005; however, they are not counted as stocks that declined because the change does not indicate a real change in status (see Table 6).

In 2005, 10 of the 30 watersheds studied in 2002 were reassessed and 20 watersheds were assessed for the first time. In 2005, all watersheds were rated as of Conservation Concern or Extreme Conservation Concern. The status of 4 of the 10 watersheds assessed in 2002 had declined; 2 moved from CC to ECC; and 2 rated healthy (Routine Management Zone) in 2002 declined to Extreme Conservation Concern.

Declines in steelhead abundance are believed to have been caused by greatly reduced ocean survival combined with low productivity in freshwater habitats. Depending on the location of the stock, factors that may affect freshwater productivity include impacts from logging, urban development, agriculture, hydroelectric projects, and other changes to water flow (Lill 2002).

Table 6. Condition of steelhead for 30 Fraser River watersheds in British Columbia.

Unit	Watershed	2005 status*	2002 status
Mid Fraser summer	Chilcotin River	CC	–
	Taseko River	CC	–
Boundary Bay	Campbell River	ECC	–
	Nicomekl River	ECC	–
	Serpentine River	ECC	–
Lower Fraser	Vedder-Chilliwack	CC	–
	Coquitlam River	ECC*	CC
	Pitt River	ECC*	CC (Upper Pitt)
	Alouette River	ECC*	RMZ
	Widgeon Creek	ECC	–
	Kanaka Creek	ECC	ECC
	Salmon River	ECC	SC
	Norrish Creek	ECC	SC
	Weaver Creek	ECC	–
	Cogburn Creek	ECC	–
	Big Silver Creek	ECC	SC
	Lillooet River	ECC	–
	Birkenhead River	ECC	–
Lower Fraser summer	Silverhope Creek	ECC	SC
	Coquihalla River	ECC	SC
	Chehalis River	ECC*	RMZ
Fraser Canyon	Nahatlatch River	ECC	–
	Stein River	ECC	–
	Seton River	ECC	–
	Bridge River	ECC	–
Mid Fraser summer	Thompson River	ECC	–
	Nicola River	ECC	–
	Bonaparte River	ECC	–
	Deadman River	ECC	–
	Quesnel River	ECC	–

Source: 2005 data from R. Ahrens, Fisheries Centre UBC; 2002 data from Lill (2002).

SC = Special Concern, RMZ = Routine Management Zone, CC = Conservation Concern, ECC = Extreme Conservation Concern. – = not assessed.

* Indicates a decline in status from 2002.

Supplementary Information: Outlooks for stocks of groundfish, pelagic fish, and marine invertebrates in BC

This section addresses the question: What is the status of the important commercial fish species in BC? Such a general question, however, cannot be answered either simply or, at this time, in any quantitative way.

The information in this section is not an indicator because it does not report quantitative data and cannot be used as a baseline measure or to show a trend. It was included to provide descriptive summaries of the status of commercially fished species and is based on assessments available at the time of writing. Given the diverse life histories of the many species and the limited knowledge of stock structure for most of these species, a single status indicator likely would not be possible or appropriate.

Fisheries and Oceans Canada publishes stock status reports for 23 species of groundfish, 5 pelagic fish species, and 16 marine invertebrates. In addition, Pacific halibut is assessed and managed by the International Pacific Halibut Commission. For species that are assessed, assessment methods vary considerably, depending on the type and quantity of data available. In some cases, only certain populations of each species are assessed. Methods used to assess the status of stocks range from simple analysis of trends in commercial landings and catch effort data to the use of complex analytical models based on various types of data collected in fisheries-independent surveys.

The following brief summaries of species or groups are based on stock status reports (*www.pac.dfo-mpo.gc.ca/sci/psarc/SSRs/ssrse.htm*) and integrated fisheries management plans (*www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/MPlans.htm*) published by Fisheries and Oceans Canada, as well as other sources as cited (DFO 1998, 1999a-v, 2000a,b, 2001a-c, 2002a-k, 2003a-d, 2004a-j, 2005a,b). Although stock outlooks used in the descriptions were the most recent available at the time of writing, in some cases the most recent reports available were from 1999. Periodically more recent reports are posted on the above websites.

Groundfish

Groundfish is a broad term used to describe fish that live on or near the bottom of the ocean as well as in the mid-levels of water. Four groundfish fisheries occur in the Pacific region: groundfish trawl; halibut by hook and line; sablefish by trap and hook and line; and rockfish and other species by hook and line. The largest of these is the trawl fishery, which lands 77 species (of which 27 are assessed). Landed value of groundfish in 2004 was $90 million, with a wholesale value of $261.4 million (BCMOE/MAL 2005).

Pacific halibut (*Hippoglossus stenolepis*)

Halibut are a highly important commercial, First Nations, and recreational species and are the most valuable species of groundfish harvested in BC, with a wholesale value of $90 million in 2004 (BCMOE/MAL 2005). The commercial fishery operates along the US and Canadian Pacific coast. The fishery is assessed yearly by the International Pacific Halibut Commission, using commercial fishery data and data from surveys and tagging programs (e.g., Clark and Hare 2003). Halibut stocks in Canada and Alaska were at an historical low in the 1970s, but increased over the next 20 years. Female spawning biomass is currently estimated to be 2 or 3 times the 1970s level. Recent average recruitment has been good by long-term historical standards and stocks are considered stable and healthy (DFO 2004b).

Pacific Ocean perch (*Sebastes alutus*)

In terms of landed catch, Pacific Ocean perch is the most important rockfish species in the BC trawl fishery. The fish ranges from southern California to the Bering Sea and is generally captured by trawl gear over cobble and rocky areas. The main part of the Canadian fishery occurs in Queen Charlotte Sound (Goose Island, Mitchell’s, and Moresby gullies). Records of catches began in 1954, but until the 1970s, similar rockfish species were also reported as “ocean perch” or “red rockfish.” Reliable biomass estimates for Pacific Ocean perch are available for the Goose Island Gully population. According to the most recent stock assessment available for Goose Island Gully, 1984 to 1995, the stock was estimated to have increased due to high recruitment and low fishing mortality; numbers have climbed to about half what they were in 1965 (DFO 1999a). In 1999, the stock was estimated to be declining slightly due to poor recruitment.

Lingcod (*Ophiodon elongatus*)

Lingcod occur from California to Alaska and inhabit nearshore rocky areas (King et al. 2003). The stock consists of an inshore stock in the Strait of Georgia and offshore stocks off the west coasts of Vancouver Island and Haida Gwaii, Queen Charlotte Sound, and in Hecate Strait.

The inshore fishery was closed to commercial fishing in 2002 (DFO 2002a). Conservation concerns for inshore rockfish and lingcod led to the development of the Rockfish/Lingcod Conservation Strategy, announced in 2002 (DFO 2002b). To date, 89 key habitat areas have been closed to fishing to protect inshore rockfish and lingcod.

Offshore lingcod are exploited primarily by the groundfish trawl fishery, with most of the catch taken from the southwest coast of Vancouver Island. Large catches are also taken from Queen Charlotte Sound. Offshore lingcod stocks are thought to be at a moderate level of abundance, although the status of the stock off the west coast of Haida Gwaii is unknown and a conservative approach to managing the offshore fishery is being taken (DFO 2002a)

Sablefish (*Anoplopoma fimbria*)

Sablefish (black cod) inhabit the continental shelf and slope along the entire west coast. The sablefish fishery is one of the most important in BC, valued at $29 million in 2000. Most of the product is exported to Japan. Sablefish are mostly caught in traps, although some are also caught with longlines or trawl gear. The biomass of sablefish that could be trapped decreased from the 1990s until recently. The current assessment shows that abundance increased through 2004 (DFO 2005b).

Pacific cod (*Gadus macrocephalus*)

Four stocks of Pacific cod are defined for management purposes in BC: Strait of Georgia, west coast of Vancouver Island, Queen Charlotte Sound, and Hecate Strait. Little information is available about any of these stocks except for the Hecate Strait stock, which is fished mainly with trawls. In 1999, the stock was estimated to be at a historical low, and stock projections suggested that the spawning stock biomass would continue to decrease through 2001 (DFO 1999c).

Pacific hake (*Merluccius productus*)

Hake are the second largest harvest in BC by volume, with 2004 landings of 124,900 tonnes. There is a BC offshore stock of Pacific hake and a smaller inshore stock in the Strait of Georgia and Puget Sound. The offshore stock migrates seasonally from southern California to northern British Columbia and is caught using large, mid-water trawls. The fishery is now managed and allocated under a Canada-US agreement. Stock size was relatively stable from 1972-1982, peaked in 1987, and then declined steadily to a historical low in 2001 (DFO 2003b). The United States declared the offshore stock overfished in 2002 when the spawning stock was 25% of the pristine level of abundance. The 2004 assessment found that higher than expected recruitment in 1999 had increased the abundance of females spawning over the next three years, bringing the stock estimates closer to 50% of pristine abundance (Canada-US Pacific Hake STAR Panel 2004).

Rockfish and thornyheads (*Sebastes* spp. and *Sebastolobus* spp.)

Approximately 28 species of rockfish are caught commercially in BC. They are very long-lived fish with low productivity, making them vulnerable to overfishing. Inshore species are caught mainly in the groundfish hook and line fishery. Offshore species are caught in a hook and line fishery and a trawl fishery.

The status of many offshore rockfish stocks is poorly understood. Abundance is thought to be low or declining and many stocks may be fully exploited. Bocaccio is currently listed as threatened by COSEWIC, which is in the process of preparing species status reports for five species of rockfish.

Serious conservation concerns for inshore rockfish species led to the development of the Rockfish/Lingcod Conservation Strategy in 2002 (DFO 2002b). Under the strategy, 89 areas have so far been closed to fishing to protect inshore rockfish, with the eventual aim of closing up to 30% of the rockfish habitat in the Strait of Georgia. Just under 20% of rockfish habitat on the West Coast of Vancouver Island, Central Coast, North Coast, and Haida Gwaii has been set aside in Rockfish Conservation Areas.

Sole (Family Pleuronectidae)

Five main species of flatfish are caught in the groundfish trawl fishery:

- Two species of rock sole (*Lepidopsetta bilineata* and *L. petraborealis*) are caught in a directed fishery in Queen Charlotte Sound and Hecate Strait and also as incidental catch in the Pacific cod fishery. In recent years quotas have been reduced for this species because of low recruitment, possibly due to changes in climatic conditions (DFO 1999m).
- Dover sole (*Microstomus pacificus*) is caught off the West Coast of Vancouver Island and Haida Gwaii. Both stocks appear to fished close to their maximum sustainable yield, and quotas have been introduced to reverse declines in abundance (DFO 1999n).
- English sole (*Parophrys vetulus*), the largest stock (Hecate Strait), is caught in a directed trawl fishery and as bycatch in rock sole and Pacific cod fisheries. Biomass in this fishery is estimated to be above the 50-year average and abundance has stabilized with no change expected (DFO 1999o).
- Petrale sole (*Eopsetta jordani*) occurs in two main populations (off the south coast of Vancouver Island, and Queen Charlotte Sound and Hecate Strait), and appears to be rebuilding after the directed fishery was closed in the mid-1980s and a bycatch cap put in place (DFO 1999p).

Populations of English sole, rock sole, and other species in the Hecate Strait have shown apparent cyclic trends in abundance over the past 50 years that may be related to oceanic conditions (DFO 1999o).

Pelagic Fish

Pelagic fish inhabit the water column and surface waters and often occur in large schools. Small pelagic fish (such as sardines, anchovy, and herring) tend to be caught in seine nets. The largest pelagic fishery in BC at present is the herring roe fishery, with a wholesale value of $83.5 million in 2004. The second largest is the albacore tuna, which are caught by troll gear; in 2004, the wholesale value was $36.3 million (BCMOF/MAL 2005). Minor fisheries have at times existed for Northern anchovy and surf smelt.

Pacific herring (*Clupea pallisii*)

Pacific herring are among the most abundant fish species on the coast of BC. Herring in BC are divided into five major migratory stocks and a number of minor stocks that spawn outside the five main stock assessment areas (Schweigert 2004). Herring have been harvested in BC since the late 1800s.There was a herring reduction fishery (which produced fishmeal and fish oil) which collapsed in 1967; since 1972 there has been a herring roe fishery (Schweigert 2004). A herring spawn-on-kelp fishery is managed separately and occurs in all areas except the Strait of Georgia. The fishery operates by suspending lines of kelp in enclosed ponds or along the shoreline where herring are expected to spawn. There is also a small food and bait fishery targeting winter migratory stocks.

Three of the five main stocks appear to be stable, with sufficient levels of abundance (Prince Rupert, Central Coast, and Strait of Georgia), but two stocks are declining due to poor recruitment (Haida Gwaii and West Coast Vancouver Island) (Schweigert, in press).

Albacore tuna (*Thunnus alalunga*)

The troll fishery for albacore tuna is one of the top ten fisheries in landed value in BC. It is assessed by international bodies: the Inter-American Tropical Tuna Commissions (IATTC) and the Western and Central Pacific Fisheries Commission. The most recent assessment shows that the North Pacific albacore is currently fully exploited and speculates that it may currently be fished at levels above what is sustainable in the long term. IATTC is recommending measures to avoid increasing the impact of fishing on stocks (IATTC 2005).

Eulachon (*Thaleichthys pacificus*)

Eulachon are a culturally important species to coastal First Nations. The fish are rendered down to extract the oil and are also eaten. Except for the Fraser River, there are currently coast-wide recreational and First Nations fisheries for eulachon. The Fraser has been closed to commercial eulachon fishing since 1999 due to extremely low returns of spawners (DFO 1999b). In 2004, the Fraser River stock was estimated to be at a 10-year historical low (DFO 2004c) and there are anecdotal reports of reduced eulachon runs in some central coast rivers. Threats to long-term sustainability include capture of eulachon as bycatch in trawl fisheries, river pollution, and predation by marine mammals (DFO 1999b).

Pacific sardine (*Sardinops sagax*)

Pacific sardine is a shared stock with the United States and is assessed annually by US scientists (DFO 2002h). Pacific sardine was listed as vulnerable by COSEWIC in 1987 and sardine fisheries were closed in BC. Abundance of sardine in BC waters depends on spawn biomass in southern California. After the recovery of the Californian stock, sardine reappeared in BC waters in 1992, increasing through the 1990s to what may be historical levels. There was a limited experimental harvest from 1996 to 2001 and Pacific sardines were de-listed by COSEWIC in May 2002. A commercial fishery started in 2002 (DFO 2004d).

Invertebrates

The term invertebrates encompasses a diverse array of animals that do not have a backbone. Many invertebrates are collectively referred to as "shellfish." These include crustaceans (e.g., shrimp, crabs, barnacles); molluscs (e.g., clams, oysters, snails, squid, and octopus); and echinoderms (e.g., sea urchins, sea cucumbers). There are significant

BC fisheries for crab, shrimp, clams, and other species. The wholesale value of shellfish harvested in BC was $194.8 million in 2004.

Dungeness crab (*Cancer magister*)

Dungeness crabs occur from California to Alaska in shallow, sandy bottom habitats. There are commercial, First Nations, and recreational fisheries throughout its range. It is one of the most valuable invertebrate fisheries in BC, with a wholesale value of $67.9 million in 2004. The commercial fishery uses baited traps fished from vessels in seven license areas. Landings are unknown for the First Nations and recreational fisheries, but may be substantial in some areas. There may be significant unreported or illegal harvest (DFO 2001a). All stocks are intensively harvested and appear to be fully exploited. Catches in all areas are subject to natural variation between years but most fisheries are expected to remain sustainable, despite a high exploitation rate (e.g., DFO 2001a).

Shrimp (*Pandalus* spp. and *Pandalopsis dispar*)

The shrimp trawl fishery lands seven species of shrimp, but the primary target species are smooth pink, northern pink, and sidestripe shrimp. Catches of other species, including prawns, are restricted to smaller quantities. With the sharp decline of fishing effort in the offshore water around 1997 (largely because the drop in the world price paid for shrimp has made the fishery less economical), less than half of the coast-wide catch is now taken from offshore waters.

There is an inshore trap fishery for prawn, coonstripe, and humpback shrimps, as well as a First Nations food fishery. There is also an unlimited entry recreational shrimp trap fishery, operating mostly in easily accessible inshore areas. Commercial, recreational, and First Nations trap fisheries for prawns are considered to be fully sustainable but fully exploited at present effort and participation levels (DFO 2004e).

Clams

- Geoduck clams (*Panopea abrupta*) are among the most valuable invertebrate fisheries in BC. There is a First Nations harvest under communal licence and a recreational fishery limited to hand digging (DFO 2004f). Recent years have seen strong recruitment in geoduck beds over a range of harvest histories (DFO 2000b). The geoduck fishery appears sustainable under the current catch and management framework (DFO 2005a).
- Horse clams (*Tresus capax* and *T. nuttallii*) are harvested incidentally to geoducks and both are harvested by divers using high-pressure waterjet. A pilot directed fishery for horse clams began in 2003 that appears to be sustainable under the current management (DFO 2004f).
- Manila, littleneck, and butter clams (*Venerupis philippinarum, Protothaca staminea,* and *Saxidomus gigantea*) currently support commercial and recreational harvests, as well as First Nations food and ceremonial fisheries. Clams are harvested during low tides using rakes or scrapers. Although other species are taken, the primary target is

Manila clam and the commercial fishery is primarily managed for this species (DFO 1999r). There is concern that intensive harvests and repeated digging may affect survival and growth rates and that the size limit may not be protecting Manila clams against poor recruitment (DFO 1999r). Littleneck clams are assumed to be adequately protected by the size limit and lower fishing pressure because they are less desirable (DFO 1999s). Quotas have been set for some clam fisheries on the coast. The invasive varnish clam may be competing with native clams (DFO 1999r,s).

Other Species

At times there are, or have been in the past, fisheries for the following invertebrate species: goose barnacle (*Pollicipes polymerus*), roe fisheries for green and red sea urchins (*Strongylocentrotus droebachiensis* and *S. franciscanus*), giant red sea cucumber (*Parastichopus californicus*), opal squid (*Loligo opalescens*), neon flying squid (*Ommastrephes bartrami*), krill (*Euphausia pacifica* and *Thysanoessa* spp.), scallops (*Chlamys rubida* and *C. hastata*), northern abalone (*Haliotis kamtschatkana*), and razor clams (*Siliqua patula*).

Interpretation

Published outlooks for assessed fish and invertebrate stocks differ greatly in the types of information presented, so it was not possible to summarize information into tables or graphs for comparison with outlooks for the stocks published in the future. This is not surprising, given the complexity and diversity of the fisheries presented. For species where assessment is done, however, it should be possible to include consistent information in all stock status outlooks. For example, the Food and Agriculture Organisation of the United Nations (FAO) and many regional fisheries agencies report the status of fish and invertebrate stocks according to their level of exploitation (i.e., underexploited, moderately exploited, fully exploited, overexploited, no data; FAO 2005). This information was included in some of the BC stock outlooks, but not for all species. Such categories have the advantage of being trackable through time and they can often be computed with information already being collected for the fishery. Adding consistent categories to published stock outlooks would help interested stakeholders to follow the progress of fisheries management through time.

Nevertheless, the high cost of conducting stock assessments means that it is simply not feasible to perform complete assessments for every species. Fisheries and Oceans Canada is exploring options with industry and First Nations for joint funding and research projects (DFO 2004g). For example, research for the sablefish fishery is now jointly funded and carried out by industry (DFO 2003a). Many invertebrate fisheries are also shifting to this kind of management. For low-value species, however, it may never be financially or logistically feasible to perform proper stock assessments. Abundance of these species will continue to be monitored by data obtained from the commercial fishery.

Supplementary Information: A Herring Tale

Herring is one of the oldest commercially fished species (caught in BC since 1877). The fishery evolved from producing dry salted fish in the early 1900s to a reduction fishery producing fish meal and oil in the 1930s. Currently the main fishery is for herring roe. Herring is also a key forage fish for other fish, and for marine mammals and birds, meaning that the level of abundance of herring can have a ripple effect on the populations of other animals in the marine food web.

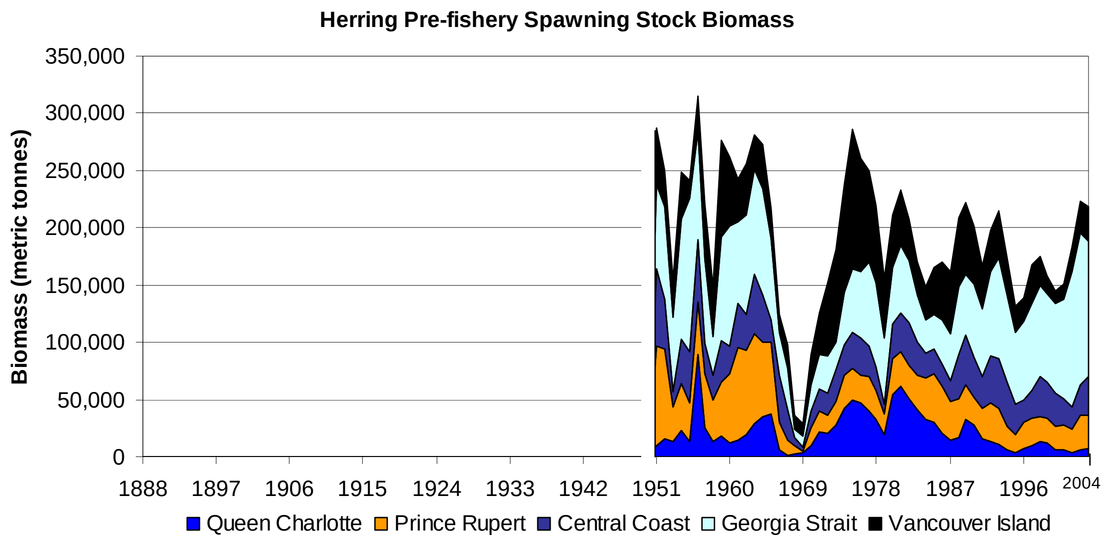
Using herring as an example, the following graphs demonstrate some of the complexity of interactions between fishing pressure and ocean conditions, fisheries management practices and market forces, on both the biomass of the fish population and what is caught.

Using retrospective analytical models, Schweigert (2004) estimated the pre-fishery spawning stock biomass for the five major stocks of herring from 1951–2004 (Figure 4a). Figure 4b shows the catch of herring from the late 1800s to 2004. Herring catches rapidly increased through the early 1960s, mainly in the reduction fishery, which had no limits on the amount of herring that could be used. Figure 4a shows the combined effects of overharvesting and the effects of climate change, which resulted in a population crash in the mid-1960s in the five major stocks (Schweigert 2004). After the collapse of the stocks, the reduction fishery was closed in 1967, and herring populations rapidly rebounded to near historical levels.

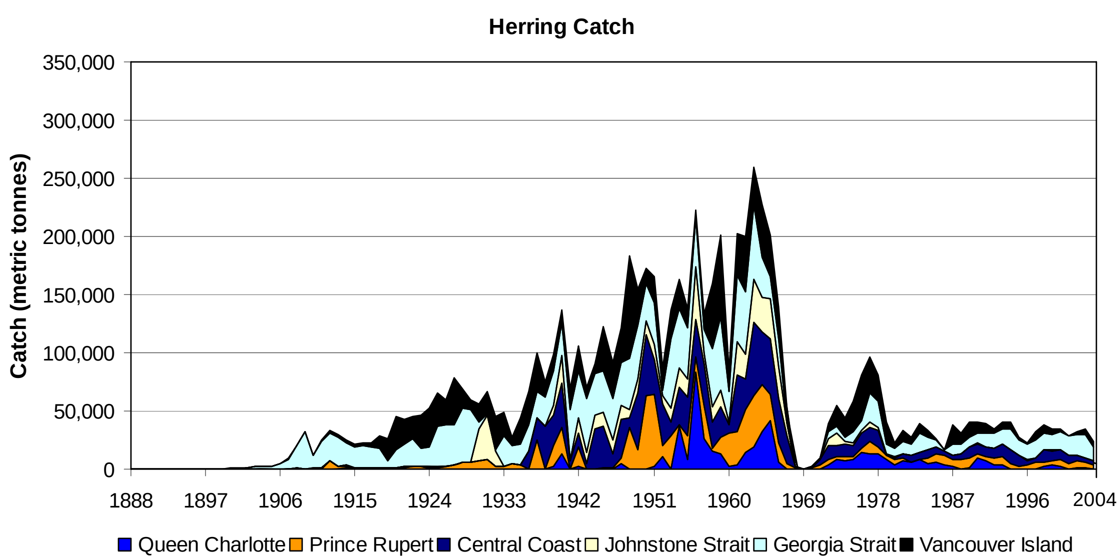
In 1972, stocks were deemed sufficiently robust and a limited herring roe fishery was opened. The fishery is managed conservatively to keep the harvest rate target at 20% of the forecast biomass in each of five management areas on the coast. Although the biomass of most main herring stocks is generally healthy, Figure 4b shows that the catch in the roe herring fishery has declined in recent years. This is predominately because of market conditions in Japan, the main export market (BCMAFF 2004), rather than because of an overall decline in stocks. The pre-fishery biomass graph, however, does show that two stocks (Queen Charlotte Islands and West Coast Vancouver Island) are declining; poor recruitment in these stocks is thought to be linked to climatic conditions.

Figure 4. a. Pre-fishery spawning biomass (in metric tonnes) of herring by spawning stock. b. Time series of herring catch (in metric tonnes) by stock.

a.



b.



Source: Schwiegert 2004 (biomass); and Fisheries and Oceans Canada (catch: *www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/tabcfram.htm*).

4. Secondary Indicator: Change in trophic level of marine catch in Canadian Pacific fisheries

This is an impact indicator. It addresses the question: Have BC marine fisheries shifted toward catching species lower on the food chain?

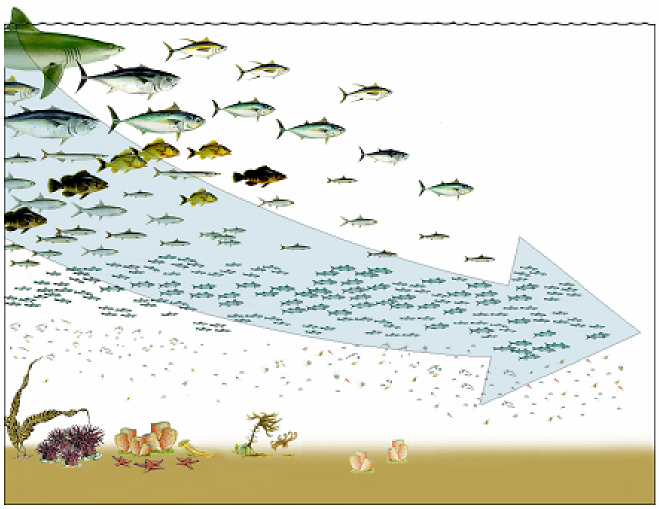
This analysis uses the commercial catch data as a proxy for measuring whether there has been a change in the underlying structure of marine ecosystems. The index does not show the cause of changes, but negative changes would provide an early warning of ecosystem impacts requiring investigation.

Fish populations are embedded within complex ecosystems and interact with other organisms largely as predators, prey, or competitors. The trophic (feeding) role played by a particular species depends to a degree on its size (i.e., larger fish tend to eat smaller fish). This indicator reports the mean trophic level (TL) for Canada's Pacific fisheries. The international Convention on Biodiversity (UNEP 2004) has proposed the mean TL as a global indicator of impacts of commercial fishing on fish stocks. A decline in the index could indicate changes in trophic structure of the ecosystem, possibly caused by unsustainable fishing practices, global climate change, or other factors.

A simple way to think about trophic structure in ecosystems is to arrange trophically linked species hierarchically along a "food chain" (Figure 5). Each link of the simplified food chain is called a trophic level (Lindeman 1942). Trophic levels range from an assigned value of 1 for plants and algae to a value rarely exceeding 5 for top predators, such as marine mammals, large sharks, and humans. The trophic level is calculated by adding 1 to the trophic level of the prey consumed. A fish feeding on algae would therefore have a trophic level of 2; a fish feeding on that fish would have a trophic level of 3; and so on.

This system becomes complicated, however, because many animals feed at several trophic levels and thus cannot be allocated to just one trophic level. To address this, fractional trophic levels are calculated from what is known about the average proportion of each type of prey in the diet of a particular species. For example, a fish that eats 20% algae and 80% herbivores would have a trophic level of $1 + (0.2 \times 1 + 0.8 \times 2) = 2.8$ (see Odum and Heald 1975; Christensen and Pauly 1992).

Figure 5. Illustration of the concept of fishing progressively farther down marine food webs. The blue arrow represents fisheries efforts moving to target lower trophic levels as the upper levels diminish.



Source: Concept by D. Pauly, illustration by A. Atanacio. Reproduced with permission from D. Pauly, UBC Fisheries Centre.

Using trends in the mean TL of fisheries catches as an indicator of the sustainability of a region's fisheries was first proposed by Pauly and Christensen (1995). Pauly et al. (1998) demonstrated a global trend of declining mean trophic levels in fisheries catches, which was also evident at a smaller scale in several FAO statistical regions. This effect, termed "fishing down marine food webs," has been shown in Thailand (Christensen 1998), the Mediterranean (Stergiou and Koulouris 2000), and the North Sea (Furness 2002). For Canadian fisheries, Pauly et al. (2001) reported a downward trend in mean trophic level of landings in east coast Canadian fisheries of approximately –0.1 TL per decade. For west coast Canadian fisheries up to 1996, Pauly et al. found a more complex pattern (see Figure 6), with a linear increase in mean trophic level from 1873 to 1894 (a slope of 0.215 TL per decade), followed by a period up to 1996 with an overall linear TL trend of –0.032 per decade.

A proposed explanation for long-term declines in TL of landings is the result of fishing pressure. Fisheries tend to switch from catching large, predatory species with high trophic levels to shorter-lived species with lower trophic levels as their relative abundance in the ecosystem changes (Pauly et al. 1998). Species with high trophic levels (cod, tuna, and sharks) tend to be less resilient to overfishing and are depleted more quickly than species with low trophic levels (Kirkwood et al. 1994). As the effort to catch these larger species increases, some or all of the fishing fleet will seek new targets. Step-wise declines in the mean TL may occur when new technology enables greater exploitation of a species, followed by collapse of that species and a shift to exploitation of others of lower trophic levels.

Other explanations for observed trends in mean trophic levels of fisheries catches have also been suggested (e.g., Caddy et al. 1998; Caddy and Garibaldi 2000):

- Changes in technology and markets may be stronger driving forces than changes in abundance. Valuable species may be selectively targeted because of high demand. Many crustaceans with low trophic level (e.g., prawns, crab) and molluscs (e.g., scallops, geoducks) fall into this category.
- Similarly, landings of valuable species (e.g., bluefin tuna, Atlantic cod) may remain high even when stocks are depleted because their value makes it worthwhile to meet the costs of continuing to pursue the fishery. For this reason, Pauly et al. (1998) and Pauly et al. (2001) have suggested removal of certain species from the analysis that may "mask" or exaggerate underlying trends.
- In certain systems, there may be a "bottom-up" effect on the food chain caused by eutrophication that kills organisms at the base of the food web. This may lead to a cascade effect on animals farther up the food chain and may be primarily responsible for observations of increased landings of species of lower trophic levels.
- There are well known problems with using commercial catch data as a proxy for underlying system structure, particularly when overfished species undergo range collapse (e.g., see Hilborn and Walters 1992). It is not yet clear how the mean TL is affected by such an effect. Furthermore, the quality of the data used in the analysis will strongly affect the outcome—especially if data are missing or species are too aggregated.

The mean TL is reported here because it has been adopted internationally by the Convention on Biodiversity as an indicator of the integrity of marine ecosystems (UNEP 2004). Within a suite of indicators, it may become a useful indicator of changes in BC marine ecosystems, especially when more fishery-independent data become available. An example of how this indicator could be used comes from a recent study of Celtic Sea fisheries, which found a significant decline in mean TL of both catches and landings. This led to study of a number of factors, in which Pinnegar et al. (2002) concluded that there had been some change in the underlying structure of the system, possibly due to fishing, but that market pressures were not a cause of the observed decline and that long-term climate variability may have contributed to it.

Methodology and Data

Mean trophic levels of landings for each year (Mean TL_y) were calculated by weighting trophic levels of each species according to catch and calculating the mean for each year:

$$\text{Mean } TL_y = \Sigma\,(C_{iy} \cdot TL_i)/\,\Sigma\, C_{iy}$$

where C_{iy} represents the landings of species *i* in year *y* and TL_i is the fractional trophic level of species *i* (Pauly et al. 1998).

Catch data were obtained from DFO from 1982 to 2003 (S. Spohn, DFO Regional Data Unit, 2004. pers. comm.), except for groundfish trawl fisheries (Option A and B) and sablefish trap and longline data, which were obtained from R. Stanley (DFO PBS, Nanaimo, 2005. pers. comm.)

The data provided by DFO for the years after 1995 represented only catches from five fisheries (bottom and midwater trawls; hook and line; trap; and longline, not including halibut). Catches from salmon gear, seine nets, shore-based invertebrate fisheries and halibut were obtained from DFO's landings statistics website (*www-sci.pac.dfo-mpo.gc.ca/sa/Commercial/AnnSumme.htm*) and added to the data.

Where possible, an attempt was made to use similar trophic level estimates to those used in Pauly et al. (2001) so that a comparison could be made. Specifically, for salmon, a trophic level of 3.8 was used for all species even though Fishbase (a free online database of biological information on the world's fish species: *www.fishbase.org*; Froese and Pauly 2000) gave estimates of 3.5 to 4.4 for the various species. The following estimates were also used, although they may disagree slightly with those found in FishBase: halibut, 4.0; hake, 3.8; Pacific herring, 3.0; all rockfish species where no trophic level was available in Fishbase, 3.4; all tunas, 4.2. In addition, a database of trophic levels was obtained from the UBC Fisheries Centre's Sea Around Us project (*www.seaaroundus.org*, R. Watson, UBC Fisheries Centre, 2005. pers. comm.). For other species where the common name coincided with that given in the Sea Around Us database, the trophic level estimated in that database was used.

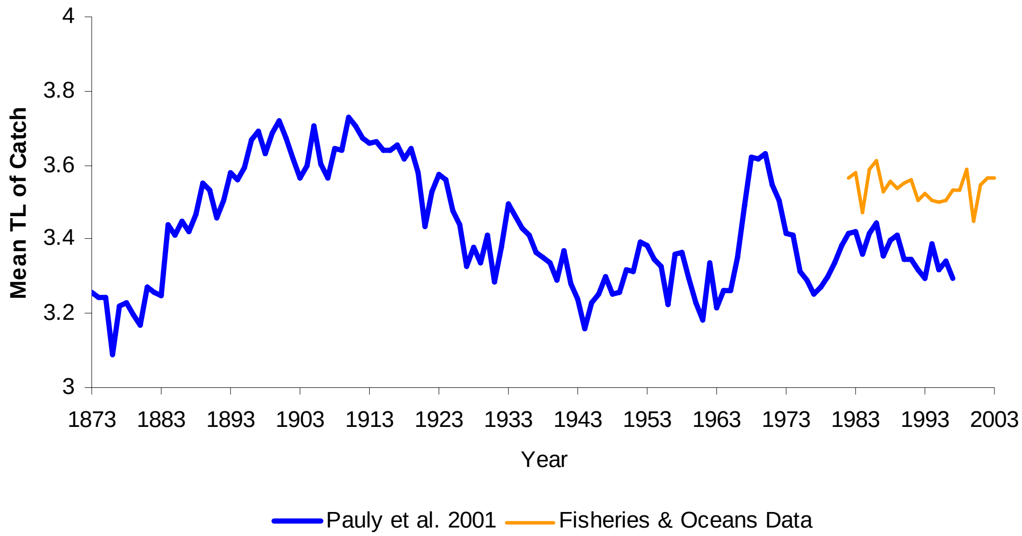
Where no common name was available, estimates from Fishbase were used. For invertebrates, most bivalves, molluscs, echinoderms, etc., were given a trophic level of 2.1; sea stars and other predatory species were assigned 3.5; crabs other than king crab, 2.6; king crab, 2.8; shrimp, 2.7; mammals and birds, 4.0; and fur seals, 4.2 (also after Pauly et al. 2001). Trophic levels for other invertebrates were taken from the Sea Around Us database. Data used for calculation of the Mean TL index in Pauly et al. (2001) were obtained from M.L. Palomares (Fisheries Centre UBC, 2005. pers. comm.). This dataset covers the period 1893–1996, with 15 years of overlap with the DFO data.

The index was calculated using catch (landings + discards), as this represents the underlying ecosystem better than landings alone.

DFO's catch reporting system changed considerably in 1996 with the introduction of Individual Vessel Quotas and mandatory observer coverage. Several discontinuities in the dataset occurred at this time, including the addition of a large number of species that had previously been recorded only under aggregate headings (e.g., after 1996, 32 species of rockfish are recorded that had all previously been reported as just "rockfish"). Although landings of most of these species would previously have been reported under aggregate categories, the extent to which individual species were or were not reported before 1996 is not known. Trends in the Mean TL index before and after 1996 were therefore also calculated separately.

The Mean TL of landings index for west coast Canada, calculated from the historical data of Pauly et al. (2001) as well as from recent DFO catch statistics is shown in Figure 6.

Figure 6. Trophic level of the landings in BC obtained from Pauly et al. (2001) and calculated for this indicator from more recent DFO catch data.



Interpretation

The analysis for this indicator, using recent DFO catch statistics, found virtually no trend in the data between 1982 and 2003 (–0.013 TL per decade), thus no evidence that there has been a detectable change in marine ecosystems. For the period 1982–1995, the linear trend in Mean TL was –0.077 TL per decade. This agrees with the findings of Pauly et al. (2001) of a linear trend of –0.070 TL per decade, for the period overlapping with the present analysis (1982–1996). The difference in magnitude between the two indices is most likely an artefact of changes in estimated trophic levels reported in FishBase.

For the period 1996 to 2003, this analysis showed a trend of +0.059 TL per decade. This reversal of trend is probably not related to changes in the underlying trophic structure of the ecosystem, because it coincides with changes in the reporting system and the resulting dataset, as well as the introduction of vessel quotas and other management measures that would reduce the reported landings of some species. For example, reported catch (landings + discards) of arrowtooth flounder (TL = 4.26) increased by an order of magnitude after 1996, due to increased reporting of discards. Catches of shrimp (TL = 2.7) have declined since 1996, due to the introduction of seasonal closures, catch ceilings and closer monitoring of landings (DFO 1998); this decline is also due to a drop in world prices that has made the west coast shrimp trawl fishery less able to compete economically. The changes in both of these fisheries contributed to the increase in the TL trend observed after 1996, but in neither case does it reflect changes in the underlying structure of the ecosystem.

The value of a composite index, such as the mean TL of landings, depends on the quality of data underlying the analysis. There is a strong possibility that species present in the ecosystem before 1996 were not represented in the analysis because they were discarded and not reported. Also, large changes in fisheries management must be accounted for in the analysis. Although not straightforward to interpret, this indicator is simple to calculate, using readily available data. As a change in the marine ecosystem structure is currently the main hypothesis to explain trends in Mean TL of landings, should a trend be found in future, the likelihood of this hypothesis should be evaluated in light of as much other evidence as is available.

5. Key Indicator: Estimated trends in illegal, unreported, and unregulated (IUU) catch since 1950 in West Coast fisheries

This is a response indicator, showing the effects of changes in regulations and technology intended to address the illegal, unreported, and unregulated (IUU) catch. It addresses the questions: What is being done to mitigate negative impacts of fishing? How successful are these efforts?

In addition to nominal fisheries landings and reported discards, fisheries catches may include a certain amount of IUU catch. There are three components to IUU fishing (see also Bray 2000; Pitcher et al. 2002):

Illegal catch: Catch concealed or misreported as other species in violation of regulatory limits (such as time or area closures, quotas, gear restrictions, licensing, etc.). It may also include unreported harvests landed in foreign ports or trans-shipped to foreign vessels at sea. This is the most difficult component of IUU to quantify. An accurate record is difficult to obtain from surveys if fishers are afraid of incriminating their industry, and the presence of onboard observers is likely to curtail illegal activities altogether during the observation period (e.g., Zwanenburg and Smith 1983; Kulka 1997).

Unreported catch: This includes discards not included in catch statistics (but that may be recorded by observers); fish taken home or eaten by fishers; and recreational catches, which may be significant (e.g., Post et al. 2002).

Unregulated catch: Catches of species that authorities do not have a mandate to monitor or catches originating from vessels or gear types not subject to strict accounting requirements.

In west coast Canadian fisheries, the only IUU component regularly assessed is discards for the groundfish trawl and hook and line fleets. Efforts to quantify discarding through use of on-board observers have been limited to large vessels. Observer coverage for the groundfish trawl is now very high (100% of vessels are covered, but not for 100% of the time); the hook and line fleet receives partial coverage (Haigh et al. 2002).

Quantifying IUU catch is extremely difficult. In the absence of reliable estimates of unreported catch, a "zero" quantity for IUU elements is often assumed (Pitcher et al. 2002), despite the possibility that absence of these records could affect estimates of stock abundance and safe harvest rates. Recently, a new methodology was developed to estimate changes in the quantity of IUU catches over time, based on influences in the history of the fishery and on independent estimates of misreporting (Pitcher et al. 2002; Ainsworth and Pitcher 2005).

Ainsworth and Pitcher (2005) estimated discards and illegal catch for the past 50 years in the major BC fishing sectors: salmon (gillnet, troll, seine, and recreational) and groundfish (bottom trawl, hook and line, and recreational). The results of the analysis are used as a response indicator, by relating relative quantities of estimated IUU catch to the regulatory and technological conditions at the time. To some extent it is also a pressure indicator, as it provides an estimate of one component of fishing pressure on stocks.

Methodology and Data

The following sections summarize the methods and results of Ainsworth and Pitcher (2005). A detailed discussion of the method and results, including underlying data tables used in calculations are available in the published paper.

To estimate missing catch, a technique similar to that reported in Pitcher et al. (2002) was used. The calculations use Monte Carlo statistical methods to mathematically simulate real systems by taking the randomness (probabilities) inherent in real systems into account. Once many simulations are performed, an average is taken from the total number of observations. Monte Carlo simulations are well established as a tool for risk and decision analysis to help make decisions where there are uncertainties in trends, model parameters, and other factors.

The basic methodology follows seven steps:

1. Create a timeline of the fishery, taking note of regulatory, technological, and political changes that are likely to have affected the quantity of fishery discards, illegal, unreported, and misreported catch.

2. Create a running score of "influence factors" describing the effects of each historical event on IUU rates to obtain the estimated trend of IUU through time. For example, quotas are known to sometimes provide incentive to discard less valuable or smaller fish to fill the quota with more valuable fish (e.g., Arnason 1994, 1996). Ainsworth and Pitcher's (2005) analysis considered 154 events in the history of BC fisheries since 1950 that are likely to have affected rates of IUU, including changes in management and policy, and technological and market developments.

3. Assign an "incentive" rating (low, medium, or high), based on the magnitude of influences, to describe the total incentive to misreport for each 5- or 10-year period in the timeline.

4. Scale the incentives trend to establish an absolute range of values for each incentive rating (in units of percentage IUU catch per target species catch). These values are based on fixed "anchor points," which are quantitative, independent estimates of IUU taken from the literature and expert opinion.

5. Estimate absolute IUU for missing periods based on relative incentive rating.

6. Using the range established in step 4, provide an estimate of total extractions for each fishery (reported plus missing catch), weighing the contribution of each gear type to IUU by its mean reported catch. For each period, estimates will contain an upper and lower bound. If possible, determine a "best guess" estimate within the total range.

7. Use Monte Carlo resampling to determine the mean weight of missing catch with associated confidence intervals for each period, based on the likely error range established in step 6. Assume an asymmetric triangular distribution around a specified mode (the "best guess").

In this analysis, IUU categories were considered separately in terms of influences acting on them. An independent history of influences for each type of IUU was developed, based on a review of the relevant literature. Categories of IUU considered were (i) discards; (ii) illegal catch; and (iii) unreported catch. Discards in the salmon and groundfish fleets were assumed to contain both "unreported" and "unregulated" catch.

Discards: Information about discards for the salmon and groundfish fisheries included data from experimental fisheries, onboard observer programs, and predictive models. In some cases, data from outside BC were used. For the groundfish trawl fishery, it was assumed that proportional discard data from the halibut trawl fishery (which has the most information) could be applied.

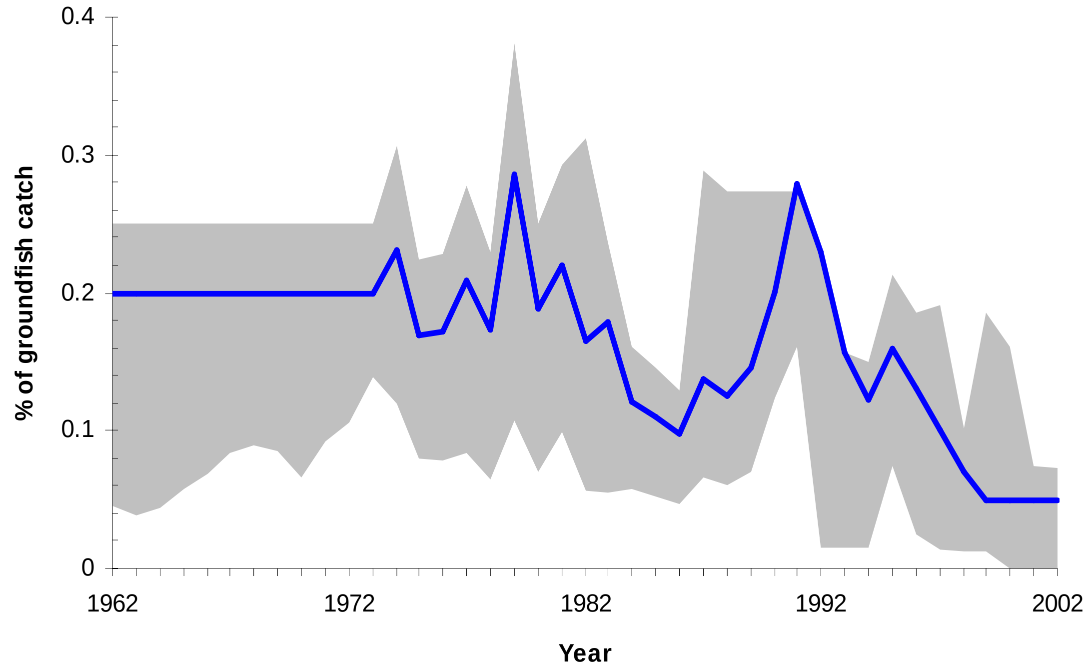
Illegal catch: Fisheries and Oceans Canada publishes news releases detailing the confiscated weight of illegally caught fish taken by fishery officers during enforcement operations. Because the news releases represent a small proportion of total incidences of illegal activity, in the absence of complete information, a critical assumption was made that DFO news releases account for 10% of the total weight of fish taken illegally (including weight confiscated but not reported, and including illegal catch that goes unnoticed by authorities).

Unreported catch: The only "unreported" catch considered by Ainsworth and Pitcher (2005) was that of the recreational salmon fleet. Anchor points were based on the discrepancy between the two available datasets for sport catches in BC. DFO Pacific Region conducts annual creel and logbook surveys (supplemented by aerial observations) to calculate recreational catch. These estimates can represent as little as one-third of the total amount estimated by mail-out surveys, conducted every 5 years by the DFO Statistical Services Branch. The disagreement is likely due to differences in methodology, because the Pacific Region's creel estimates do not account for landings in many ports and do not capture activity on the shore or at private docks.

The nature of IUU catch demands an unavoidably subjective method for quantification. The methodology depends on the reviewed literature and other independent sources to set the range of likely values and therefore makes the major assumption that these sources adequately represent the scope of IUU catches. Other assumptions made the analysis are summarized in Ainsworth and Pitcher (2005).

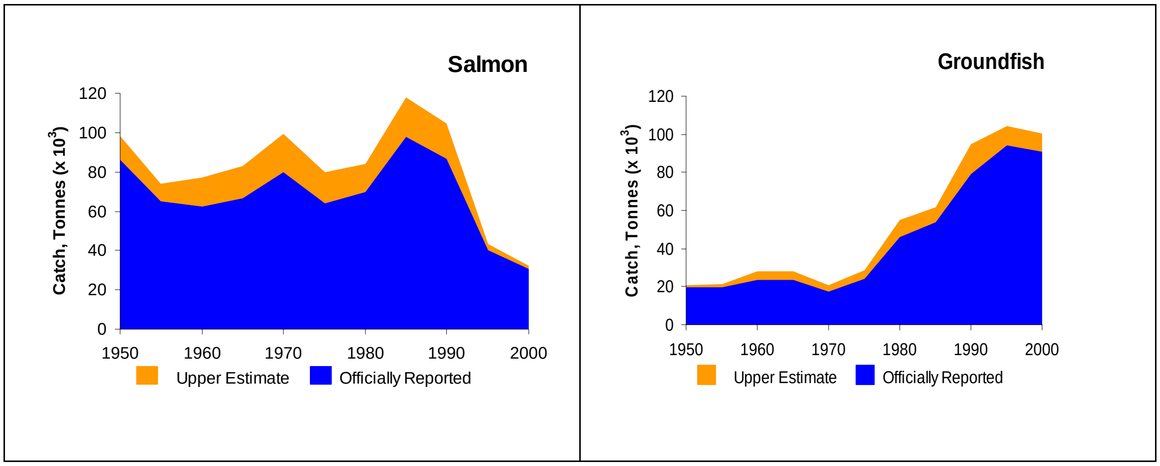
The likely range of groundfish discards resulting from this analysis is shown in Figure 7. Estimated total extractions from the salmon and groundfish fisheries are shown in Figure 8.

Figure 7. Likely range of groundfish discards. Shaded area shows full range of estimates available in the literature; the line shows "best guess" estimate from calculations.



Source: Ainsworth and Pitcher (2005).

Figure 8. Total estimated extractions in BC salmon and groundfish fisheries, 1950–2000. Upper area shows upper estimate of IUU catch at the 95% confidence limit.



Source: Ainsworth and Pitcher (2005).

Results for the three types of IUU are summarized below. For caveats and assumptions, see Ainsworth and Pitcher (2005).

Discards: Discards in the salmon fleet appear to have been small in comparison to reported catch. The highest values found in the published literature were around 5 to 6% of total landings. This analysis suggests that discards were around 2.2% until the mid-1980s, then dropped to the current estimated level of less than 1%. The estimated decrease was related largely to gear modifications introduced in the 1980s (e.g., weedlines in gillnets and brailing boards in the seine fishery) used in conjunction with new techniques to improve selectivity.

At its worst (from 1990–1995), it was estimated that the hook and line groundfish fleet discarded a weight of fish equivalent to 22.6% of reported catch. Between 1975 and 1980 the trawl fleet is estimated to have discarded approximately 17.8% of reported catch. In recent years, however, bycatch reduction initiatives have had an impact. Mesh size regulations, exclusion panels, grates, unhooking techniques, and species-selective baits have been used to reduce incidental capture. Despite a three-fold increase in groundfish landings, the rate of discarding in the groundfish fleet is now estimated to be relatively low.

Illegal catch: Illegal catch appears to have declined in the past decade. Incentives and opportunities to poach in both salmon and groundfish fleets remained stable until the mid-1990s, when observer programs were introduced for several fisheries (Ainsworth and Pitcher 2005). Also, illegal catch that had been occurring in unofficial commercial aboriginal fisheries was legitimized by political changes (e.g., the Sparrow decision; the pilot sales program; Wappel 2003).

Unreported catch: In recent decades, the recreational sector officially accounted for only 8% of salmon landings. For this sector, reporting is usually voluntary and there are large data gaps in the catch record, making estimates of unreported salmon catch significant. Unreported sport salmon catches may have exceeded the official statistics (obtained from creel and logbook surveys) by 220% until the mid-1990s. Since then, unreported catch appears to have been reduced by almost an order of magnitude relative to recorded landings.

Interpretation

IUU catch is estimated to be declining for salmon and groundfish, both in proportion to reported weight and in absolute terms. Between the 1950s and 1980s, 10,000 to 20,000 tonnes of IUU catch is estimated to have been taken in BC salmon and groundfish fisheries, mostly as discards and recreational salmon catch. IUU catch is estimated to have increased throughout the 1980s and, by 1990, the amount was probably closer to 30,000 tonnes per year (equivalent to 18% by weight of recorded landings). By 2000, it is estimated that IUU catch had fallen to about 8000 tonnes per year (6.6% of landings).

Obtaining the estimated trend of IUU through time was key to addressing the question of how successful regulatory efforts have been to mitigate IUU fishing (see Table 7). These sources suggests that, in general, direct regulatory attempts to reduce IUU (e.g., by introducing observers on vessels and improving enforcement) have been most successful, especially in the salmon fleets.

In contrast, regulations that limit the size or quantity of fish that can be landed may have increased incentives for IUU and appear to be related to the higher incidence of IUU in the groundfish fleet. Technological improvements specifically designed to reduce bycatch (e.g., sorting grids) have been successful, whereas those aimed at increasing fishing power (e.g., larger vessels, “rock-hopper” gear that allows trawls to operate on rough ocean bottoms) have tended to increase incidences of bycatch, although these influences appear to be low compared with the effects of various quota systems.

Table 7. Timeline of regulatory and technological changes affecting BC fisheries (see Ainsworth and Pitcher 2004, 2005 for original data sources)**.**

Date(s)	Event
1950-1954	1950: Otter trawls, drum seiners introduced, purse seining mechanized using hydraulic systems. American fleet begins to enter BC waters in numbers. 1952: International North Pacific Fisheries Commission established. 1953: Canada/US Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and Bering Sea signed. 1954: Voluntary trawl logbook program improves collection of catch statistics for Pacific Ocean perch, other rockfish.
1955-1959	c1955: Nylon, polyester used in net construction. Echo-sounders integrated into fleet.
1960-1964	c1960 Larger trawl vessels in use. Spawning channel construction, flow control projects and hatchery programs initiated to improve salmon production. Rockfish fishery begins. 1961: Foreign catch now includes sablefish. Foreign vessels required to carry licence. 1964: Territorial Sea and Fishing Act (international jurisdiction). 1965: USSR fleet enters BC waters. Canadians groundfish trawl begins in earnest.
1965-1969	c1966: Japanese fleet enters BC waters. 1967: Rockfish records begin. Improved technology to preserve fish at sea (e.g., quick freezing). Long-range navigation systems (LORAN) in use.
1970-1974	c1970: Fishers report greater variety of rockfish species (misreporting may have occurred to avoid restrictive regulations). Freezers enable market for less valuable species for use in processed foods (e.g., imitation crab, scallops). 1971: Large area fishery closure in Queen Charlotte Sound to reduce foreign fishing for POP.
1975-1979	c1975: Polish fleet enters BC waters. Average vessel size doubled since 1940, now up to 60 tonnes. Trawl fishery shifts away from POP to other species. 1976: Limited entry to groundfish trawl established using trip limits. 1977: Canada extends fisheries jurisdiction to 200 nautical miles under Economic Exclusive Zone (EEZ). Soviet and Japanese rockfish catches cease. Salmonid Enhancement Program begins. A change in British Columbia Fishing Regulations [1888] prohibits natives from selling catch commercially. Late 1970s: Salmon aquaculture begins in BC on Sunshine Coast and NE coast of Vancouver Island. 1978: Annual quotas applied to groundfish fishery. 1979: Department of Fisheries and Oceans established, implements license limitations, total allowable catches, species/area/time closures and trip limits to control harvest of groundfish.
1980-1984	c1980: Global Positioning System use begins. Rock-hoppers/tickle chains used to reduce habitat damage and bycatch in trawl fleet. Most foreign fishing ends in EEZ. Increasing engine power and fiberglass hull designs for salmon gillnet fleet results in shorter "soak" times and reduces bycatch. 1980: Groundfish trawl advisory committee formed. Vessel trip limits and area quotas imposed on yellowtail rockfish fisheries; quota applied on rock sole. Misreporting and discards in rockfish fishery increase in response to new regulations. 1981: Amendment to BC Fishing Regulations restricts number and species caught by Aboriginal people for food, social, and ceremonial purposes. New techniques improve age determination of major groundfish species.

	1982: US ceases rockfish catch. 1983: Quota for widow rockfish implemented.
1985-1989	1985: Salmon Enhancement Plan integrated into Pacific Region Salmon Resource Management Plan. Fisheries Act introduced, gives DFO authority to close fisheries for conservation. Canada ratifies Canada/US Pacific Salmon Treaty of 1984. 1986: Commercial fishery for widow rockfish begins. 1987: First quota for lingcod introduced. DFO initiates Pacific Regions Fisheries Observer Program to monitor trawl offloading, collect data for research and enforcement; observer coverage contracted for foreign and domestic vessels in EEZ. 1989: Observer coverage extended offshore to seamount fisheries. Late 1980s and 1990s: Salmon prices fall due to increasing aquaculture production, high yields in Alaskan salmon fisheries. Commercial size limit for lingcod increased to 65 cm in Strait of Georgia.
1990	Sparrow decision affirms Aboriginal right to fish under 1982 Constitution Act. Individual transferable quota (ITQ) established for sablefish fishery. Annual quotas for English sole and vessel trip quotas for petrale sole applied. Commercial lingcod fishery closed in area Strait of Georgia. Dockside monitoring with 100% coverage of landings initiated for ITQ sablefish fishery. Weedlines used in gillnet fishery to reduce steelhead bycatch. Use of sorting grids begins.
1991	Joint Canada/US commitment to reduce halibut bycatch through International Pacific Halibut Commission. BC initiates individual vessel quota system for halibut. Voluntary 140 mm cod-end mesh size suggested by 1991 Pacific groundfish trawl management plan for Pacific cod fishery (78 mm mesh size legislated). Dockside monitoring initiated for halibut IVQ fishery Recreational lingcod fishery size limit of 65 cm imposed.
1992	TAC and trip limits imposed on Hecate Strait Pacific cod fishery. DFO cooperates with Department of National Defence to conduct air surveillance patrols of North Pacific looking for high seas drift netting. Canada/US salmon agreements under the 1984 Pacific Salmon Treaty expire leading to competitive harvesting. Aboriginal Fishing Strategy established in response to Sparrow decision. Pilot Sales Program permits limited commercial catch for natives to reduce poaching. DFO issues permits for commercial aboriginal salmon fisheries in Port Alberni, Lower Fraser R., Skeena R. under the Aboriginal Fishing Strategy. 1992 Fraser R. sockeye fishery an "environmental disaster"; Pearse-Larkin report commissioned to investigate link to AFS. Pacific license retirement plan initiated.
1993	North Pacific Fisheries Commission dissolved, replaced by Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean. Sustainable Fisheries Program launched by DFO to conserve Skeena R. salmonids, includes steelhead observer program. Previously unrestricted widow and canary rockfish receive coast-wide quotas and trip limits. Quota for lingcod introduced. Aboriginal Communal Fishing Licenses Regulations approved.
1994	Misreporting reduced by mandatory dock-side monitoring program now in place for majority of groundfish trawl fisheries. UN Law of the Sea enters into force (ratified by Canada 2003).
1995	Directed fishery for petrale sole discontinued coast-wide. IPHC regulation requires halibut to be dressed before offloading, allows halibut bycatch in Pacific cod and sablefish fisheries to be kept. Staged reduction of halibut trawl bycatch mortality. Mesh size regulation for rock sole fishery to minimize juvenile mortality. 140 mm mesh size for Pacific cod trawl fishery now legislated. Under 1992 Pilot Sales Program, commercial licenses granted to three lower mainland First Nations bands on lower Fraser River. UN Food and Agriculture Organization draft "Code of Conduct for Responsible Fisheries," adopted by Canada. Groundfish trawl fishery suspended mid-season (TAC exceeded), hook and line limited. Voluntary buy-back of commercial fishing licenses announced. To improve data collection, BC Sport Fishing Regulations prohibits on-sea canning. Restrictions on west coast Vancouver Island, Strait of Georgia coho stocks due to conservation concerns.
1996	New sport fishery limits introduced for many previously regulated species; higher fines for offences under BC Sport Fishing Regulations. Canada Oceans Act passed: recognizes Canada's ocean jurisdiction, guidelines for integrated management and consolidates federal

	fisheries responsibilities. Amended coastal fisheries protection regulations require foreign fishing vessels to notify DFO on passage through BC waters. New aerial surveillance pilot project augments DFO's enforcement capabilities, improves collection of commercial fisheries effort statistics. Public consultation begins for groundfish IVQ allocations. IPHC increases recreational halibut limit in Strait of Georgia, prohibits halibut fletching (filleting) at sea. Lingcod size limit increased from to 65cm near Queen Charlotte Is. and west coast Vancouver Is. Trawl catch for Pacific cod in Hecate Strait limited to bycatch only, IVQs implemented. IVQs implemented for dover sole (replace area quotas) and English sole. New Groundfish Management Plan includes mandatory on-board observer program for groundfish trawl (replaces limited observer program of 1987) and caps on bycatch for trawlers. IVQ scheme stimulates large increase in the number of active trawlers (probably increasing illegal sales and high grading practices). BC government places 6 year moratorium on new salmon aquaculture (net pen) operations.
1997	Major changes to groundfish trawl regulation sets comprehensive IVQ scheme for 25 groundfish species; allocates IVQ holders 80% of TAC (formalized 1998). Pacific halibut management plan reallocates halibut IVQ. Groundfish Development Authority (GDA) formed to protect non-quota shareholders. Limited entry established for groundfish hook and line. Delgamuukw decision affirms Aboriginal right to fish commercially. Quota for lingcod introduced. Large decline in salmon prices due to expansion of aquaculture, particularly in Norway and Chile. Retention/possession of coho, chinook and steelhead disallowed for all seine fisheries.
1998	Industry develops Canadian Code of Conduct for Responsible Fisheries under new Pacific Fisheries Adjustment and Restructuring Program. Selective Fishing Program initiated by DFO: 5% of salmon TAC allocated to improve selectivity; experimental fisheries authorized for data collection and aboriginal fisheries using fish wheels, weirs, beach seine, and other methods; gear modifications to reduce coho bycatch mortality mandated through licensing conditions 1998-2002 (includes: revival tanks; shorter nets and soak times for gillnetters; brailing with dip nets for seiners, knot-less mesh to reduce abrasion, plastic escape holes to release undersized fish; barbless hooks for trollers); this reduces coho bycatch mortality from 60% to 5%. New Coho Response Team seeks new methods to reduce bycatch. Fisheries Renewal BC established to coordinate resources for habitat enhancement under Pacific Salmon Endowment Fund and Pacific Salmon Treaty. IPHC issues new halibut logbooks to improve in-season data collection. DFO and BC Wildlife Federation create first fishery officer-dog team trained for fisheries enforcement. 10% observer coverage implemented for lower Strait of Georgia commercial troll fleet. DFO releases "A new direction for Pacific Salmon Fisheries," reinforcing commitment to developing selective fishing. BC Fisheries Survival Coalition organizes large protest fishery on Fraser R. to protest native-only fisheries.
1999	DFO pilots satellite technology to collect real-time catch data, also biological, oceanographic data. Groundfish trawl fleet now composed of 142 licensed vessels, of which ca. 88 recorded landings. DFO observer program extended to hook and line halibut fisheries and rockfish fisheries. Rockfish Protected Areas implemented and rockfish discarding prohibited. Size limit for recreational lingcod increased to 65 cm off West Vancouver Island. BC recreational fishers required to supply catch records. Joint Canada/US commitment to restore salmon habitat, improve management under 1985 Pacific Salmon endowment funds totalling $200 million CDN established. Additional selective fishing experiments in Juan de Fuca Strait. Supreme Court Marshall decision affirms rights of Maritime aboriginal groups to fish in pursuit of "moderate livelihood." Canadian Environmental Protection Act passed, includes additional marine protection provisions and addresses land-based marine pollution concerns.
2000	Nis'ga treaty ratified, includes exclusive aboriginal fishing rights. Groundfish trawlers accept voluntary area closures to protect Hexactinellida sponge reefs. Environment Canada announces National Programme of Action to reduce land-based marine pollution in response to UNEP Global Plan of Action. Additional DFO funding strengthens fishery enforcement.
2001	UN Fish Stocks Agreement ratified by Canada in 1999, goes into effect. DFO extends observer coverage to all groundfish hook and line fisheries. IPHC allows limited filleting of halibut while at sea. To aid data collection, halibut fishers keep log books throughout season, rather than surrendering books at each off-loading. Race Rocks established as Canada's first Marine Protected Area under Oceans Act.
2002	Moratorium lifted, permits for new Atlantic salmon net-pens issued. DFO announces Rockfish

	Conservation Strategy, including planned Rockfish Conservation Areas, which are extension of Rockfish Protected Areas. Pacific Scientific Advice Review Committee (PSARC) document reports unfavourable lingcod recovery, therefore commercial closure maintained for Strait of Georgia, recreational closure commences. Fraser River coho listed as "endangered" by the Committee on the Status of Endangered Wildlife in Canada. Coast-wide commercial fishery closure for sablefish. Areas surrounding Hexactinellida sponge reefs closed to commercial trawling by annual regulations and area under review for designation as Marine Protected Area. Fisheries Renewal BC ceases operation.
2003	Species at Risk Act (SARA) comes into effect. Green/shortnose sturgeon and Bocaccio rockfish listed as "threatened" by SARA. Pink Salmon Action Plan began in Broughton Archipelago to address poor returns at north end of Vancouver Is., including investigation of mortality factors, such as sea lice infections.

Source: Ainsworth and Pitcher 2004, Appendix Table A.1.

6. Secondary Indicator: Trends in discards in trawl fisheries since the introduction of mandatory observer coverage

This is both a response indicator, showing the effects of management measures to mitigate discards, and a pressure indicator, showing a type of fishing pressure on non-target species. It addresses the question: How effective are efforts to reduce impacts on non-target species from commercial fishing?

Bycatch, discards, and incidental mortality are terms frequently discussed in fisheries as sources of unnecessary fishing mortality. These term are often used interchangeably, which is confusing. In a global study of bycatch, Alverson et al. (1994) provided the following definitions:

- Target catch: The catch of a species or species assemblage which is primarily sought in a fishery, such as shrimp, flounder, cod.
- Incidental catch: Retained catch of non-targeted species.
- Discarded catch: That portion of the catch returned to the sea as a result of economic, legal, or personal considerations.
- Bycatch: Discarded catch plus incidental catch.

The term "bycatch" is still used by some to imply discards, which is appropriate for species that are clearly not targeted (such as seabirds, turtles, or marine mammals). In multispecies fisheries, however, the term bycatch leads to confusion when applied to fish, because many "non-target" species are marketable and are landed. In this case, "discarded" is a better term.

Discarding is a problem because it is wasteful and causes unnecessary fishing mortality. It occurs because fishers may discard fish for which there is no market; that are below minimum size limits; that exceed quota; that exceed carrying capacity of the hold; or that are damaged or undesirable for other reasons. A particular form of discarding, known as "highgrading," occurs when fishers seek only the most valuable fish and discard less valuable, but marketable, individuals.

Of particular concern is bycatch of inshore rockfish (DFO 2004g). For species for which there are conservation concerns (e.g., inshore rockfish, inshore lingcod, petrale sole), targeted fishing has been banned in many areas in BC because bycatch (either landed or discarded) may be a serious impediment to the recovery of such populations.

After extensive consultation with the Groundfish Trawl Advisory Committee, Fisheries and Oceans Canada introduced new management measures in 1996. Key changes were the introduction of Individual Vessel Quotas (IVQs) for all vessels and the introduction of mandatory at-sea observer programs. The Integrated Management Plan for the groundfish fishery (DFO 2004g) states that catch (both retained and released) at-sea will be determined using mandatory observer coverage. There is 100% at-sea observer coverage for Option A vessels, which fish by bottom trawl and midwater trawl in all areas except the Strait of Georgia. There is 10% at-sea observer coverage for the mid-water hake fisheries and for the small Option B fishery, which fishes only by bottom trawl in the Strait of Georgia.

Methodology and Data

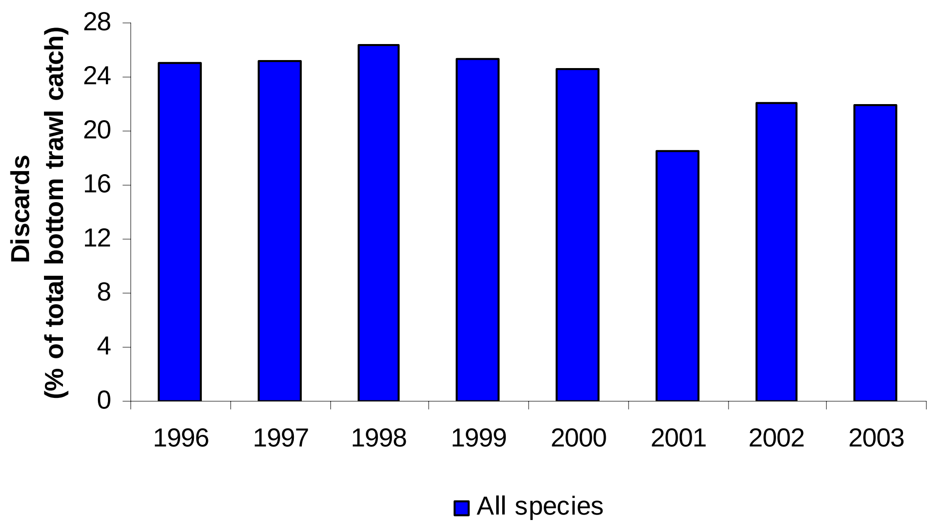
Data for this indicator came from information collected by observers on large trawlers. When observer coverage began in 1996, the number of species reported by fishers was approximately 80; this number has increased to approximately 200 species. Additional data are collected through the dockside monitoring program and fishers' logbook programs. Both sets of data are currently kept by Pacific Biological Station, Nanaimo (DFO, Alan Sinclair, Rick Stanley) and include only data for the larger (Option A) trawlers that have 100% observer coverage.

Figure 9a shows discards of all species and of all types of rockfish (including Pacific Ocean perch) as a proportion of total catch (landings plus discards). Figure 9b shows discards and landings of three species of inshore rockfish. There were no discards reported for the other inshore rockfish species.

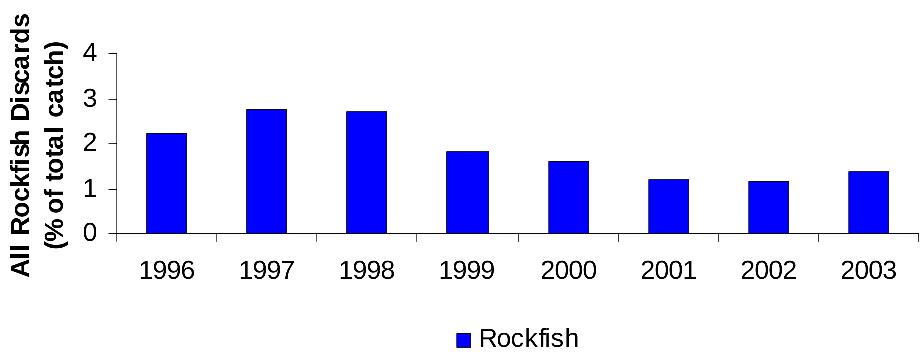
A closer analysis of the data for the Option A bottom trawl fishery shows that, in total, 143 species were recorded as discarded by the fishery, most in small quantities. Species contributing most to the discarded tonnage were arrowtooth flounder (24,673 tonnes), spiny dogfish (8786 tonnes), spotted ratfish (5741 tonnes), Pacific halibut (3609 tonnes), sablefish (3301 tonnes), Dover sole (2497 tonnes), Rex sole (2149 tonnes), big skate (1849 tonnes), English sole (1733 tonnes), and rock sole (1485 tonnes) (all totals are since 1996).

Figure 9. a. Proportion of total catch (landings plus discards) of all species discarded by Option A trawlers in BC. b. Proportion of total catch (landings plus discards of all species) of all species of rockfish discarded by Option A trawlers in BC. Rockfish species include Pacific Ocean perch. Note different scales.

a.



b.



Source: Alan Sinclair, Rick Stanley, DFO Pacific Biological Station, Nanaimo, pers. comm.

Interpretation

Percentage discards of all species have declined slightly since the introduction of IVQs and mandatory observer coverage (Figure 9). Approximately 25% of the total catch was discarded in 1996. This figure declined to a low of 18.5% in 2001, then rose again to 22% in 2003.

Percentage discards of rockfishes have also declined from 2.7% in 1997 to 1.4% in 2003 (Figure 9b). It was not possible from the data to determine the cause of the declines, which may be due in part to more selective fishing practices, but also may be due to declines or reduced catchability of some species. With the present data, it is difficult to draw conclusions about reasons for the observed trends in discarding by the bottom trawl fishery.

In future, Fisheries and Oceans Canada has committed to monitoring the discards of all species in its Integrated Fisheries Management Plan. DFO will begin to require full observer coverage and electronic monitoring in 2006 for commercial groundfish fisheries. When fully implemented, all fish will be counted, including discards, and fishers will have to have enough individual quotas to cover the estimated mortality from discards. This program is expected to provide further incentive to reduce discarding.

Supplementary Information: Other Incidental Fishing Mortality

Fisheries can cause unintentional mortality to non-target species through accidental deaths from collisions with fishing boats, entanglement with fishing gear, and continued “ghost fishing” by lost gear. Ghost fishing has been listed as one of the issues to be addressed under the Canadian Code of Conduct for Responsible Fishing Operations, a set of protocols developed by the fishing industry and Fisheries and Oceans Canada to meet international obligations for sustainable fishing.

Whale entanglement: Accidental catch of whales in fishing gear is not as much of a problem in BC as it is on the East Coast. Most of the problems in BC occur with gray whales and humpbacks because of their coastal habits. Most gray whales stay within 2 km of shore and are most commonly entangled in crab gear. A recent study to quantify mortality of gray whales in Canadian waters estimated 20 collisions a year with fishing gear, killing an average of two whales per year (Baird et al. 2002).

Humpback whales become entangled in crab gear but are more likely to get caught in gillnets in the inlets (J. Ford, Fisheries and Oceans Canada, pers. comm., 2005). Entanglement incidences with humpback whales have increased in recent years, likely due to an increase in their number.

“Ghost” fishing: Removal of animals from a population by lost fishing gear is an issue in fisheries that uses passive gear such as traps or gillnets (Breen 1990). When traps or nets are lost, they may keep fishing for many years until the gear rots or becomes so overgrown by animals or algae that it no longer catches fish. Trapped animals die of starvation or injuries, becoming bait themselves for other individuals. The species most likely to be affected by ghost fishing are those originally targeted by the gear (Brown et al. 1998).

Breen's 1987 analysis of ghost fishing in BC's Dungeness crab trap fishery estimated a trap loss rate of about 11%, resulting in 2,861 traps lost annually; 53% of those traps were estimated to be ghost fishing for an average period of 2.2 years, causing the death of 9.3 crabs per year. This gave an estimated total mortality of approximately 31,319 crabs per year (Breen 1987, summarized by Poon 2005).

Seabird bycatch: Incidental catch of seabirds by hook and line fishing gear is a worldwide concern. Birds are attracted to fishing boats and may be killed either by trying to take bait and becoming hooked and drowning, or by collision with fishing gear. Of primary concern in BC are the short-tailed albatross (*Phoebastria albatrus*), black-footed albatross (*Phoebastria nigripes*), and Laysan albatross (*Phoebastria immutablis*). The short-tailed albatross was listed as Threatened by COSEWIC in 2003, with incidental catch in longline fisheries listed as a major potential threat. No incidental catches of this species have so far been reported in BC. Black-footed albatross is, however, regularly caught in BC (COSEWIC 2003b).

The Integrated Fisheries Management Plans for the hook and line fisheries for halibut and rockfish and other species state that Canada is committed to reducing the incidental mortality of seabirds by longline fisheries. Fisheries and Oceans Canada requires mandatory seabird avoidance measures in the 2005/2006 commercial longline fisheries (DFO 2004b,h,i,j).

WHAT IS THE STATE OF BC FISHERIES?

This question is only partly addressed by the indicators in this paper. These indicators were chosen from a larger field of indicators to provide an overview of the state of West Coast marine ecosystems and fisheries. Although they were defined through a long process of discussion and review, the final choice of what to report was ultimately constrained by the data available. These indicators are being presented as the basis for a suite of fisheries indicators that will be improved upon in future reporting.

Overall, the indicators in this paper show that, although there are conservation concerns for some populations or stocks of fished species in BC, many appear to be doing well.

- An estimated 81% of the salmonid populations in BC (outside of Strait of Georgia) and the Yukon, are at no risk or have a low risk of extinction. Stock assessment outlooks for 2004 classed about half (49%) of managed salmon stocks as stable, increasing, or well above target abundance.
- Other important commercial species, such as Pacific halibut, Pacific ocean perch, Pacific hake, geoduck clam, Dungeness crab, and herring, among others, have levels of abundance sufficient to sustain current harvest levels. Although many groundfish

species are considered to be fully exploited, this does not necessarily mean they are in danger; it does mean they warrant cautious management.

- An international indicator of marine ecosystem structure, calculated for Pacific commercial fisheries, showed no trend in the trophic levels of fish caught since 1982. This means that there was no visible indication of changes in the structure of underlying marine ecosystems according to this measure, whether from fishing or other pressures.
- Estimates of the impact of regulatory and technological changes on reducing illegal and discarded catch in the salmon and groundfish fisheries showed that the regulations have had a positive effect.

Indicators highlighted areas of concern, including:

- Lower Mainland steelhead trout, with all assessed stocks classified as of conservation concern or extreme conservation concern.
- Stock assessment outlooks for 2004 classed 13% of managed salmon stocks in the category of greatest concern. Other research on salmonid populations found that just over 13% of BC and Yukon populations were either extinct (2%) or at the highest risk of extinction. Three Pacific salmon stocks (interior Fraser coho, Sakinaw and Cultus lakes sockeye) have been listed by COSEWIC as Endangered (COSEWIC 2002, 2003a).
- Many inshore rockfish species are at low abundance levels or are experiencing poor recruitment, and 89 areas were closed to fishing at the time of writing. Fisheries are closed for Bocaccio (listed as Threatened by COSEWIC), inshore lingcod (stocks are rebuilding and may be reopened in the near future), Fraser River eulachon, and Northern abalone (listed as Endangered), among others.

Marine ecosystems are complex and difficult to observe. Determining definitive causes for observed changes, whether positive or negative, is rarely straightforward. Poor recruitment during the 1990s was cited as a factor in the decline or low abundance of many species discussed in this paper. This may be caused by overfishing and/or by ocean conditions unfavourable for recruitment. Poor oceanic survival is cited as a reason for the decline in steelhead stocks and some salmon stocks. Climatic "regime-shift" events, such as the Pacific Decadal Oscillation, have been proposed as forces affecting abundance of many commercial species (e.g., Beamish et al. 1997, 1999; Mantua et al. 1997), and may presage the type of changes resulting from global climate change.

Globally, there is concern that fish stocks are not being fished sustainably (e.g., Pauly et al. 2002; Schiermeier 2002). This concern is driven, in part, by collapses of major fish stocks such as the Peruvian anchoveta and northwest Atlantic cod (Ludwig et al. 1993; Walters and Maguire 1996). There is a growing awareness that fisheries are embedded in complex marine ecosystems that may be directly or indirectly affected by fishing pressure (e.g., Hall 1999; Pikitch et al. 2004). The effects of overfishing can rarely be completely excluded as a cause of population decline in fished populations, even when correlations with climatic events exist (Walters and Collie 1988). For example, in BC, during the

1980s and early 1990s salmon and groundfish fisheries were overcapitalized and stocks, such as inshore rockfish, lingcod, and some salmon stocks, were overfished as a result.

The famous "Thompson-Burkenroad debate" of the 1950s about causes of population trends in Pacific halibut (see Hilborn and Walters 1992, p.53) illustrates the difficulty in separating effects of the environment from fishing, even with some of the best data in the world. Both sides of the debate provided compelling evidence for observed cyclic behaviour of halibut populations: one citing cycles in oceanic conditions that affected juvenile survival, and the other citing overfishing as the cause of declines in abundance and reduced fishing, after years of low abundance, as the cause of recovery.

WHAT IS BEING DONE ABOUT IT?

Progress in two major areas of human impact on marine ecosystems—climate change and designation of marine protected areas—are covered in other papers for the Coast and Marine Environment project. With respect to the impacts of fishing, recent national and international efforts to ensure that fisheries are managed sustainably are listed below:

- Since 1996, a large number of changes have been introduced into the management of BC fisheries to address concerns about fleet overcapacity and conservation. The generally positive effects of such changes were reported in the Key Indicator 5 on estimated trends in IUU catch. Although Fisheries and Oceans Canada has worked with the commercial fishing industry for decades, the last decade has shown highest level of cooperation between it, First Nations, and the commercial and recreational fishing industries in Integrated Harvest Planning committees. For example, Integrated Fishery Management Plans for groundfish have been developed with advice from the Commercial Groundfish Integrated Advisory Committee, a stakeholder committee with broad representation. The management plan for the groundfish trawl fishery outlines a sustainability strategy for inshore rockfish, including reducing bycatch, improving catch monitoring, and other steps to ensure a sustainable fishery (DFO 2004g).
- Canada's Policy for Conservation of Wild Salmon was published in May 2005 by Fisheries and Oceans Canada. The stated goal of the Wild Salmon Policy is to restore and maintain healthy and diverse salmon populations and their habitats. It provides for incorporation of information on ecosystems and ocean climate impacts in annual assessments of salmon abundance.
- Canadian Code of Conduct for Responsible Fishing Operations: In response to growing concerns over global depletion of fish stocks, the United Nations Food and Agriculture Organization (FAO) developed a Code of Conduct for Responsible Fisheries. The code was adopted by 80 countries, including Canada, at the 28th conference of the FAO in 1995. The Canadian fishing industry took the lead in applying the international code by developing the Canadian Code of Conduct for Responsible Fishing Operations in 1998. The code contains a set of protocols developed by the fishing industry and Fisheries and Oceans Canada to meet international obligations to promote conservation-based harvesting practices. To date,

more than 60 Canadian fisheries organizations, representing 80% of the landings, have ratified the Canadian code. This means they volunteer to take appropriate measures to ensure fisheries are harvested and managed responsibly. (See *www.ncr.dfo.ca/communic.fish_man/code/eng/con_eng.htm.*)

- The Pacific Fisheries Resource Conservation Council was created as an independent organization to advise the governments of Canada and BC, as well as the public, on the conservation and environmental sustainability of Pacific salmon stocks and their freshwater and ocean habitat. The Council prepares reports on wild salmon stock, salmon aquaculture, fisheries management policy, and recently sponsored a conference to address the impact of climate change on BC fish stocks and implications for fisheries management. (See *www.fish.bc.ca/*; PFRCC 2002.)
- The Marine Stewardship Council (MSC) was established in 1997 with the goal of promoting sustainable marine fisheries by certifying and labelling products from fisheries that use environmentally, socially, and economically viable practices. It has developed a wild fisheries certification standard consistent with the FAO guidelines for ecolabelling of fisheries and operates an accreditation program for independent certification bodies that do the assessments. As of 2005, 12 fisheries in the world have been granted MSC certification. By the end of 2005, 20 more were in the process of assessment for certification, including the BC salmon fishery and Canada's Pacific halibut fishery. Although concerns have been raised that MSC grants certification based on intent to improve methods, rather than waiting until the fishery has met requirements (e.g., Pearce 2003), MSC defends its certification standard as a pragmatic step that will achieve the desired changes. As more fisheries are assessed and consumer awareness of ecolabelling and certification standards increases, such certification programs are a way to support sustainable fisheries. (See *www.msc.org/*)
- The BC Pacific Salmon Forum was appointed by the Premier of British Columbia in 2004. It consists of seven appointed members who are charged with examining the issues surrounding the wild and farmed salmon in BC and making recommendations to the province based on their findings. The forum is intended to generate balanced advice for managing the salmon resource based on the results of scientific research. (See *www.pacificsalmonforum.ca/*)

WHAT CAN YOU DO?

In terms of individual actions, consumers can become informed about fisheries conservation issues and can make an effort to support sustainable fishing practices by purchasing seafood products that come from fisheries with good environmental practices. Sources of such information include:

The Pacific Fisheries Resource Conservation Council: (*www.fish.bc.ca*) The Council website carries online reports as well as information for teachers and students on a wide range of issues related to conservation and environmental sustainability of Pacific salmon stocks.

The Marine Stewardship Council: (*www.msc.org/*) Look for seafood products that are MSC certified and labelled as products from fisheries using environmentally and socially viable practices.

Ocean Wise: (*www.vanaqua.org/conservation/oceanwise/faq.html*) Closer to home, the Vancouver Aquarium launched the concept of Ocean Wise in January 2005. Ocean Wise is a conservation program created to help local restaurants and their customers make environmentally friendly seafood choices. Participating restaurants aim to present a completely sustainable menu and can display an Ocean Wise symbol on their menus. Sustainability of each species that is harvested for seafood is evaluated individually, using information on individual fisheries from the Vancouver Aquarium's own fisheries research, as well as other research from BC and Canada.

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