Research Note

BRITISH COLUMBIA MARINE FISHERIES CATCH RECONSTRUCTION, 1873 TO 2011

Cameron Ainsworth

Having an accurate estimate of total fisheries removals is essential for developing population models used in fisheries management and, generally, for understanding the impacts of human beings on marine ecosystems. Unfortunately, few fishing sectors, even in the developed world, are able or required to compile a comprehensive catch record, leaving a large portion of the catch unaccounted for in official government statistics. Depending upon its magnitude, the incorporation of unreported catch into population estimates for any particular fishery might profoundly alter predictions of stock dynamics in exploited species and ecosystems, and help to explain observed ecological trends. Fisheries management that fails to consider unreported catch may put fish stocks at risk of overfishing or extinction. The presence of unreported catch also devalues catch information obtained from well regulated fisheries.

This short contribution synthesizes available catch information for BC marine fisheries from 1873 to the present. All data originate from Canada's Exclusive Economic Zone, corresponding to FAO Area 61. Recent and historical landings data for industrial and recreational sectors are collated from governmental and non-governmental sources. Estimates of catches before 1950, and estimates of unreported catch (discarded catch and unreported subsistence, artisanal, and recreational landings) for these years, are derived from previous catch reconstructions.

This research note updates to 2011 the unreported catch estimates made by Ainsworth and Pitcher (2005), extends the catch reconstruction back to 1873, and provides an electronic database consistent in format with the Sea Around Us Project's *Atlas of Fisheries Impacts on the World's Marine Ecosystems, 1950–2010* to be published by Island Press, Washington, DC

(D. Pauly and D. Zeller, in preparation). These data are available in Ainsworth (2015), Pauly and Zeller (in press), or as an online appendix to this document.

MATERIAL AND METHODS

The core contribution of this note is a catch database in MS Excel that includes the following data fields: (1) CountryFishing, (2) EEZarea, (3) SubAreaEEZ, (4) FAOarea, (5) Otherarea, (6) Year, (7) TaxonName, (8) Original FAO name, (9) CatchAmount, (10) Sector, (11) CatchType, (12) Input, (13) Notes. The "Notes" field includes reference(s) for each data point.

The database separates fishing sector (field "Sector") into four categories: industrial, artisanal, recreational, and subsistence. "Industrial" fisheries are large-scale commercial fisheries that account for most of the recorded catch. All industrial landings data prior to 1950 are taken from Wallace (1999), who compiled historical landings from twenty-six separate articles and databases covering all major industrial fisheries in British Columbia. He used catch statistics, naturalist accounts, archaeological and anthropological literature, newspapers, expert opinion, and First Nations interviews to estimate historical catches, cross-validating where possible. Combining historical and ecological data in this way is a powerful method for describing ecosystems of the past (Wiersma and Sandlos 2011), although the social context of historical reports and literature must be considered (Taylor 2013). Salmon and herring landings from 1951 to 1995 are provided by historic catch statistics available online from the Pacific Regional Data Unit (PRDU) (DFO 2012b), and information for more recent years is provided by online commercial catch statistics summaries (DFO 2012d). Historical groundfish landings from 1951 to 1995 are available in the PRDU historical catch statistics on CD-ROM (DFO 2004). DFO (2012d) supplies information from 1996 to 2011 for eighteen additional fish groups, including several species of flatfish, rockfish, and demersal fish. Halibut data from 1951 onwards are taken from the International Pacific Halibut Commission (Hare 2010). However, those data represent head-off and gutted fish, so a 25 percent correction factor was added after the report of the Pacific Fishery Management Council (PFMC 2010). Sardine information from 2006 onwards is provided by the Canadian Science Advisory Secretariat (DFO 2012c).

Artisanal fisheries for butter clams, lingcod, and abalone are defined in Food and Agriculture Organization (FAO) catch statistics (FAO 2010).

"Recreational" fisheries data are compiled from the Department of Fisheries and Oceans (DFO) creel and logbook surveys (DFO 2012a) for salmon and some groundfish, Wallace (1999) for some groundfish, and Hare (2010) for halibut. "Subsistence" fisheries are documented for five species of salmon (Wallace 1999), halibut (Hare 2010), and herring roe (DFO 2012d). These sources generally define the subsistence catch in much the same way as does FAO – as catch that is "shared and consumed directly by the families and kin of the fishers rather than being bought by intermediaries and sold at the next larger market" (FAO 2015), but all estimates of this catch are shaped by the lack of formal reporting requirements. Catch in subsistence fisheries is estimated for years after 1995 by extrapolating Wallace's trends, assuming a constant fraction with respect to recorded catch, where the fraction is calculated using an average of 1990 to 1994 data. Note that this assumption may represent a lower estimate of reported catch for years as early as 2009 since an Indigenous right to fish commercially was recognized in *Ahousaht Indian Band and Nation v. Canada Attorney General*, 2009 B.C.S.C. 1494 (Madame Justice Garson) – a decision recently confirmed by the Supreme Court of Canada.

Catch type (field "CatchType") is divided into reported landings, unreported landings, and discards. Consistent with the Sea Around Us catch database, catch amounts for each species reported to FAO constituted the "reported" data. Any catch beyond this (originating, for example, from unreported catch estimates or governmental landings data not appearing in FAO records) was aggregated into the "unreported" category. Consequently, a search in this database for reported data will yield a total catch amount equal to FAO recorded quantities but have finer taxonomic resolution than the FAO records (since disaggregated national-level data were preferred over FAO figures). A search for unreported data will yield all information absent from FAO records. All subsistence, artisanal, and recreational catch, as well as discards, is categorized here as "unreported." Discard information originates mainly from observer programs: for example, in the halibut (Hare 2010) and groundfish trawl fleets (see Ainsworth and Pitcher [2004, 2005] for various source articles).

For groundfish trawl and all salmon fisheries, the rates of discards and unreported catch (including illegal fisheries) were determined originally by Ainsworth and Pitcher (2004, 2005) and are here extrapolated to 2011. Ainsworth and Pitcher used a subjective methodology in which the historical factors influencing the unreported catch (regulatory, technological, and political changes likely to have affected the rates of

TABLE 1

*Excerpt of influences table from Ainsworth and Pitcher (2004) showing the timeline of misreporting influences from 1970 to 1974**

PERIOD	EVENT SUMMARY				REFS	INFLUENCE			AFFECTED FLEET							RATIONALE	DURATION		TERMINATION EVENT
									Salmon				Groundfish						
	Policy	Technology	Political	Supply /market		Discard	Illegal	Unreported	Gillnet	Troll	Seine	Rec	Trawl	H&L	Rec		Start	End	
1970–1974	new rockfish regulations				82	▲		▲					✓	✓		Rockfish misreporting increases to contravene restrictions	1970	1980	DFO regulations
				"Cold chains" introduced	128	▼			✓		✓		✓	✓		Cold chains open a market for less valuable species previously discarded	1970	2003	
	POP closure (QCS)				57	▽	△						✓	✓	✓	Affects only a portion of study area (QCS); opportunity for poaching	1971	1974	

* Events are divided into policy, technology, political, and supply/market types. The event's influence on the rate of misreporting is scored as a major increase (closed up triangle), minor increase (open up triangle), minor decrease (open down triangle), or major decrease (closed down triangle). The numerical score is tabulated as a running total indicating the relative incentive to misreport during that time period.

misreporting) were considered in developing a relative time series of unreported catch by fleet and species. Every significant event, such as the introduction of a new type of bycatch reduction device or implementation of quotas, was scored according to its potential to affect the rate of misreporting (Table 1). The running numerical trend tabulated on the base of these scores indicated the relative incentive to misreport catch in each five-year time period. The relative trends were scaled to absolute estimates of unreported catch using quantitative "anchor points" from literature – known quantities of catch missing from the official record (e.g., bycatch estimates from onboard observer programs such as Haigh et al. [2002]).

RESULTS

The catch database is presented in Appendix A, openly available at: http://ojs.library.ubc.ca/index.php/bcstudies/article/view/187480.

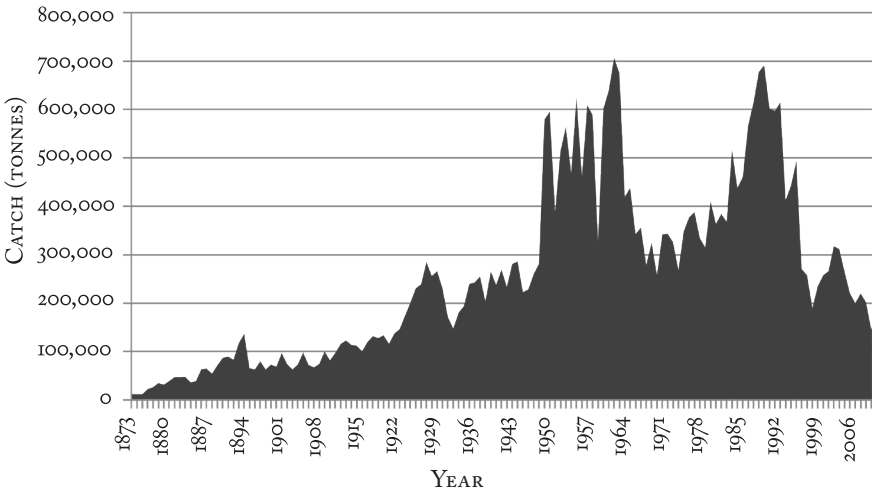

Figure 1. Total extractions of fish from BC waters, including reported and unreported landings and discards.

TOTAL CATCH

Annual extractions of fish from the ecosystem increased slowly and consistently for about eighty years and then jumped sharply after the Second World War, reaching a maximum of 700,000 tonnes in 1963 (Figure 1). Catches then dropped precipitously to an average level of about 300,000 to 400,000 tonnes per year and held more or less steady at that rate until the late 1980s. A second rapid increase then occurred, peaking at almost 700,000 tonnes in 1991. This was followed by a sharp decrease in catch in the late 1990s, leading to the current catch levels of about 200,000 to 300,000 tonnes per year.

UNREPORTED CATCH

Historically, a large portion of the catch came from unregulated fisheries, so unreported catch was relatively high around mid-century (Figure 2). Unreported catch constituted about 50 percent of total extractions from 1950 to about 1970. After that, better reporting mechanisms were brought into place (Ainsworth and Pitcher 2005), and unreported catch gradually fell to about 35 to 40 percent of total extractions until the late 1990s. Subsequently, the fraction of unreported catch fell again to about 15 to 20 percent of total extractions, a rate that has maintained to the present.

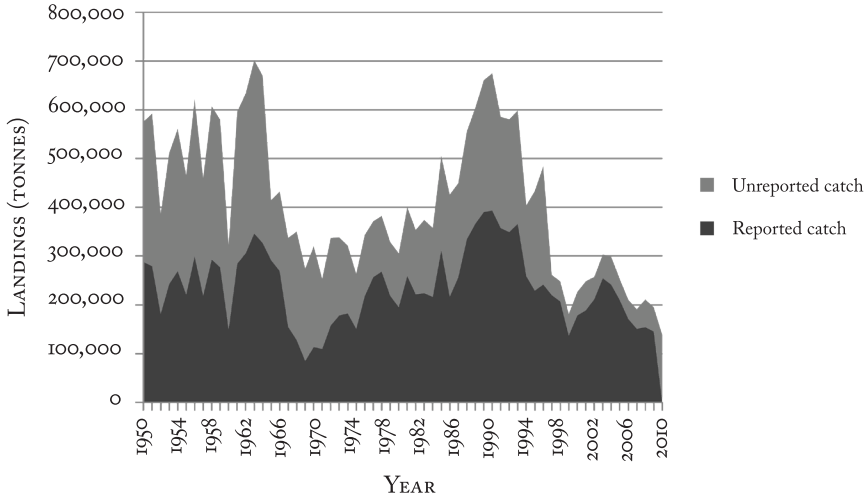

Figure 2. Industrial landings.

NON-INDUSTRIAL FISHERIES

Recreational, artisanal, and subsistence fisheries together capture only a small fraction of the catch of the industrial fleets (Figure 3). Throughout the 1950s and 1960s that fraction was consistently between 2 and 5 percent. In the 1970s and 1980s, a significant increase in recreational fishing increased that fraction to an average of between 5 and 7 percent, with a peak in 1986 at almost 8 percent. In the mid-1990s, the total recreational catch dropped to about one-third of its size in the previous two decades. Since the mid-1990s, recreational, artisanal, and subsistence fisheries have accounted for about 4 to 5 percent of total extractions.

DISCARDS

From the 1950s to the early 1970s, discarded catch is estimated to have been less than 1 percent of total industrial landings (Figure 3). This fraction increased to between 2 and 3 percent during the 1980s and 1990s, driven primarily by increases in the amount of benthic trawling (Ainsworth and Pitcher 2005); this is evidenced by a proportional increase in the amount of groundfish discards relative to landings (Figure 4). By the early 2000s, discards constituted 4 to 5 percent of industrial landings and have remained at this level to the present.

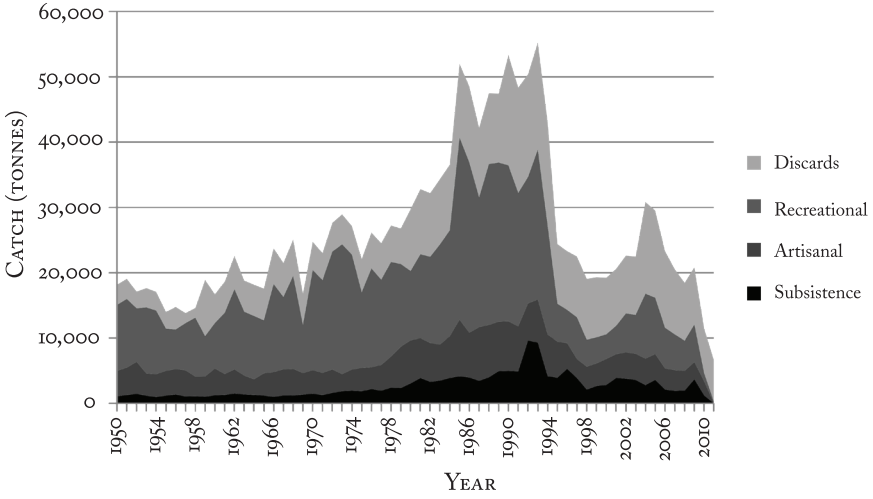

Figure 3. Non-industrial landings and industrial discards.

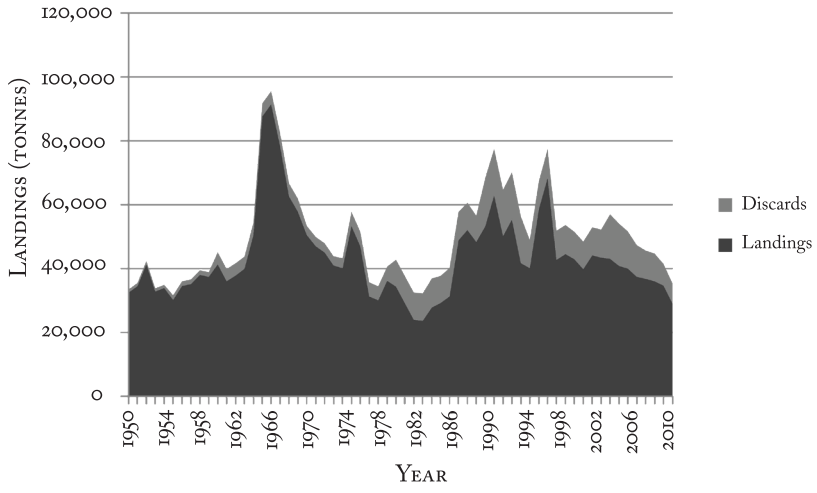

Figure 4. Groundfish catch.

DISCUSSION

Fao statistics currently account for about 80 percent of actual fishery removals from BC waters. The missing catch amounts to about forty to fifty thousand tonnes every year. That amount is likely sufficient to alter population dynamics in ecosystem and predictive fisheries models

and introduce a bias in management indices. In particular, retrospective methods requiring long time series, such as cohort analysis and model fitting, are likely to be affected since the rate of misreporting was significantly higher in past decades. From the 1950s to the 1970s, only 50 percent of total extractions were recorded by FAO. In the 1980s and 1990s, only 60 percent of removals were documented. FAO statistics should therefore be considered a lower bound of fisheries catch and treated as unreliable for ecological modelling without correction. Species aggregation in FAO data, though inconvenient, is less of an obstacle to effective use in temperate waters like those in British Columbia than in more biodiverse settings.

Historical evidence tells us that pre-industrial fisheries in British Columbia were large enough to have an impact on fish populations. Our estimate suggests that, by 1900, total removals were almost half of the current levels. It is likely that there were significant removals much earlier, even prior to European contact (Hewes 1973). Yet the prehistory of British Columbia fisheries suggests that there was both active management and sustainable use of resources that lasted for millennia (Alcock et al. 2007). For this reason, historical reconstructions of fisheries catch provides a baseline for what may be extracted safely from healthy marine ecosystems. This analysis also provides correction factors useful for interpreting governmental catch statistics in social and ecological modelling applications.

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Dr. Daniel Pauly and Dr. Dirk Zeller at the University of British Columbia Fisheries Centre contributed by reviewing the database and commenting on an early draft of this article. The author's time was funded by the USF Marine Resource Assessment Program and the Sloan Foundation.

REFERENCES

Ainsworth, C.H. 2015. "British Columbia Marine Fisheries Catch Reconstruction: 1873-2010." Fisheries Centre Working Paper Series. Working Paper #2015-62. http://www.seaaroundus.org/doc/publications/wp/2015/Ainsworth-Canada-BC.pdf

Ainsworth, C.H., and T.J. Pitcher. 2004. The Dark Side of BC Marine Fisheries: Estimating Illegal, Unreported and Unregulated Catch. Internal Report. British Columbia Ministry of Water, Land and Air Protection. Available from author (ainsworth@usf.edu).

—. 2005. "Estimating Illegal, Unreported and Unregulated Catch in British Columbia's Marine Fisheries." *Fisheries Research* 75: 40-55.

Alcock, E., D. Harris, D. Ings, J. Kennedy, Q. Mackie, G. Murray, B. Neis, T.J. Pitcher, N. Haggan, C. Ainsworth, U.R. Sumaila, K. Rogers, D. Ryan, K. Vodden, and J. Whelan. 2007. "A Social-Ecological History of Canada's Fisheries." In Coasts Under Stress: Restructuring and Social-Ecological Health, ed. R. Ommer, 33-67. Montreal-Kingston: McGill-Queen's University Press.

Dfo. 2004. 1951-1995 British Columbia Commercial Catch Statistics (cd-rom). Pacific Regional Data Unit. Available from author (ainsworth@usf.edu).

—. 2012a. Creel/Logbook Official Recreational Statistics. Pacific Regional Data Unit. Department of Fisheries and Oceans. Available at http://www.pac.dfo-mpo.gc.ca/stats/rec/index-eng.htm.

—. 2012b. Historic Catch Statistics. Pacific Regional Data Unit. Department of Fisheries and Oceans. Available at http://www.pac.dfo-mpo.gc.ca/stats/comm/summ-somm/index-eng.htm.

—. 2012c. Pacific Sardine 2011 Seasonal Biomass and Migration in British Columbia and Harvest Advice for 2012. Canadian Science Advisory Secretariat Science Advisory Report 2012/026. Available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2012/2012_026-eng.pdf.

—. 2012d. Preliminary Summary Commercial Statistics 1996-2011. Pacific Regional Data Unit. Department of Fisheries and Oceans. Available at http://www.pac.dfo-mpo.gc.ca/stats/comm/summ-somm/index-eng.htm.

Fao. 2010. *Fao Yearbook: Fishery and Aquaculture Statistics. Food and Agriculture Organization of the United Nations*. Available at http://www.fao.org/fishery/publications/yearbooks/en.

—. 2015. *Fisheries and Aquaculture*. Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations. Electronic resource. Available at http://www.fao.org/fishery/topic/12306/en.

Haigh, R., J. Schnute, L. Lacko, C. Eros, G. Korkman, and B. Ackerman. 2002. "At-Sea Observer Coverage for Catch Monitoring of the British Columbia Hook and Line Fisheries." Canadian Science Advisory Secretariat. Research Document 2002/108, http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2002/RES2002_108e.pdf

Hare, S.R. 2010. *Assessment of the Pacific Halibut Stock at the End of 2010*. International Pacific Halibut Commission. Available at http://www.iphc.int/papers/sa10.pdf.

Hewes, G.W. 1973. "Indian Fisheries Productivity in Pre-contact Times in the Pacific Salmon Area." *Northwest Anthropological Research Notes* 7 (2): 133-55.

Pauly, D., and D. Zeller, eds. In press. *Global Atlas of Marine Fisheries: Ecosystem Impacts and Analysis*. Island Press: Washington, D.C.

Pfmc. 2010. Washington Department of Fish and Wildlife Report on the Calculation of Halibut Individual Bycatch Quota for the Trawl Rationalization Program. Washington Department of Fish and Wildlife Report, November 2010. Available at http://www.pcouncil.org/wp-content/uploads/H5c_WDFW_NOV2010BB.pdf.

Taylor, J. 2013. "Knowing the Black Box: Methodological Challenges in Marine Environmental History." *Environmental History* 18: 60-75.

Wallace, S., 1999. "Fisheries Impacts on Marine Ecosystems and Biological Diversity The Role for Marine Protected Areas in British Columbia." PhD diss., Resource Management and Environmental Studies, University of British Columbia.

Wiersma, Y., and J. Sandlos. 2011. "Once There Were So Many: Animals as Ecological Baselines." *Environmental History* 16: 400-7.