Historical Commercial Catch Statistics for Pacific Salmon (*Oncorhynchus* spp.) in British Columbia, 1828 to 1950

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2005

Canadian Technical Report of Fisheries and Aquatic Sciences 2601

Fisheries and Oceans
Pêches et Océans

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Canadian Technical Report of
Fisheries and Aquatic Sciences

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Cat. No. Fs97-6/2601E ISSN 0706-6457

Correct citation for this publication:

Argue, A.W., and Shepard, M.P. 2005. Historical commercial catch statistics for Pacific Salmon (*Oncorhynchus* spp.) in British Columbia, 1828 to 1950. Can. Tech. Rep. Fish. Aquat. Sci. 2601: 595 p.

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LIST OF ACRONYMS

cwt	Hundred weight i.e one cwt equals 100 pounds
DFO	Government of Canada, Department of Fisheries and Oceans
District I	Fraser River and Howe Sound area
District II	North Coast areas (i.e. north of Cape Caution)
District III	South Coast areas excluding District I
DMF	Government of Canada, Department of Marine and Fisheries
DBS	Government of Canada, Dominion Bureau of Statistics of the Department of Trade and Commerce
FCBC	Government of the Province of British Columbia, Fisheries Commissioner of British Columbia
FRC	Government of Canada, Federal Records Centres of Archives Canada
GLW	The round weight of salmon that was landed was referred to as "Green Landed Weight" and was presented in **cwt** in most federal publications prior to 1951
HBC	Hudson's Bay Company
IPSFC	International Pacific Salmon Fisheries Commission
PFY	Yearbooks of the Pacific Fisherman trade periodical
PSC	Pacific Salmon Commission
QCI	Queen Charlotte Islands
WCVI	west coast of Vancouver Island

ABSTRACT

Argue, A.W., and Shepard, M.P. 2005. Historical commercial catch statistics for Pacific Salmon (*Oncorhynchus* spp.) in British Columbia, 1828 to 1950. Can. Tech. Rep. Fish. Aquat. Sci. 2601: 595 p.

We compiled annual Pacific salmon (*Oncorhynchus* spp.) landings, by area, in weight and numbers of fish for the commercial salmon fishery in British Columbia from 1828 to 1950. This more than doubles the time series of harvest data for the British Columbia salmon fishery. These statistics are based on Hudson's Bay Company and Canadian government records of the volume of each product form (canned, fresh/frozen, pickled, salted, smoked, etc) obtained annually from upwards of 100 processors. Product forms are converted to landed weights by species and area using industry-standard conversion factors, measures of species composition for each product form, and adjustments for transfers between areas.

The report involved comprehensive analysis of the post-1875 statistical material on annual quantities of each product form. In less detail, the report covers fragmentary records of commercial production in years before 1876, beginning with commercial activities of the Hudson's Bay Company (1828) and the early independent entrepreneurs (1860). Coverage ends in 1950 the year before the then Department of Fisheries of the Canadian Government implemented the sales slip system for enumerating catches. Summary tables contain landed weights (tonnes) and catch-in-numbers, by species and year, for the commercial fishery for ten areas along the British Columbia coast. The reliability of the assembled data during different data collection periods is assessed.

RÉSUMÉ

Argue, A.W., and Shepard, M.P. 2005. Historical commercial catch statistics for Pacific Salmon (*Oncorhynchus* spp.) in British Columbia, 1828 to 1950. Can. Tech. Rep. Fish. Aquat. Sci. 2601: 595 p.

Dans ce rapport, nous avons compilé les prises de saumons du Pacifique (*Oncorhynchus* spp.) et nous les avons converties en poids et en nombre de poissons par région pour la pêche commerciale en Colombie-Britannique de 1828 à 1950. L'étendue de cette compilation représente presque le double de la durée au cours de laquelle des données ont été recueillies sur la pêche au saumon en Colombie-Britannique. Ces données statistiques sont basées sur l'information fournie par plus de 100 usines de transformation à la Compagnie de la Baie d'Hudson et au gouvernement canadien relativement au volume de chacune des formes de produits (saumon en boîte, frais/congelé, mariné, salé, fumé, etc.) Les formes de produits ont été converties en poids de poissons capturés par espèce et par région en utilisant les facteurs de conversion habituellement employés par les industries de transformation et en tenant compte des compositions relatives des espèces pour chaque forme de produit de transformation. Nous avons également apporté les corrections nécessaires pour tenir compte du transfert entre régions.

Le rapport consiste en une analyse complète des données statistiques sur les quantités annuelles de chaque forme de produit de transformation pour la période commençant en 1875. De plus, le rapport comprend une analyse moins détaillée des données fragmentaires sur la production commerciale précédant 1876, débutant avec les activités commerciales de la Compagnie de la Baie d'Hudson (1828) et des premiers entrepreneurs indépendants (1860). La période couverte dans ce rapport se termine en 1950, année de la mise en oeuvre par le ministère des Pêches et des Océans du système des récépissés d'achats pour la détermination du nombre de prises. Les tableaux récapitulatifs présentent les poids (en tonnes) et les nombres de prises par espèce et par année des pêcheurs commerciaux dans dix régions de la côte du Pacifique de la Colombie-Britannique. La fiabilité des données recueillies au cours des différentes périodes de collecte a été également évaluée.

1. INTRODUCTION

Scientists commonly use time series of fishery catches to develop theories about the impacts of the fishery and environment on stocks (Ricker 1954, Beamish *et al.* 1999). Examples of such records for Pacific salmon (*Oncorhynchus* spp.) are described in Rounsefell and Kelez (1938), Kasahara (1963) and Wong (1983). For the first 100 plus years of commercial salmon fishing in British Columbia, however, most investigators of stock and fishery dynamics only had access to aggregate and often incomplete data on British Columbia harvests (e.g. Hoar 1951, Milne 1955, Shepard and Withler 1958, INPFC 1962, Milne 1964, Hewes 1973, Mysak 1986, Beamish and Boullion 1993, Hare and Francis 1995). In this report we use records of the products produced from salmon in order to develop a comprehensive catch database for such analyses. We present estimates of historical, annual landings, by area and species, for salmon caught commercially in British Columbia from the beginning of the fishery in 1828, to 1950, a period for which area-based catch statistics were not previously available.

Before 1951, British Columbia production statistics for salmon processed in cans or for other products were collected in each area from processing plants and arrayed primarily for economic purposes. Since then, data on catches by species and area have been collected from sales slips in a format that provides easily available information for biological assessments (Wong 1983). With a view to increasing the availability and usefulness of the pre-1951 data, we converted annual records of the volume of various products (canned, fresh and frozen, salted, etc) produced in an area, into annual estimates of each species caught in an area, using product-to-landed-weight conversion factors, measures of species composition, and adjustments for transfers between areas.

Our objective is to turn the records of processed fish, which are variable in detail, completeness and reliability, into a basic set of data for scientific assessments that, to the extent practicable, reflects the magnitude of annual catches by species, in tonnes and numbers of fish, for 10 broad areas of the British Columbia coast. Throughout the report we have made these early data as comparable as possible to the post-1950 commercial harvest data from the same areas.

In the process of assembling the early production data and converting these to landings we encountered a wealth of information on the data sources and methods used by government officials to compile the pre-1951 statistics for Pacific salmon, and on the products that Canadian commercial establishments prepared and sold at home and abroad. This report provides a comprehensive summary of this historical information for British Columbia fisheries for Pacific salmon.[1]

In the report we present our analyses of the canned pack (the bulk of the commercial harvest) and other products separately because of the different nature of these data. For example, canned packs were broken down by species early on in government publications

1. Our search for data for this report began in 1984. We prepared preliminary reports on the pre-1951 salmon harvest statistics while on contract to the Department of Fisheries and Oceans (Argue and Shepard 1984MS, Shepard *et al.* 1985, 1985a; Argue *et al.* 1986MS; Shepard and Argue 1989). The harvest statistics in these early versions have been superseded by the harvest data in this report.

but products such as dry salted, fresh/frozen and smoked salmon were not. In this context, references to "products" in the report are to the "non-canned" or "other" products.

1.1. Coverage

Our coverage starts in the next section with some brief comments on Aboriginal peoples' usage of salmon prior to European contact, and on subsistence use of salmon by the early fur traders prior to 1828.

The main work of our report involves analysis of the post-1875 statistical material on annual quantities of each product form. However, in less detail, the report also covers fragmentary records of commercial production in years before 1876, beginning with commercial activities of the Hudson's Bay Company (HBC), which began in 1828. Our coverage ends in 1950 the year before the then Department of Fisheries of the Canadian Government implemented the sales slip system for measuring salmon catches.

Studies of salmon population dynamics require information on the quantities of each salmon species harvested in different areas along the coast. Prior to 1951, records of salmon production were collected for economic purposes and failed to provide the necessary breakdowns needed for biological analyses. This report makes these data considerably more useful for such assessments by providing species breakdowns for products and the canned packs, converting these to landed weights and numbers, and then arraying the combined weight and numbers into areas where the production was most likely caught.

Making such conversions required some interpretation of the information that, as will be made clear in the report and Appendices, introduced a degree of uncertainty regarding a number of the assumptions underlying the analyses.

For the pre-1951 period, we provide estimates of annual quantities of salmon caught for commercial purposes and landed in an area, in a form that is consistent with the published pre-1951 government statistics on canned packs and products produced in each area, and which is comparable to salmon landings in weight and numbers by area for the post-1950 era. Breakdowns are provided by:

Time: Annually from 1828 through 1950; no attempts were made to provide catch for shorter time intervals (i.e. by week or month);

Area: The ten geographic divisions (see Figure 1) for which information could be provided throughout the history of the fishery, and for which the boundaries were consistent with those in place from 1951 onwards (see Figures 2 and 3 and the tabulation below);

Weights and numbers: Reported as "green landed weight" (GLW), which is the estimated total weight of fish landed by fishermen before any gutting, heading or further processing occurs, and by "pieces" (numbers) of fish that comprised the landed weight; hundred weight (cwt) was the most commonly used unit of weight (1 cwt = 100 lb),

Species: Sockeye (*O. nerka*), pink (*O. gorbuscha*), chum (*O. keta*), chinook (*O. tshawytscha*), coho (*O. kisutch*) and steelhead (*O. mykiss*) .

Areas Used in this Report	**1951 DFO Statistical Areas**
Queen Charlotte Islands	1, 2A-2B East, 2A-2B West
Nass River	3
Skeena River	4
North Coast	5, 6, 7, 8, 30
Rivers and Smith Inlets	9, 10
Johnstone Strait	11, 12, 13
Strait of Georgia	14, 15, 16, 17, 18
Juan de Fuca Strait	19, 20
West Coast of Vancouver Island (WCVI)	21, 22, 23, 24, 25, 26, 27, C
Fraser River including Howe Sound	28, 29

Commercial harvest records for northern British Columbia were more detailed by area than those for southern parts of the Province. As outlined above, we aggregated harvest data for ten rather large areas because we wanted a consistent set of geographical areas that we could report on for the whole history of the fishery. The finer northern data cover 1930 to 1950 landings by species, adjusted for transfers, for geographic divisions that are consistent with each of today's statistical areas in northern B.C, and are subdivisions of our larger areas. These data may prove useful for those investigators wanting more precise landings information.

Commercial harvests do not account for all of the removals from the stocks during our main period of interest, 1875 to 1950. There were fisheries by Aboriginals, by recreational fishermen and, prior to 1900, subsistence fishing by fur traders and miners. We comment on these sources of removal (minor compared to commercial catches) in the following short section on history of the fishery.

Also, it should be noted that commercial landings of salmon in British Columbia waters include salmon bound for United States rivers in Washington, Oregon, Idaho, California and Alaska (called interceptions); and United States fisheries in Washington and Alaska harvest substantial quantities of salmon bound for British Columbia rivers. For example, in 1913 catches of sockeye salmon from British Columbia's largest river, the Fraser, reached record levels but of the total Canada/United States harvest of over 31 million fish, Canadian fishermen harvested less than a third (Rounsefell and Kelez 1938, Roos 1991).[2]

2. In 17 years between 1889 and 1934 Fraser River canneries packed small amounts of imported sockeye that had been caught by Washington State traps near Point Roberts (Gilhousen 1992); these sockeye are included in our GLW data. They generally amounted to well below ten percent of Canadian caught sockeye.

Because of these interceptions, statistics of Canadian catches alone usually do not represent estimates of total production. Studies of exploitation of British Columbia salmon stocks should take into account interceptions by both countries. We do not estimate such interceptions.

When considering effects of commercial fishing on the resource, it should be kept in mind that not all salmon taken by fishing gear are landed for processing and sale. In the early years especially, species for which markets had not yet been developed such as pink and chum salmon, caught incidentally with more valuable species such as sockeye, coho and chinook salmon, were discarded and therefore were not included in commercial production statistics (Chettleburgh 1979). In some years of high abundance, the catching capacity of the fleets exceeded the processing capacities of the fish plants, again resulting in surplus fish being discarded and therefore unrecorded (Rounsefell and Kelez 1938). Such discards were probably most prevalent on the Fraser River when very large sockeye runs materialised in four year cycles, and where it is known that canneries imposed landing limits on the fleets (Ricker 1987, Gilhousen 1992). As well, fishing often causes mortality beyond that incurred through harvesting the fish. For example, the "drop-out" of salmon from gillnets that was a subject of concern to scientists studying the offshore salmon fishery in the north Pacific (Anonymous 1989), and the mortality among below legal sized fish that are returned to the water by trollers (so-called "shakers"), a longstanding concern to fishery managers (Pitre 1970, Wright 1972, Stohr and Fraidenburg 1986). The present report makes no attempt to estimate such quantities of salmon captured and killed, but not brought on board vessels to be landed, sold and processed.

In summary, prior to 1951 commercial catch dominated the total Canadian harvest. Our coverage attempts to document, in as thorough and comprehensive a manner as possible, the annual commercial landed catches that were used to produce the canned packs and other products during this important period for the salmon fishery in British Columbia.

1.2. Early Historical Background

1.2.1. Aboriginal Fisheries

Salmon was a valuable source of protein for the Aboriginal people that occupied British Columbia for thousands of years before first contact with Europeans (circa 1770s). The extent of Aboriginal utilization of salmon is a matter for speculation. It is estimated that in pre-contact times the human population of what is now British Columbia numbered close to one hundred thousand (Duff 1964), and perhaps was substantially higher (Richard Inglis, Royal British Columbia Museum, pers. comm., Glavin 2000). Annual per capita rates of consumption were in the order of several hundreds of salmon (Hewes 1973). Using consumption rates from Hewes and the conservative population estimates from Duff, led Argue *et al.* (1990) to estimate an average annual utilization of salmon by Aboriginal people in excess of 18,000 tonnes (mt), a level rivalling that of the commercial fishery in the late 1800s and today. In the 1879 Annual Report of the Federal Department of Marine and Fisheries (Anonymous 1868-1913), the Chief Inspector of Fisheries stated his belief that the total annual consumption of salmon by Aboriginals in 1879 was about 17.5 million fish, equivalent to approximately 60,000 mt (based on 1951-1954 average weight of salmon in the commercial catch of 7.4 lb). This is close to average harvests in the commercial fisheries some 40 years later and is a level some researchers (Glavin 2000)

speculate that Aboriginals utilized prior to first contact with Europeans. However, for post-contact years the Inspector's estimate, which was unsubstantiated, is undoubtedly far too high given the greatly reduced Aboriginal population in 1879 (Duff 1964).

In general, the evidence cited above emphasizes the view that before extensive European settlement of the coast of British Columbia, Aboriginal harvest of Pacific salmon in British Columbia was substantial. In contrast, the annual Aboriginal catch for the first half of the Twentieth Century seldom reached 500,000 salmon and steelhead (approximately 2,300 mt or three percent of the commercial harvest) (Argue *et al.* 1990).

1.2.2. Arrival of the Europeans

The first visits of Europeans to the coast of British Columbia probably occurred with the voyages of the Spaniard Juan Perez Hernandez (1774) and of the Englishman James Cook (1778). Subsequently, Cook's crewmen sold sea otter skins taken off the Pacific coast of North America in China. This sparked commercial interest in development of the trade in furs west of the Rocky Mountains (Woodcock 1990). As a result, in the closing years of the 18th and the early years of the 19th Century, a fleet of, first, English and then of American vessels exploited the sea otter offshore and also began to trade with Aboriginal people on shore to obtain furs from land animals (Gibson 1992). There is no evidence that salmon appeared prominently in these coastal trading arrangements.

1.2.3. Subsistence Use by the Fur Traders

Most of the coasting activity discussed above took place in waters northwest of British Columbia. Settlement by Europeans on land in what is now British Columbia did not begin in a significant way until land-based Canadian fur traders pushed eastward from Athabasca to the Pacific slope across the Rockies. Thus it was that, in 1805, the North West Company (the predecessor to the Hudson's Bay Company in western Canada) established its settlement at Fort McLeod in the Peace River drainage. Between 1805 and 1821 the Company established eleven posts spreading southward from Fort McLeod through the Fraser and Columbia River drainages as far as what is now Astoria at the mouth of the Columbia. In 1821, the North West and Hudson's Bay Companies amalgamated under the Hudson's Bay banner and for the next twenty years expanded their operations along the Pacific slope from the Taku River in the north (in what is now Southeast Alaska) to the Columbia River in the south (Cullen 1979).

These posts depended heavily on dried salmon as the principal year-round source of protein for the Company's staff. The fish were obtained in trade from Aboriginal fishermen and supplies were shared between posts. Whereas the dependence of the posts on salmon was high, the number of employees throughout the region was probably in the low hundreds and utilization by the Company as a whole was very small when compared to total volume of the resource and removals at the time by Aboriginals. For example, fairly complete records for northern British Columbia in 1835-1836 (when the Company's activities in the area were near their peak) indicate that the aggregate utilization of dried salmon each year by the seven posts operating there was only about 67,000 fish, contrasting to harvests in the commercial fishery 50 years later numbering several millions. In addition to dried salmon, it is likely that small but significant quantities of fresh salmon were also consumed during the upriver spawning migrations. However, the total quantity of salmon utilised could not have been very great.

1.2.4. Hudson's Bay Company Salting Operations

In 1827, HBC built Fort Langley in the lower reaches of the Fraser River. The Fort was established with the expectation that it would become the Pacific terminus for the Company's land-based fur collection operations for the Fraser and adjacent drainages. However, in the 1830s, coastal trade in competition with American and Russian operations (which were offering better prices for furs) became an increasing focus for the Company. As a consequence, Fort Victoria, located on Juan de Fuca Strait at the doorstep of the open Pacific Ocean, established in 1843, became the Company's Pacific depot. Despite the change in plans, for three decades after its establishment, Fort Langley formed a vital link in the Company's operations as a supplier of food stuffs, particularly salmon, and as a communication centre for traffic from the Company's inland posts on the Fraser and adjacent northern watersheds.

Fort Langley was well located to utilise abundant runs of Fraser River salmon ascending the river to upstream spawning grounds. Aboriginal fishermen freely traded their catches to the Bay men, obviating the need of the latter to develop independent means of harvesting the resource. In fact, an attempt to start an independent commercial fishery by Bay men in 1828 led to the conclusion that the "expense in trade would hardly exceed the very cost of Lines and Twine" (Cullen 1979, quoting Chief Trader, Archibald McDonald).

Exactly when external trade in pickled salmon (salmon cured in a brine solution), beyond Company subsistence use, began is not clear (the Fort Langley Journal recorded a test production of pickled salmon in 1828). In his paper on Hudson's Bay Company activities in Hawaii, Alexander Spoehr (1986) noted that:

> *By 1830, the Company was preserving salmon on the Columbia River and at Fort Langley on the Fraser River as well, mainly to feed Company personnel, but with some 200 to 300 barrels of Columbia River salmon exported that year, presumably to Hawai'i. Preserved salmon found a ready market on O'ahu, particularly among native Hawaiians.*

As reported by Cullen (1979), direct shipments of salmon from Fort Langley to Hawaii began in the 1830s and continued until the early 1870s. Levels of harvests are estimated in later sections of this report. The heyday of the Hudson's Bay Company's overseas pickled salmon trade was in the late 1840s and early 1850s when the Company had a monopoly on trade on the mainland west of the Rocky Mountains.

1.2.5. Production by Non-HBC Entrepreneurs

The discovery of gold in the Fraser River in the late 1850s brought an influx of outsiders into the territory which, in turn, led to the development of substantial permanent non-Hudson's Bay Company settlements in the lower mainland of British Columbia. Associated with this influx, the HBC was forced to give up its monopoly trading rights west of the Rockies and, in 1858, the mainland territory became the Colony of British Columbia.[3] With these developments came entrepreneurs who initiated their own fisheries.

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3. The mainland Colony of British Columbia amalgamated with the Colony of Vancouver Island to form the single Colony of British Columbia in 1866, which in turn, joined Confederation to become the Canadian Province of British Columbia in 1871.

These soon eclipsed the Hudson's Bay activities in terms of scope, variety of products and markets; their production is estimated in Section 3.1.1.

1.2.6. Large Scale Commercial Fishing Expands

The fishery by independent entrepreneurs began as salting operations in the vicinity of New Westminster in 1860.[4] By the end of the decade canning had been introduced and by the late 1870s a burgeoning industry, employing hundreds of drift-net fishermen and shore-workers, had begun to spread beyond the reaches of the Fraser to other parts of the Province. By the end of the century the salmon industry operated virtually everywhere throughout the inside passages and estuaries of the Province, and was intensively utilising all five species of salmon and steelhead (earlier catches in the fishery were limited mainly to sockeye, coho and chinook salmon). Trolling apparently had also made its debut as evidenced by the federal Inspector of Fisheries, who remarked in the 1883 Department of Marine and Fisheries (DMF)[5] Annual Report on the high quality of "salmon caught by trolling in the saltwater throughout the winter season". However, it was not until around 1910 that trolling became a substantial source of salmon (Milne 1964).

Shown below are the years that canned and other products first were recorded in the official government statistics for each area. Product forms other than canned generally were produced first; however, in most areas canned product was put up very soon after.

Area	Product Form	
	1st Year Other	1st Year Canned
Queen Charlotte Islands	1888	1901
Nass River	1878	1881
Skeena River	1877	1877
North Coast	1883	1890
Rivers & Smith Inlets	1882	1882
Johnstone Strait	1878	1881
Strait of Georgia	1883	1906
Juan de Fuca Strait	1877	1905
WCVI	1887	1895
Fraser River	1860	1870

In just under two decades commercial fisheries spread from the Fraser River to the rest of the coast. After the start of commercial salmon fishing on the Fraser River in the 1860s (1870 for canned), the Skeena River and Juan de Fuca Strait fisheries recorded their first salmon production in 1877; these were followed a year later by production from fisheries on the Nass River and in Johnstone Strait. North Coast, Rivers and Smith Inlets and the Strait of Georgia commercial fisheries first showed production in 1882/1883 and the last

4. The best account of the early development of the fishery is provided by Lyons (1969).

5. We use the acronym DMF throughout the report to refer to all versions of the federal fisheries department prior to 1951, and the abbreviation DFO to refer to versions of the department from 1951 onward.

commercial fisheries to start were in the more remote areas of the west coast of Vancouver Island (WCVI) (1887) and the Queen Charlotte Islands (1888).

During the first three decades of the Twentieth Century the salmon fishery continued to expand. In terms of the number of canneries (see tabulation below) it reached its peak during the decade beginning 1910 when on average 71 canneries were licensed to operate each year throughout the Province (maximum of 94 licensed in 1917).

Decade Beginning	Number of Canneries		
	Minimum	Maximum	Mean
1870	2	10	6
1880	9	28	18
1890	26	59	40
1900	50	73	62
1910	52	94	71
1920	56	79	68
1930	35	85	46
1940	24	38	31

Source: Anonymous (1958) for 1912-48 and Lyons (1969) for 1870-1910 and 1949.

During the 1920s salmon dominated commercial fishing with salmon fishermen operating over 7,000 vessels. Close to 20,000 men and women worked on all kinds of fish boats and processing establishments (Anonymous 1958). The prohibition against motorised fishing vessels in northern areas was rescinded in 1924 (Lyons 1969) and the first purse seine licenses were issued in 1927. In 1929, the licensed salmon fleet was 4,578 gillnet vessels, 2,592 trollers, and 278 seiners (Anonymous 1958). Today (2003) there are 1,406 gillnet, 539 troll and 276 seine licenses on just over 2,000 active salmon vessels; and there are approximately 15,000 workers on all commercial fish boats and processing companies, mostly working on species other than salmon (Anonymous 2002, GSGislason & Associates Ltd. 2004).

After the salmon harvest peaked in the 1920s, availability of the resource began to limit expansion of the industry. Through to a second peak in the 1980s, commercial catches fluctuated widely at generally lower levels, partly as the result of human activity (e.g. overfishing in some areas and environmental degradation[6]) and partly as the result of climate facilitated changes in the marine and freshwater environment (Hare and Francis 1995, Beamish and Bouillon.1993).

1.2.7. Recreational Fishing

Recreational fishing for salmon probably started with the first European settlers on this coast. By 1924, the year the Tyee Club of British Columbia was formed, there were many

6. For example, railroad construction on the banks of the Fraser River blocked Canada's largest sockeye salmon runs in 1913 and several years thereafter. Over the next decade, consequent mortality among spawners coupled with continued heavy fishing on the small surviving runs resulted in Fraser sockeye yields dropping to less than 15% of their pre-1914 levels.

ardent anglers in pursuit of salmon, but only scant records of their total catch. The recreational harvest in British Columbia went undocumented until Young and Campbell (1956) estimated that by the early 1950s recreational fishermen annually harvested 30,000 to 75,000 coho and 35,000 to 50,000 chinook, or between one and two percent of the commercial coho catch at that time, and between four and six percent of the commercial chinook catch. In addition, sport fishermen took around 125,000 "grilse", chinook and coho below the commercial minimum size limit of 3 pounds (1.4 kg) round weight, and a handful of the other salmon species. The recreational fishery prior to 1950 was undoubtedly much smaller, particularly relative to the commercial harvest.

1.3. Development of Fishery Statistics

During the first five decades of the fishery until the Mid-1870s, there were no formalized systems for recording amounts of salmon harvested or processed. During these years we depended on various historical accounts, particularly those associated with the activities of the Hudson's Bay Company (e.g. Lyons 1969; Cullen 1979) to obtain information on quantities of salmon products that were processed. Beginning in the 1870s, the Federal Government began collecting information from processing establishments and, as the years went on, required companies to provide such information on a series of prescribed forms. Annual government reporting of production from salmon harvests began in 1874 when DMF reported "Cases of fresh salmon" and "Bbls. salt (salmon)" for five processing establishments on the lower Fraser River. In 1876, when DMF began implementing the Federal Fisheries Act in British Columbia waters, DMF also initiated comprehensive publications of production and fishing statistics for individual areas along the British Columbia coast.

As mentioned at the start of this report, from the beginnings of the commercial industry by the Hudson's Bay Company until the years immediately following World War II, interest in measuring fish production was primarily in economic terms, concentrating on volumes of product sold and traded, rather than weight and numbers of each salmon species caught. The fact that from 1917 until 1950 the Dominion Bureau of Statistics (DBS) of the Department of Trade and Commerce published the fisheries statistics of Canada emphasizes that the purpose of data collection was economic rather than biological. Reflecting this, it was not until the 1920s that data on the annual numbers of fish caught first appeared in DMF annual reports, and then only for the whole British Columbia coast.

The economically-oriented production data generally lacked breakdowns by species for products other than canned salmon. Since canned salmon were marketed by species, the canned pack was the first product form whose statistics were available by species and area starting in 1901. Annual Reports of the Fisheries Commissioner for British Columbia (FCBC) starting in 1902 (Anonymous 1902-1930) and Pacific Fisherman Yearbooks (PFY) starting in 1901 (Anonymous 1901-1950) provided canned salmon packs by species for individual canneries throughout British Columbia. The other products were never reported by species in government publications but were recorded by species on forms submitted annually by processors to government. We found these data in the archived material starting in 1923.

Until 1910, all published data dealt with quantities and values of the canned pack and other products processed in an area and not landings. From 1910 onward, however, published

statistical reports contained estimates of the actual landed weight of salmon in individual areas. Until 1933, these were simply calculated by using industry-standard conversion factors to convert the canned pack and products produced in an area to green landed weight, which assumes that the fish processed in an area had been caught and landed there. In interpreting the pre-1933 data, one is faced with the question of whether or not this assumption was valid. From about 1920 onwards in most areas it was not. Data from the archives indicate that by 1930, substantial quantities of salmon were being packed from one area to another for processing and many vessels in the fleet were motorised and capable of moving at least between adjacent local areas, thus being able to catch fish in one area and deliver them in another.

Published statistics took such transfers into account from 1933 onward. During this period DBS reports consistently presented data on GLWs by fishing area for all salmon species combined that took account of transfers between areas for processing. However, a search of historical records revealed that to assemble such material DMF statisticians expended considerable effort contacting field staff and company bookkeepers in order to ensure the data were complete and accurate on a species-by-species basis. Fortunately we found archived DMF data for District II that accounted for transfers by species and area from 1930 onward. Coverage of transfers in the historical material was less complete for fisheries in southern British Columbia waters (i.e. in Districts I and III). The system apparently became cumbersome in later years, particularly when keeping track of transfers of each salmon species on a monthly basis or finer time scale became important. By the late 1940s there was a widespread feeling that the system needed an overhaul, particularly for the purpose of providing accurate "in-season" data for management. This led, in 1948, to a study of the problems of the statistical system by Professor G.L.Burton that in turn led to the sales slip system (Burton 1949) that was in place for the 1951 fishing season.

The new Federal statistical system provided weekly landings, in weight and numbers of fish, by species, fishing gear and fishing area (Figure 2). The system was designed specifically to provide information on landings of salmon by area for use by fisheries managers for management of the fisheries, and by scientists for research and assessments of the status of salmon stocks. The system was developed in response to needs for more precise biological information in order to improve inseason salmon management so as to reverse declines in catch and escapement for several important stocks (e.g. Fraser River and Skeena River sockeye). The post-1950 system, based on recommendations from the study of statistical requirements by Professor G.L. Burton (see also Section 4.1.6), had as its basic units, sales slip records of numbers, weight and value of fish landings by fishermen, recorded at buying establishments along the coast at the time of each transaction between buyer and fisherman.

2. METHODS

Because, as outlined in the preceding section, the system for collecting and recording production statistics changed substantially over time, our data sources and methods varied. We have divided our estimation of commercial salmon GLW into five time periods to reflect these changes. These are:

1) 1828 – 1875, colonial and early federal records of production are fragmentary and therefore estimates of landings are approximate,

2) 1876 – 1900, annual government records are available, but these are limited to quantities of products processed and few data are available on the species composition of the canned pack or products,
3) 1901 - 1922, species composition data are available by area for the dominant product, canned salmon, and in 1910 DMF statisticians introduced estimates of the landed round weight of the catch,
4) 1923 - 1929, species composition data are available by area for all product forms, and
5) 1930 – 1950, (1933 to 1944 in Districts I and III), comprehensive published and unpublished estimates are available for landings by species and area, taking into account raw material transfers.

Prior to 1923, we were unable to find many original records of production and landings in the archive files and, to a great extent our analyses were based on published records. The burning of the Centre Block of the Canadian Parliament in 1916 may have contributed to this paucity of early data. In contrast, from 1923 to 1944, most of the original data forms recording the volume of canned packs and other products, by species, were preserved in the archive records. For the period 1945 through 1950, archived DMF forms for each area (Schedule IA) provided full breakdowns of annual landings by weight, species and area, taking into account transfers.

As a result of differences in available data during each of the above periods, we had to adjust our general methods, described below, in order to calculate GLW by species and area. These specific method changes are explained at the beginning of each section in the results and are illustrated in the accompanying flow charts.
We make extensive use of Appendices because of the complexity of our source data and methods. In Appendix tables we present intermediate data (e.g. species compositions) and selected final catch data in order to illustrate our methods.

Tables at the end of the main text present for each area and year, canned packs, product amounts, catch in hundredweight, average fish weights and our summaries of landings data in metric tonnes (mt) and numbers of fish.

2.1. General Approach for Estimating Green Landed Weight

Figure 4 illustrates the general approach that we followed to estimate from the company production statistics, the annual landed weight of the commercial salmon catch prior to 1951 in each area. The various steps in the analysis are discussed below.

The work involved extensive searches of archival and historical material stored in facilities of the Canada Department of Fisheries and Oceans (DFO), Federal Record Centres (FRC) of the Public Archives of Canada, the University of British Columbia, the Province of British Columbia, the Hudson's Bay Company and the Pacific Salmon Commission. Appendix A describes the historical material that we searched.

To present data for each major area in a consistent manner, tables of canned packs, other products, and summary tables of landed weights/numbers are placed in the same, north-south order throughout the report: Queen Charlotte Islands, Nass River, Skeena River, North Coast, Rivers and Smith Inlets, Johnstone Strait, Strait of Georgia, Juan de Fuca

Strait, West Coast of Vancouver Island and Fraser River. Data summed from two or more separate tables may not total exactly due to rounding.

2.1.1. Canned Pack and Product Quantities

Commercial salmon processors were the source for basic company production data (top level of Figure 4). Beginning in the 1870s, the federal government published product and canned pack totals (second level in Figure 4), by area, in Annual Reports of the Dominion Department of Marine and Fisheries through to March 31, 1914 (Anonymous 1868-1913), then in the Annual Reports of the Fisheries Branch of the Department of Naval Service until the end of 1918 (Anonymous 1914-1918), and thereafter in annual publications of Fisheries Statistics by the Dominion Bureau of Statistics (Anonymous 1917-1950). Most pre-1951 landing statistics in this report derive from these sources.

Appendix B details our data sources and provides examples of the original source documents. Appendix C describes the many area names under which production statistics were aggregated and groups these into our ten areas.

2.1.2. Conversion Factors

At the start of our study it was by no means clear which product/canned pack to GLW conversion factors were used by government bookkeepers and over what period. A second problem was to determine the appropriate measures that were used during the earliest years of the fishery before official collection of statistics began. For example, were tons of canned salmon long (2240 lb) or short (2000 lb) tons, was a tierce of pickled salmon the same weight as a barrel or a package of pickled salmon?

Once we verified the appropriate measures and the industry-standard conversion factors (Table 1) from the historical government records, estimates of GLW were derived. These were developed by applying conversion factors and data on quantities of canned salmon and other salmon products produced in each area, and published in DMF and DBS annual publications, or developed from other sources for the early years (third level in Figure 4). Beginning in 1930, we used the government's own estimates of total GLW by area.

The full range of procedures that we followed to establish product measures and then conversion factors is presented in Appendix D.

2.1.3. Species composition

Once landed weights were estimated the next step was to allocate these to species (fourth level in Figure 4). To do this, species compositions from the canned pack and raw product statistics from each establishment were used to develop schedules of species composition, by product form, year and area.

For the canned pack prior to 1900 we used 1901-1903 average species compositions (Table 2). Starting in 1901 the total canned packs in each area from either DMF or DBS were apportioned to species by multiplying the pack data by the species compositions that were obtained from the data for individual canneries in PFY and FCBC publications (called the "sample" later in this report) (see Section 2.2 in Appendix E).

For products other than canned, species compositions were only available for each area from 1923 onward (averages by District in Table 3). Prior to 1923 we generally used 1923-1930 average species compositions in each area to allocate landed weights from other products among species.

Appendix E details the procedures we used to obtain species compositions in order to allocate landed weights from the canned pack and other products to species.

2.1.4. Transfers

To calculate GLW landed in an area government statisticians took the GLW based on products and canned packs produced in each area, subtracted GLW brought into the area from landings in other areas, and added in the GLW caught and landed in the area that was taken out of the area for processing. Following the same procedures and utilising background data contained in historical records, we carried out the analyses to estimate transfers (fifth level in Figure 4) by species and area from 1933 to 1944 for District I (Fraser River and Howe Sound) and for each of the areas in Districts III (the waters surrounding Vancouver Island). DMF results from similar analyses provided GLW data, adjusted for transfers, for District II from 1930 onward, and for District I and the areas in District III from 1945 to 1950. The transfer-adjusted DMF data for District II were found amongst the historical files from the Prince Rupert office of DFO. These were tables of GLW in cwt by species and DBS area for 1930 to 1950. In this report these data are referred to as the "Prince Rupert" data.

For the pre-1933 period (pre-1930 in District II) we estimated the extent of transfers between areas that occurred but were not taken into account in the published record (Section 6 in Appendix F). These estimates provide indications of the order of magnitude of transfers in the period. We then made adjustments for transfers prior to 1933 (prior to 1930 in District II), but only in the summary tables of annual harvests in weight and numbers, by area and only when we had evidence of transfers (adjusted numbers are italicized and bolded). We did not adjust the production and GLW data in our intermediate tables because we wanted to ensure that these data were unchanged from the published record. Thus for years prior to 1933, it is possible to compare landed weights unadjusted and adjusted for transfers by comparing GLWs in mt summed from the intermediate canned pack and product tables with GLWs in the summary tables.

The methods used by government bookkeepers and us to account for transfers from 1933 onward are described in detail in Appendix F.

We assume that under the product-based statistical system DMF statisticians accurately adjusted for transfers as far as annual harvest statistics were concerned. In Appendix F we note that varying amounts of salmon caught in outlying areas (e.g. Queen Charlotte Islands and WCVI) often were transferred to processors concentrated in the Skeena and Fraser River areas, respectively. If the product-based system did not accurately capture such transfers then we would expect marked differences in harvests to appear when the sales slip system was introduced in 1951. In Section 3.3 we compare catches in each area for ten years before and after the sales slips were introduced to check for this possibility.

2.2. Estimating Numbers of Salmon

To this point we have described, in general terms, our methods to arrive at our principal objective, GLW by species and area of catch (sixth level in Figure 4).

We now turn to estimates of the numbers of salmon and steelhead caught in each of the ten areas. These were calculated by dividing the total weight of each species caught in each area by the 1951-1954 average round weight of the commercial catch of each species. Pink salmon were heavier in odd years in all areas (Figure 5), so in computing numbers for this species, odd and even year averages were used. Numbers/weight data used for the conversion were limited to1951-54 rather than a longer post-1951 period because, as shown in Figure 6, several species underwent significant declines in weight between 1955 and 1985 (Ricker 1981).

Average weights were taken from the catch in pieces and cwt in 1951 to 1954 publications of British Columbia Catch Statistics (Anonymous 1951-1996). The weight of troll and handline caught salmon was reported in dressed weight with the head on in Anonymous (1951-1996). Seine and gillnet-caught salmon were reported in round weight. To calculate the 1951 to 1954 average round weights of the total catch in each area, we converted the troll/handline dressed weights to round weight by dividing by DFO's 0.85 dressed weight to round weight conversion factor.

By using 1951 to 1954 average weights we are assuming that:

a) there were no long term changes in average size (Ricker 1981, 1995) due, for example, to size selection by fishing gears or to systematic changes in average size due to ocean environmental effects, and
b) 1951-1954 averages represent average fish size in the pre-1951 fishery.

To assess the reasonableness of these assumptions, a second independent source of data for the salmon and steelhead catch-in-numbers for British Columbia as a whole (i.e, not broken down by area) was analysed. The data comprised information supplied to DMF by licensed fishing vessel owners, and cannery, cold storage, and trap operators. As discussed in Appendix B, Section 9.4, DMF published the numbers data from these sources for 1920 to 1948, by species and gear (troll, gillnet, purse-seine, drag-seine and trap-net), but only for British Columbia as a whole (Anonymous 1919-1929, 1930-1950). The data sources, forms and procedures used by DMF to compile these data were separate from those used for the product-based salmon landing statistics on which we based our landings estimates.

Simple linear regression and correlation were used to compare the product based and DMF catch-in-number statistics for each species. The hypothesis that both data sets estimated the same catch of each species was examined by regressing one data set on the other, and for those regressions that were statistically significant, testing slopes for significant departure from a slope of one, and intercepts for significant departure from zero. Regression coefficients and the $\mathbf{R^2}$ statistic, a measure of goodness-of-fit, were calculated for various combinations of landings data to attempt to deduce why the two data sets differed for some species and not for others.

To test for significant trends in average fish size prior to 1951 we used simple linear regression and correlation to examine previously published average weight data for some

species and fisheries (Hoar 1951, Killick and Clemens 1963, Ricker 1981, Marshall and Quinn 1988, Ricker 1995, Welch 2002MS) as well as unpublished data on the numbers of a species of salmon required to produce a case of canned salmon (David Welch, pers. comm.).

3. RESULTS

Following general procedures described above and illustrated in Figure 4, adapted to the data sources available at different times, we developed tables estimating canned packs and quantities of other products, by area, for five periods between 1828 and 1950. These tables comprise data on pre-1876 production on the Fraser River (Tables 4-6), summary tables of canned packs for all areas to 1929 (District II) or to 1932 (Districts I and III (Tables 7-16) and similar tables for products Tables (17-26). As an "accounting check, Table 27 compares data derived in this paper with summary data prepared by the Canada Department of Marine and Fisheries in the late 1950s. Tables 28-37 combine GLW data from canned packs and other products, by area for 1930 through 1950. Tables 38–43 contain average weights by species and area for 1951 to 1954.

In Summary Tables 44 –53, data from the above tables are combined to provide listings of total landed weights, by area and species for 1828-1950. On the right side of these tables landed weights are converted to numbers of salmon using the data on average weights by species and area during 1951-54. GLW and numbers data for B.C. as a whole are listed in Summary Table 54 and illustrated in Figure 7.

3.1. Landed Weight (GLW) of Salmon in the British Columbia Commercial Harvest for Five Time Periods

3.1.1. 1828–1875, Commercial Harvest by HBC & Non-HBC Entrepreneurs

As outlined above, commercial production of salmon in British Columbia by Europeans began in 1828 when HBC men at Fort Langley experimentally salted ("pickled") salmon in barrels to facilitate over-winter preservation (first level in Figure 8). Most of these pickled salmon are thought to have been sockeye, with only about one-fifth consisting of chinook and coho (see Appendix E). In 1828, the Fort Langley Journal indicated that, in four days, some 1,150 salmon were packed. In 1829, similar records indicated that 4,550 salmon were salted, 4,500 in tierces (at 90 salmon to a tierce) and 50 in various other types of containers (Shepard and Argue 1989).

Cullen (1979) provided estimates of the numbers of barrels or other containers of salmon pickled at Fort Langley and also the quantities marketed by the post from 1830 through 1873 (Table 4).

In the 1860s, private entrepreneurs entered the commercial field and, by the 1870s, had largely displaced the Hudson's Bay Company in the pickled fish trade. Production of canned salmon by some of these entrepreneurs began in 1870.

Drawing on records maintained by the Colonies of Vancouver Island and British Columbia and from 1871 by the Government of Canada, Shepard and Argue (1989) collated records on the quantities of salmon processed and/or exported from 1860 through 1875 (Table 5).

As illustrated at the top level of Figure 8, data from these various sources were combined to provide estimates of total landings during 1828-1875. Data for the early years were fragmentary and quite likely were incomplete. For example, although Fort Langley was the most important pickled salmon production centre in British Columbia, other posts reportedly contributed to production, particularly Fort Victoria that was purported to have carried out a salmon harvesting and pickling operation on San Juan Island, now part of Washington State. In this regard, Howay (1914) reported that, in 1851, operating out of Fort Victoria, the HBC established a fishery along the shores of San Juan Island. According to Howay, the operation produced 2-3,000 barrels of pickled salmon annually. In their search of Company documents, Shepard and Argue were unable to find any records of such operations. More research might confirm the nature and extent of the San Juan operation and other possible sites for HBC production of Pacific salmon for trade.

Product amounts from 1828 through 1873 from compilations of Hudson's Bay Company records of production or export of pickled salmon compiled by Cullen (1979) and Shepard and Argue were small and variable, ranging from 1,350 to 360,000 lb (Table 4). Data on production and export were not available for all years. For years when production data were not available, we chose the export figures as the "best estimate" of production for that year. When both production and export data were available we chose the higher of the two as our "best estimate". These estimates are listed in column XII of Table 4.

Formal records of production of pickled salmon from the non-HBC entrepreneurs' fisheries in the early years are fragmentary, but for most years some records of total fish exports from the colonies of Vancouver Island and British Columbia and eventually of Canada (from the Province of British Columbia) are available (right side of level 1 of Figure 8). Following a procedure similar to that used for HBC data, estimates of production by non-HBC entrepreneurs were based on commercial production data for years when such data were available, and on export data for other years (left side of level 1 of Figure 8). As for the Hudson's Bay data, such "best estimates" must be viewed as minimal (level 2 of Figure 8).

The HBC and independent entrepreneur's data overlap for 1860 through 1873. However, in these years the Hudson's Bay operation was in decline. In all years between 1860 and 1873, Government records of production (where recorded) and exports exceeded those listed in HBC records. It is assumed that the Hudson's Bay operations would have been conducted under colonial or federal control and therefore production and exports by the Company would have been included in colonial or provincial totals. For this reason, from 1860 through 1875, records from sources other than the HBC were used as a basis for our estimates of production.

As depicted in level 3 of Figure 8, using conversion factors and species compositions developed in Appendices D and E, HBC and independent entrepreneurs figures on product weight for pickled fish were converted to landed weight by species. Firm data on species composition of both canned and pickled products during 1828-1875 are lacking. As outlined in Appendix E (Sections 2.1 and 3.2.2), proportions of each species during this period were estimated mainly on the basis of an analysis of narrative accounts of the fisheries found in DMF reports.

Commercial canning of salmon began in 1870. Early records were found for canned packs on the Fraser for 1870, 1873 and 1874, but records of quantities of canned salmon that were exported were available for all years from 1870 through 1875 (Shepard and Argue 1989). Using export data where cannery production data were not available, these canned packs were allocated to species based on the 1901-1903 average species composition for the Fraser River in Table 2, slightly modified as described in Section 2.1.1 of Appendix E.

Table 6 aggregates information on product amounts for both HBC and the entrepreneurs' operations and, using the highest estimate for each year, develops "best estimates" for 1828 through 1875.

These estimates are converted to landed weights, by species, in the right hand columns of Table 16 for canned product from the Fraser River and of Table 26 for other products from the Fraser River. Table 53 combines the landed weights from both sources to provide summary estimates of the amounts of each species caught in the Fraser River area between 1828 and 1875. The largest harvest during this period was 1,071 mt in 1874.

3.1.2. 1876-1900, Large Scale Commercial Fishing Begins

3.1.2.1. Beginning of formal statistics

Formal reporting of salmon production began in the 1870s, focussed primarily on the Annual Reports of the Department of Marine and Fisheries (see examples in Appendix B).

Following the general analytical approach illustrated by Figure 4, for the 1876 to1900 period the DMF data on total canned packs in each area (left side of Figure 9) were allocated to species using assumed species compositions (Table 2) developed in detail in Appendix E. As outlined on Appendix D, these in turn were converted to landed weights in mt using an 84 lb per case conversion factor (level 5).

For products other than canned salmon, product amounts for each area from DMF Annual Reports were converted to landed weights by species (right side of Figure 9), using the product weight conversion factors (Table 1), and assuming that species compositions for each product during the period generally were the same as average 1923-1930 species compositions (Appendix E). Small adjustments to the 1923-30 averages reflect the somewhat different species utilization during the pre-1901 period as discussed in Section 3.2 of Appendix E.

3.1.2.2. 1876-1900 GLW, canned packs and products

By the turn of the Century the commercial fishery had expanded throughout British Columbia coastal waters. As shown in Summary Table 54, the total GLW of salmon had increased to over 30,000 mt, as compared to less than 1,100 mt prior to 1876. The salted chum salmon markets in the Orient had opened; 4 million pounds or 1,800 mt were exported in 1898 from the Fraser River harvest (Table 26, Anonymous 1868-1913) and canners were for the first time beginning to show serious interest in pink salmon (3,925 cases produced on the Fraser River in 1899). From 1876 on, canned product accounted for more than 80% of the landings in most years, with the average for 1876-1900 being 88% (Table 55).

An interesting sidelight in the canned salmon statistics is the recording of significant quantities of pink salmon being processed in 1900. In recent times, the prevailing belief has been that pink salmon, with a virtually invariable two-year life span are absent from the Fraser River in even-numbered years. In contrast, the DMF Annual Report for the 1900 fishery clearly states that 12,267 cases of pink salmon (about 150,000 fish) were packed on the Fraser in that year. Modest even-year canned production continued through 1912 and for a few years after (Table 16). Gillnet vessels, powered by sail or towed by steam powered tugs, were unlikely to have travelled much further than the river mouth and Howe Sound, and there were, to our knowledge, no transfers between areas of such a volume of unprocessed salmon prior to 1920. This suggests a modest presence of even-year pink salmon in District I prior to the Hells Gate slide.

Of the approximately 12% of salmon harvested commercially that were processed by means other than canning, slightly over half were pickled, smoked or salted (Table 55). For the most part these products were prepared in established plants from which DMF officers would have routinely collected product weight data.

The remaining half of non-canned production comprised fresh and frozen fish. In contrast to pickled, smoked or salted fish, many fresh fish were sold directly to the public by fishermen or through middlemen. DMF obviously had trouble determining how to handle the estimation of quantities of such fresh and frozen fish entering trade. For example, DMF records for 1882-1887 variously included fresh/frozen fish as fish handled by processors, fish used "for home consumption", "fish sold by hawkers", and fish used by "Chinese labourers and others on railways". As discussed in Appendices D and E, it was apparent that procedures for recording quantities of salmon sold in fresh or frozen form differed between areas and it was possible that in some areas, no records at all were kept. For a few years it appeared from narratives in the DMF Annual Reports that quantities listed as "for home consumption" were actually salmon landed for sale (see Section 3.3 in Appendix D). In these cases the volumes are included in Tables 17 to 26.

Tables 7 to 16 present the annual canned packs and the corresponding landed weights, by species, for each of the ten areas for 1876 to 1900. The column headed "Sample/Total" is explained in Section 3.1.3.2 below. Tables 17 to 26 present the annual amounts of each product, and the corresponding estimated landed weights of each species from all products combined, for each of the major areas. Summary Tables 44 to 53 total the 1876 to 1900 GLW by species and area from Tables 7 to 16 and 17 to 26.

From narratives in DMF reports there is firm evidence that between 1888 and 1900 small amounts of GLW destined for products other than canned salmon were transferred from processors in the North Coast area to processors in Prince Rupert in the Skeena River area (Section 6.1.3 in Appendix F). We made adjustments for these transfers to the final harvest data in Tables 46 (Skeena) and 47 (North Coast). We did not adjust GLW data in intermediate tables for transfers in order to maintain the original DMF figures.

Between 1889 and 1913 small amounts of sockeye caught by U.S. traps and canned in Canada (Gilhousen 1992) are included in the tables (<10% of the total, see Table 16).

3.1.3. 1901-1922, Continued Commercial Expansion

3.1.3.1. Improved reporting of GLW and emergence of the transfer problem

Data sources for the 1901-1922 period did not change from those in the previous section (Figure 10). However, reporting changed in 1910 when DMF began converting products and the canned pack to GLW in cwt and recording the total so calculated for each area in their Annual Reports. DBS continued this practice when it took over reporting in 1917. In Appendix D, Section 4 we determined the conversion factors used by DMF. Instead of using DMF's calculated GLW, we used our calculated GLWs. These avoided inconsistencies that we found in the DMF calculated GLWs.

Supplementary information for canned packs from each cannery, first recorded by species in 1901, was available from Annual Reports of the FCBC and PFY (level three in Figure 10). We used these data to estimate landed weight by species for salmon that went into the canned pack since DMF/DBS Annual Reports only recorded total canned packs for each area. We also made minor adjustments to the 1923-1930 average species compositions (level 5) for pickled and fresh/frozen products to reflect changes in the importance of sockeye, pink and chum salmon during the 1901 to 1922 period (see Section 3.2.2 and 3.2.3 in Appendix E).

In the DMF/DBS reports there is only one category of "Salmon fresh and frozen". In the historical records beginning in 1923, these data were subdivided into fresh/frozen production by companies and production by fishermen. We maintained this subdivision in Tables 17 to 26 because the species compositions were substantially different for these categories (see Sections 3.1.1 and 3.2.3 in Appendix E). For each area and year we applied 1923-1930 average proportions prepared by fishermen, and 1923-1930 average species compositions (adjusted for different species contributions in the early years) to the 1910 to 1922 DBS fresh/frozen totals. We chose 1910 to start the companies/fishermen split because that year marked the beginning of substantial troll landings (see Section 3.2.3.1 in Appendix E).

There were references in the DMF narratives to transfers of some salmon in northern BC waters (District II) starting in 1915. Between 1915 and 1919, paralleling the growth of trolling, increasing numbers of chinook salmon began to be processed in major fishery centres such as Prince Rupert. Those reporting on the fishery in the DMF reports stated that most chinook caught in the Queen Charlotte Islands, and possibly half of those caught in the Nass area were transported to Prince Rupert. We assumed that some coho would have been transferred along with the chinook. Transfers of species primarily used for canning (sockeye, pink and chum) were assumed to be negligible. In Sections 6.1.1 to 6.1.4 of Appendix F we detail the procedures we used to adjust the final harvest data for these relatively minor transfers. Our procedures were based on the evidence of transfers from DMF narratives and our judgement as to how to best adjust for these movements of raw product (level 6 in Figure 10).

Starting in 1920, transfers of all species in District II increased. Fortunately, for three northern areas DFO's Statistical Basebook Number Three (Anonymous 1958) provided tables of canned packs of each species, by area of harvest and area of processing (Skeena

1925-1929, Nass 1925-1929 and Rivers-Smith Inlets 1920-1929). These data gave us the means for adjusting GLW that was used for canned salmon for transfers back to 1920; however, we were left with the other product data that were unadjusted for transfers.

The simplest approach to this problem was to treat salmon destined for canning and other products the same. In other words we assumed that for these three northern areas transfers of each species of salmon destined for processing into other products would be proportionally the same as transfers of the same species of salmon that were destined for canning.

We then developed rules for using the adjusted GLW data (Section 6.3 in Appendix F) to calculate annual transfers for the remaining two District II areas back to 1920. For years prior to 1920, except where we had specific accounts of transfers, as noted above, our underlying assumption was that transfers between the large areas defined in this report were insignificant. We also assumed that prior to 1933 there were no significant transfers between District II and Districts III and I to the south (see discussion in Appendix F Section 6.4).

For southern British Columbia areas, information on the amounts of transfers prior to 1933 was virtually non-existent in the historical material. It was possible only to measure the biases that transfers introduced from 1933 onward. However, there were occasional references in the narrative reports in the 1920s to significant transfers from Johnstone Strait, Juan de Fuca Strait and the Strait of Georgia, mainly to the Fraser River area (District I). Thus, GLWs for those areas based on unadjusted production data likely would be somewhat underestimated and those for the Fraser overestimated if adjustments for transfers were not made. As we describe in Appendix F, Sections 6.2 and 6.5, we applied adjusted average transfer rates from 1934 to 1936 (1935 to 1937 for odd-year pink salmon) to estimate transfers between 1920 and 1932 for District I and the areas of District III. We did not use 1933 because the raw transfer data for 1933 were incomplete (see Section 4.2 in Appendix F). As in the north, we assumed that all transfers in the south were between southern areas, and that except where we had specific accounts of earlier transfers, transfers prior to 1920 were negligible.

3.1.3.2. 1901-1922 GLW, canned packs and products

During the first two decades of the Twentieth Century, British Columbia salmon landings increased rapidly. By 1922, the landed weight of salmon caught in British Columbia reached 68,000 mt (Table 54), which compares with landings that generally were under 30,000 mt prior to 1901. This period was marked by initial high production of canned sockeye (over 975,000 cases or 44,000 mt in 1901), followed by a crash to less than half that total following the Hells Gate slide which occurred just before the bonanza 1913 Fraser sockeye run (Roos 1991). As in the previous period, salmon caught for canning dominated the harvest, accounting for three-quarters of the total green landed weight of the catch (Table 55). The dry-salted trade in chum often exceeded 12 million lb per year and coupled with yearly canned chum production exceeding 300,000 cases, province-wide chum landings often were in excess of 15,000 mt. Pink salmon landings destined almost exclusively for the canned market were about the same order of magnitude.

In terms of GLW, the proportion of salmon used for products other than canned increased during the period (from 12% to approximately 25%, Table 55). Most of the increase, however, was in products for which species compositions were well known (dry salted being the largest single contributor). Pickled salmon production, which had posed problems for estimating species breakdowns in earlier years, was much reduced during the 1901-1909 period (Figure 11).

In contrast to 1901-1909 when fresh and frozen fish accounted for only around a fifth of the non-canned harvest, during 1910-1922 fresh and frozen salmon accounted for approximately 60% of the non-canned harvest (Table 55). This mirrored the development of the hook and line troll fishery that targeted chinook and coho salmon. A substantial part of the production from this fishery was sold directly by fishermen to the public or through middlemen and not through larger companies. Salmon sold by fishermen dominated the fresh/frozen trade in southern British Columbia, whereas companies accounted for the vast majority of the fresh/frozen trade in the north (compare data in Tables 17-21 with data in Tables 22-26).

Coho and chinook landings steadily increased as markets for fresh/frozen product and landings by trollers grew.[7] Between 1915 and 1920, 10 to 20 million pounds (4,500 to 9,000 mt) of fresh/frozen product, most of which was chinook, was produced each year. There were record chinook landings of 17,000 mt in 1916, and landings of over 10,000 mt per annum from 1915 to 1920. Over one third of these landings were from WCVI where the Canadian troll fleet was rapidly expanding, as it also was in other coastal areas. Likely many of the chinook were of Columbia River origin as during these years stocks from the Columbia were still abundant, as indicated by annual canned packs there in excess of 400,000 cases, not far off the record Columbia chinook packs of 600,000 cases in the 1880s (Shepard *et al.* 1985). These high WCVI landings were not to be repeated as Columbia River stocks accelerated their long term decline.

The official DMF/DBS canned pack statistics did not break the canned packs down by species, however, as noted in the last section, other sources listing each cannery's production did. So the official canned packs were allocated to species using packs by species from these other sources. In many instances total packs from the other sources and the DMF/DBS packs were identical. In these cases the "Sample/Total" ratios shown in our tables equalled 1.0000. In only 29 of 209 cases from 1901 to 1922 were the pack totals from the other sources (the "Samples") more than 25 percent different than the DMF/DBS totals (the "Total"); three-quarters of these cases were in three areas, Queen Charlotte Islands, North Coast and WCVI (Tables 7, 10 and 15).

The DMF/DBS product data, allocated to species using the 1923-1930 average species compositions, are presented in Tables 17 to 26.

It should be noted that the landings on the right side of Tables 7 to 26 have not been adjusted for transfers. Estimates of the degree to which the early landings were biased by not considering transfers and our procedures to correct for this bias, are discussed in

7. In 1917, when troll licences were first issued, 1,370 fishermen were permitted to troll for salmon (Milne 1964).

Appendix F. We estimate that prior to 1920 transfers accounted for the most part for a relatively small (<10%) proportion of the production of each species in each area.

Summary Tables 44 to 53 total the 1901 to 1922 GLW by species and area from Tables 7 to 16 and 17 to 26. The summary tables include our corrections for transfers (bold and italicized font) for years when we had a basis to do so (mostly from 1915 onwards, see Section 6 in Appendix F).

3.1.4. 1923-1929, The First Peak in Commercial Landings,

3.1.4.1. Transition in statistical procedures

We singled this period out for several data-related reasons. First, 1923 was the first year that species composition data for each product were available. Second, 1929 marked the last year in northern British Columbia (District II) that transfers went unaccounted for by DMF bookkeepers. And third, we had access to data for adjusting the landings in weight and pieces from the combined product and canned pack analyses for transfers that previously had been unaccounted for by DMF.

As illustrated by the first two levels in Figure 12, data sources for the 1923-1929 period (also 1930-1932 for District I) did not change from those in the previous section. We calculated GLW by using the annual species composition data for each product in each area (fifth level in Figure 12) to apportion landed weight for each product to species. Estimates of species compositions for total canned packs continued to be based on packs for each establishment from FCBC and PFY reports, and our application of conversion factors was unchanged from the previous period.

As described in Appendix F, substantial quantities of fish were transferred between areas for processing during the 1920s. In deriving estimates of GLW by area for 1923 to 1929, government statisticians did not take such transfers into account. As discussed in detail in Appendix F, limited data on the extent of transfers were available to us for all areas for these years. Using these data and firm information on the extent of transfers during the early 1930s, it was possible to estimate the extent of transfers in the pre-1930 period (level 6).

In doing so we altered the published total GLWs for some of the areas, but retained the total GLWs for the Districts. Specifically, we scaled the adjusted annual GLW data for the areas within District II so that the total annual GLW for District II remained the same before and after adjustment. We felt this was justified because our search of the archived DMF records revealed only minor amounts transferred between District II and the southern Districts (see Section 6.4 in Appendix F). Similarly, we scaled GLW for Districts I and III combined so that annual GLW totals for the combined Districts remained unchanged.

3.1.4.2. 1923-1929 GLW, canned packs and products

This was a period of sustained high landings in the province. Landings averaged over 80,000 mt per year, dominated by chum (over 30,000 mt) and pink salmon (over 20,000 mt) (Figure 7, Table 54). In contrast, sockeye, by far the dominant species prior to 1923, now accounted for less than 15% percent (12,000 mt) of the total British Columbia

landings. In 1928 a massive harvest of chum salmon, 45,000 mt, contributed almost half of the record catch to date of 101,000 mt.

Tables 7 to 16 contain canned packs and equivalent GLW for 1923 to 1929; Tables 17 to 26 present the corresponding product data and equivalent GLW. As noted earlier, we did not adjust the canned pack and product data in these tables for transfers. Instead, we made the adjustments for transfers to the estimates of annual harvests by area in Summary Tables 44 to 53 (adjusted data are shown in bold and italicized font).

3.1.5. An "Accounting" Check, 1876-1929

As previously explained, in using the canned and other product data from several government sources to estimate harvests in ten areas, the possibility existed that the finely detailed data were in error or incorrectly transcribed by us producing errors in our province-wide totals. To explore this possibility, we carried out an accounting check.

In the 1950s, DFO published a series of Statistical Basebooks. Basebook No. 3, published in 1958, provided a compendium of statistics on the British Columbia fishery, including annual, province-wide amounts for canned packs and other products from 1876 through 1956 (Anonymous 1958). As outlined in the sections above, product quantities used in this report were taken from the product data for each area published in annual reports of DMF and DBS. Since the Basebook represented, at a minimum, an independent compilation of published DMF/DBS records, and may have included more up-to-date assessments of quantities of canned and other products that had been processed throughout the history of the fishery, we compared our annual totals for 1876 through 1929 for canned packs and other products with the consolidated figures in the Basebook.

The results of this comparison are shown in Table 27, which contrasts our product totals, taken from Tables 7 to 26, with totals from the Basebook. For our basic data, we chose the published totals of canned pack and products from annual publications by DMF and DBS. The only modifications we made were to a few of the canned pack totals when we were certain that they were in error, or were inconsistent with our reporting areas (see Section 2.2 in Appendix E). These were minor changes that didn't significantly alter totals for the Province.

There was good agreement between the two data sets. In all cases where discrepancies were found, the original DMF/DBS data were checked. Some discrepancies were due to rounding. For example bait in 1927 in our tables totalled 9,300 lb, whereas the Basebook presented bait rounded to the nearest 1000 lb. Differences for smoked salmon in the first few years were due to our use of more accurate information on price/lb to convert smoked salmon values to weights. Between 1914 and 1929, the Basebook mistakenly reported pickled salmon in barrels (presumably of 200 lb each), when the original data were actually recorded in cwt on the Schedules (and in the DBS reports). The remaining discrepancies in the table were either due to transcription errors in the Basebook, to Basebook numbers being obtained from sources other than DMF/DBS Annual Reports, or else to minor errors in the government canned pack data. The close conformity of data from the two sources provides reassurance that the basic data we have compiled are complete and consistent with, if not an improvement on the statistics published in DFO's 1958 compendium.

3.1.6. 1930-1950, The Fishery Matures

Data sources and methods for calculation of landed weights differed amongst the administrative Districts between 1930 and 1944. For this reason the special methods for each District are dealt with separately. In contrast, between 1945 and 1950, DMF statisticians calculated GLW by species and area, adjusted for transfers, for all three Districts. These data, recorded in cwt, were obtained from Schedule 1A forms held at DFO headquarters in Vancouver.

We were impressed with the quality and quantity of data for the 1930 to 1950 period. The DMF historical records for District II from 1930 to 1944 and for all Districts from 1945 to 1950 were comprehensive, comparable to those of the sales slip statistical system. File material for Districts I and III for 1933-1944 were not as comprehensive, but sets of statistical forms filled out by enterprises and by Departmental field officers were available for District III for most years and areas. These records provided information on catch transfers not contained in the published record. A number of worksheets used by DFO statistical officers to prepare published statistical summaries were also found. The latter were helpful in assisting us to determine the exact procedures employed by DFO to derive their transfer-adjusted estimates of catch. Therefore whereas published DFO records for District III lacked species-specific records of transfers, we had sufficient information to adjust each species' landings for transfers ourselves.

3.1.6.1. Procedures for District I

Neither transfer worksheets nor transfer-adjusted landed weights could be found for District I. Without these data it was impossible to follow the same procedures we used for Districts II or III. Instead, for 1933 to 1944 (1930-1932 methods explained in Section 3.1.4.1 above and Section 5 in Appendix F) we derived independent estimates of GLW by species by using three data sources (three paths in Figure 13): the canned pack of salmon landed in the District (Table 15 in Anonymous 1958[8], and similar data from Rounsefell and Kelez 1938), the total canned pack processed in the District (Table 16 in Anonymous 1958), and the total products processed in the District (from Schedules).

As outlined earlier, for years prior to 1876, estimates of quantities of each species of salmon caught in District I were developed from various narrative historical documents (Table 4). For years from 1876 onward, the general approach first involved estimating the total GLW (both for canned and for other products) processed in District 1 (right and centre paths in Figure 13) and dividing it among species using procedures used for other areas as described above (level 4 in Figure 13).

Lacking archival data on amounts of salmon transferred in and out of District 1, we were then left with the problem of how to estimate the effects of such transfers. We based our estimates on information in the 1958 DMF Basebook (Anonymous 1958) which, for 1876 through 1950, provided data not only on the quantities of salmon canned in individual areas, but also estimates of the quantity of the pack that had been harvested in that area "irrespective of processing location." We used comparisons of these two parallel sets of

8. These data are described in the caption to Table 15 as "INDICATING AREA OF ORIGIN IRRESPECTIVE OF PROCESSING LOCATION".

data to develop "bias correction factors" for canned fish that we applied to the total GLW estimates to arrive at new estimates of the total weights of salmon actually caught in each area. The bias correction factor equals the canned pack adjusted for transfers divided by the unadjusted canned pack (see Tables F35a and F35b in Appendix F).

The resulting annual total GLWs by species differed somewhat from the DBS total GLWs for District I. Remember that DBS's GLWs had already been adjusted for transfers, but we were unable to find the species breakdown for the DBS GLWs. Therefore the second to last step was to scale each species' GLW so that the annual totals matched the DBS total GLW (level 7). In the last step GLWs were converted to numbers of each species using average weights.

The foregoing approach was based on the assumption that, on average, the proportions of transfers in and out of each area were the same for non canned products as they were for canned products For individual years this obviously was not true because we had to scale our calculated GLWs to remain consistent with the DBS GLWs. However, although differences for an area in a single year ranged between +61% and –27%, on average, DBS and our estimates of total GLWs differed by less than 1%

3.1.6.2. Procedures for District II

For northern British Columbia (District II) from 1930 to 1944, tables of GLW, by species and area, were available from the Prince Rupert historical files (level 5 in Figure 14). As demonstrated in Section 3.3 of Appendix F, these statistics were calculated from the same canned pack and product data that were used to compile statistics for the published DBS reports. Procedures and data sources used (Figure 14) were essentially the same as those illustrated in Figure 13, although the conversion factor for canned salmon changed twice during the 1930-1944 period (Table 1). As discussed above, the Prince Rupert GLW data for District II accounted for transfers of fish between areas for the full 1930 to 1944 period.

3.1.6.3. Procedures for District III

Other than our own accounting for transfers (level 4 in Figure 15), the methods and source data for the areas in southern British Columbia, that is waters south of Cape Caution on the central coast, were the same as for District II.

To account for transfers we compiled canned pack and other product amounts from the Schedules, from DMF estimates of total transfers (all species combined) into and out of each area, and from transfers by species recorded on the Schedules and on worksheets prepared by DMF Fishery Officers (see Section 4.0 in Appendix F). The DMF raw data proved adequate for us to calculate transfer-adjusted landings for each species from 1933 to 1944 using the methods of the government bookkeepers. For 1930 to 1932 we used bias correction factors to adjust for transfers (see Section 6.4 in Appendix F). With only a few minor exceptions we were able to account for the exact GLW in the DBS publications (DBS/Total ratios equal or very close to 1.0000).

3.1.6.4. 1930-1950, GLW, canned packs and products

The Great Depression and World War II led to considerable consolidation in the salmon

industry and the beginning of centralization of processing operations, with a resulting drop in the numbers of canneries to less than 40 by 1940 (see Section 1.2.6 above). Canned salmon production peaked between 1930 and 1944, reaching over 2 million cases (76,000 mt) in 1930 and 1941 (Figure 11), 1.5 million of which were pink and chum.

British Columbia production of fresh and frozen salmon fell to less than 20 million lb (9,100 mt) per year in the early 1930s, then rose to and exceeded the high levels of the 1915-1920 period (25-40 million lb) by 1947, (Figure 11). Production of salted salmon dropped off dramatically during World War I then peaked at 38 million lb (17,000 mt) in 1931, falling to zero by 1939. Mild cured salmon were produced at a rate of around three million lb (1,400 mt) per year starting around 1905 and continued near this level through 1950. In terms of volume, mild cured salmon replaced pickled salmon, whose annual production fell to less than 1,000 lb by the 1940s.

This also was a period of record high landings with the highest pre-1951 total, 104,000 mt, occurring in 1931 (Table 54). There were sustained large catches of sockeye, pink and chum salmon (totalling 30,000 to 65,000 mt per year), and coho salmon catches almost doubled 1920s levels, exceeding 11,000 mt per year for nine years between 1930 and 1944 (Table 54). In contrast, chinook landings fell to 4,000 to 7,000 mt in the 1940s, about half the level in the previous 25 years. In spite of consolidation and centralization in the canning industry, total annual landings held steady around 72,000 mt, similar to the long-term average from 1915 to 1950.

Tables 28 to 37 contain the 1930 to 1950 GLW data for each area. The column "DBS/Total" is the ratio of the published GLW to the GLW from sources explained in footnotes to the tables. DBS GLW and Total GLW sometimes differed in these tables due to rounding errors, due to updates after DBS data were published, and in the case of District II areas between 1930 and 1932, due to DBS GLW not accounting for transfers. With the exception of data for 1930 to 1932 for Districts I and III, the GLWs in Tables 28 to 37, converted to mt, are reproduced in Summary Tables 44 to 52. We use these GLWs rather than the published GLWs because the former included post publication adjustments that we believe make these data more accurate than the published DBS GLWs; in general the differences were small. For Districts I and III our bias correction procedures to account for transfers (Sections 6.2 and 6.5 in Appendix F) were applied to the 1930 to 1932 GLW data in Tables 33 to 37 and the adjusted landed weights entered into Summary Tables 49 to 53 (the data we adjusted are shown in bold and italicized font). For more details on how landed weights were compiled for this period see Section 8 in Appendix F.

3.2. Numbers of Salmon in the British Columbia Commercial Harvest

We estimated the numbers of salmon harvested prior to 1951 from the canned pack and product data, converted to GLW and then to numbers of fish using average fish weights for 1951 to 1954. The use of this time period represents a major assumption. It raises the question as to how representative was 1951-1954 of fish harvested in earlier years. To assess this question we first examined available information for trends in size prior to 1951. The results of this analysis and consequent evaluation of our choice of the 1951-1954 period are summarized below.

Whereas historical data on actual numbers of salmon for individual fishing areas are lacking, DMF did provide information on numbers of salmon for the province as a whole. As a further assessment of the accuracy of our approach to estimating catch in numbers, we compared the sum of our area by area estimates with the DMF aggregated data for British Columbia as a whole. This comparison is limited to 1920 to 1948 since these were the only years that DMF reported salmon catch in numbers of fish. Here we reason that if the two independent measures of the total British Columbia harvest are not significantly different they must be measuring the same commercial harvest. Therefore our estimates by area are more likely to be accurate.

DMF records of salmon catch-in-numbers for the Province as a whole appeared first in the DMF Annual Report for 1927. It listed 1920-1927 catch-in-numbers, by gear and species. There were identical tabulations for succeeding years through 1948 (Table 56). Kasahara (1963) reported these data (omitting steelhead) in International North Pacific Fisheries Commission Bulletin 12, a widely quoted compilation of historical salmon catch statistics around the Pacific rim. In Sections 3.2.3 and 3.2.4 below, regression analyses are described that compare estimates of aggregate catch from this report with the above DMF catch-in-numbers data.

3.2.1. Trends in Average Size

As outlined above, the key assumption in the procedures that we used to derive numbers of salmon using average weight data from 1951 to 1954 is that there were no significant trends in average weight prior to 1951. The purpose of this section is to explore the appropriateness of this assumption in light of pre-1951 data on changes in fish weight from other sources.

We examined several diverse sets of data for salmon in addition to the average size analyses in Ricker (1981, 1995) and Welch (2002MS). Marshall and Quinn (1988) used annual statistics on the numbers of salmon caught in Southeast Alaska commercial fisheries and GLW from converted product and canned pack amounts in order to estimate average weights for commercially caught pink, chum, sockeye and coho from 1910 to 1957. Figure 16 shows Marshall and Quinn's average weights through 1954. We included 1951-1954 because we had chosen these years for the purpose of converting GLW to fish numbers. Killick and Clemens (1963) present average size of the dominant Fraser River sockeye age class, age four, based on sampling from the Puget Sound purse seine and Sooke trap catches between 1915 and 1960. For 1892 to 1944, Gilhousen (1992) converted the numbers of Fraser River sockeye-per-case of canned salmon to average round fish weights using Killick and Clemens' relationship between sockeye-per-case and the average annual sockeye weights of commercial landings. Figure 17 shows these two series of Fraser sockeye average weights through 1954 (upper panel) and a significant statistical relationship ($p<0.01$) between the two sets of average weights for the years of overlap between 1915 and 1944 (lower panel). Numbers of each salmon species per case of canned salmon from cannery records for ABC Packing Company for 1906 to 1944 are reproduced in Figure 18 for Nass River, Skeena River and Rivers Inlet canneries (data compiled by Duncan Stacey, independent consultant, and obtained from David Welch, DFO, Pacific Biological Station, Nanaimo, pers. comm.). Finally, Hoar (1951) was the source of numbers per case for pink and chum salmon from canneries in several areas of the coast between 1927 and 1943 (Figure 19). Table 57 contains the linear regression

results for each of the data sets in the Figures; separate regressions were performed for odd and even-year pink lines.

Of 34 linear regressions to test for significant long-term trends in average fish size prior to 1951, only five were significant (1 sockeye, 2 pink, 1 chum, 1 coho). Four were from the fish per case data sets for ABC Packing Company. Skeena River even-year pink salmon underwent a significant decrease in average size (increase in numbers of fish per case) between 1906 and 1943. Nass River sockeye and odd-year pink salmon underwent significant increases in average weight and Rivers Inlet coho underwent a significant decline over the same period. In contrast, for the Southeast Alaska data set, there were no significant trends in sockeye, pink and coho average weight, but chum underwent a significant decline. Fraser River sockeye showed no trend through 1950 for both data sets. However, for the Gilhousen (1992) data series, including 1951 to 1954 averages resulted in a statistically significant regression ($p<0.05$) with a positive slope, suggesting Fraser sockeye were abnormally large during these later years.

Computed size changes (Table 57) between 1915 and 1945 averaged minus 1.3% for sockeye, ranging from minus 11.0% (Rivers Inlet) to plus 5.4% (Nass River). Average computed change for even-year pink was plus 10% but the values for each regression were highly variable, ranging from plus 64.6% (Southeast Alaska) to minus 26.7% (Rivers and Smith Inlets). Only the Skeena River regression for pink salmon was significant (-14.0% between 1915 and 1945). The 1915-1945 average change in odd year pink size was minus 0.4%; the chum average was minus 3.2%. Our chinook and coho average percentage changes (-11.6% and –13.6%) were greater than those for sockeye and pink, but again there was variability between regressions, and only the Rivers Inlet coho regression was significant (-35.7%).

The more numerous regression analyses of Ricker (1981) covering a later period, 1951 to 1975, had 144 of 265 (54%) statistically significant regressions, and significantly more negative regressions than were in the data sets we analyzed for the pre-1951 period (257 negative of 265 vs 21 negative of 34, $p<0.01$ using one-tailed Chi-square). As well, his average declines for pink, coho and chinook were much greater than ours, ranging from minus 11% (odd-year pinks) to minus 42% (even-year pinks). Ricker's analyses of chum salmon catch data showed significant declines in average size (average changes of -7% to –11%) more than double ours. His sockeye regressions were consistently negative, averaging -5% to -8%, whereas ours averaged plus 3%. Later, Ricker (1995) analysed post-1975 average size data and concluded that most of the declining trends observed in catches for north and central British Columbia fisheries between 1951 and 1975 had been arrested or reversed. This was not the case in southern British Columbia where coho and pink salmon continued to decline in size after 1975. Ricker (1995) concluded for sockeye and chum caught in British Columbia fisheries that there had been "no sustained trends in size since 1951."

In comparison to the post 1951 analyses by Ricker (1981) from which he concluded that all salmon species underwent significant declines in average size in the catch between 1951 and 1975, our changes in average size prior to 1951, over generally longer time periods, were mixed in terms of direction (within and between areas), and the amount of change was much less on average.

3.2.2. Average Weights used to Estimate Catch-in-Numbers

The choice of 1951-1954 average sizes to convert GLW to pieces prior to 1951 now resurfaces because regression results in Table 58 show that except for coho, addition of 1951-1954 data to the Southeast Alaska and Fraser data series increased the calculated percentage change in size between 1915 and 1945 (and the predicted size in 1945). This suggests that sockeye, pink and chum were larger in 1951-1954 than they were on average prior to 1951.

Consistent with the above observations, we present evidence in Section 3.2.3 below, based on regression analysis of our and DMF's province-wide catches, that our use of 1951-1954 average weights for pink salmon may have underestimated the catch-in-numbers by over 10%, particularly in years of exceptional pink salmon abundance (i.e. 1951-1954 average weights were too high). However, the +6% difference in pink average weight between 1951-1954 and earlier years in the Marshall and Quinn (1988) data series (Figure 20) was not statistically significant, so for northern British Columbia pink salmon our use of 1951-1954 averages appears less of a concern. However in Welch (2002MS), graphs of pink average weights based on the numbers of pink per case of canned salmon for the 1927 to 1998 period suggest that in several areas along the B.C. coast pink salmon during the 1950s were larger than they were for 20 plus years before or after this decade. Taken together, this evidence suggests that our numerical catch data for pink salmon are underestimates.

We were faced with a quandary regarding whether or not to attempt adjustments for suspected biases in our average weights. The comparisons for sockeye and chum in Figure 20 suggest that contrary to the regression results below for these species, our catch-in-numbers estimates for sockeye and chum may be underestimated by using 1951-1954 averages, at least in northern areas. Figure 8 in Ricker (1981) graphs time series of average sockeye weights; these data also suggest that 1951-1954 was a period of abnormally large sockeye compared to earlier years, particularly for the Fraser River and Rivers Inlet stocks. That and the 12% that our 1951-1954 average weight of Fraser sockeye (6.95 lb) exceeded the Gilhousen (1992) average for the earlier years (6.00 lb) (Figure 20) do suggest a level for a cross-the-board adjustment. Alternatively, we could simply use the average weights produced by Gilhousen and Killick and Clemens (1963). In the end we chose not to adjust our estimates because there was no obvious way to do so consistently for each species and area.

3.2.3. Comparison of Numbers Estimates for Sockeye, Pink and Chum

The next step in this analysis is to show the relationship between our catch-in-numbers and the DMF catch-in-numbers. The purpose of this comparison is to test the hypothesis that the two independent data sets measure the same commercial catch. Sockeye, pink and chum are grouped together because they are the so-called "net" species, that is prior to 1950 they were caught overwhelmingly by gillnet and seine gear. With a few exceptions, differences between the two data sets are slight (Figure 21). As expected, the ratios of the annual catches from the two sources are close to one and without obvious trends over the 1920 to 1948 period (Figure 22). These results suggest that catch estimates for sockeye, pink and chum from the two data sets are similar, and that biases due to use of 1951-1954 average weights, if present, were not of major consequence.

The regressions of sockeye, pink and chum catch-in-numbers from DMF Annual Reports on catch-in-numbers from this report were all significant ($p < 0.01$) with the goodness of fit values, $\mathbf{R}^2$, falling between 0.87 and 0.94, indicating close statistical relationships between the two data sets (Figure 23). The slopes for sockeye and chum salmon were not significantly different from a slope of one ($p > 0.05$) when each was tested individually. The intercepts were positive, but not significantly different from an intercept of zero. The slope for pink salmon (and for odd and even-year brood-lines regressed separately) was significantly less than one ($p<0.01$). The intercept was positive and significantly different from zero ($p<0.05$) for even year pink and even and odd-year pink combined, but not for even year pink. This suggests a small systematic bias in the relationship between the DMF pink salmon catches and ours.

Based on paired sample t-tests, there were no significant differences in mean catches from the two data sets for sockeye, odd-year pink, even-year pink and chum ($p>0.05$), but there was a significant difference when odd and even-year pink salmon were combined ($p<0.10$). Landings of pink salmon in numbers from this report were on average 4.8% less than the estimates of catch-in-numbers from DMF. As well, in 19 of 29 years our numbers for pink salmon were less than DMF's; this was significantly different from 50:50 at $p<0.05$ (one tailed Chi-square). Landings of sockeye and chum salmon in pieces from this report were on average 3.1% more and 5.0% less, respectively, than the estimates of catch-in-numbers from DMF. For sockeye and chum, in 11 of 29 and 17 of 29 years, respectively, our numbers were less than DMF's; neither was significantly different from 50:50 ($p>0.05$).

On the basis of these results, we conclude that catch-in-numbers data for sockeye and chum from this report and from DMF, each derived from independent collections of statistics, measure the same commercial catches. In addition, these results suggest that for these species possible trends in average weight and our use of 1951-1954 average weights did not seriously distort our 1920 to 1948 estimated catch-in-numbers from those published by DMF.

For pink salmon, the high $\mathbf{R}^2$ values suggest a strong and consistent relationship between our catch-in-numbers and those from DMF. However, the fact that slopes were significantly less than one and that there were more years (66%) when our catches were less than DMF's, suggests a systematic bias in the pink data set.

The deviations of slopes from one could have arisen if the average weights that were used in this report to calculate numbers of pink salmon caught were too high. Given this was the only source of error[9], let us assume that true catch-in-numbers, $\mathbf{N}_{ij}$, equals $\mathbf{N}_{DMF\,ij}$, where $\mathbf{N}_{DMF\,ij}$ is the annual catch-in-numbers in year i of species j from DMF. In this report we estimate true catch-in-numbers for the same years by,

$$\mathbf{n}_{ij} = \mathbf{T}_{ij}/\mathbf{w}_j \qquad (1)$$

9. Clearly there are more potential sources of error than just average weights. Canned pack/GLW conversion factors and species compositions could have had systematic errors, reports from companies could have been consistently biased, as could have been, for example, DMF records of fresh/frozen salmon prepared by fishermen, or DMF catch-in-numbers. We discuss some of these potential sources of error in the Discussion, but are generally of the view that these other error sources were minor.

where, $\mathbf{T}_{ij}$ is our catch-in-mt of species j, and $\mathbf{w}_j$ is our estimate of the true average weight, $\mathbf{W}_j$, of species j for 1920 to 1948. Recall that $\mathbf{w}$ is the average weight for the 1951 to 1954 period. The regression relationship we used to compare the two sets of numbers data is,

$$\mathbf{n}_{ij} = a + b\mathbf{N}_{\mathrm{DMF}ij} \qquad (2)$$

Let us further assume that $\mathbf{T}_{\mathbf{ij}}$ is the true catch-in-mt, and is equal to $\mathbf{T}_{\mathrm{DMF}ij}$, where,

$$\mathbf{T}_{\mathrm{DMF}ij} = \mathbf{N}_{\mathrm{DMF}ij}\mathbf{W}_j \qquad (3)$$

Now the regression relationship is,

$$\mathbf{T}_{ij}/\mathbf{w}_j = a + b\mathbf{T}_{\mathrm{DMF}ij}/\mathbf{W}_j \qquad (4)$$

Because $\mathbf{T}_{ij}$ is assumed to equal $\mathbf{T}_{\mathrm{DMF}ij}$, a equals zero, and the relationship becomes,

$$\mathbf{W}_j = \mathbf{w}_j b \qquad (5)$$

So, given that we have accurately estimated the total GLW of pink salmon landings, and that the DMF data accurately estimate the respective catch-in-numbers, then true average weights, $\mathbf{W}_j$, can be estimated from equation 5 using the slopes, b, from the two catch-in-numbers regressions. Values in pounds of $\mathbf{w}$ (1920-1948 averages from our analyses) and $\mathbf{W}$ for pink salmon are compared below:

	Odd-year	**Even-year**	**Combined**
w	5.33	4.64	5.00
W	3.95	4.12	4.26

These differences imply our analysis could underestimate pink catches by, on average between 13% and 35%.[10] However our catch-in-number were on average only 4.8% less than DMF's so a 13-35% bias due to using 1951-54 average weights seems too high.

Closer inspection of the pink data sets showed that the discrepancy between them was largest in years when DMF's numbers were exceptionally high. Eliminating the six years when DMF's catches exceeded 12 million from the regressions, 1926, 1928, 1930, 1936, 1945 and 1947 (see below), increased the regression coefficients to 0.87 for odd years from 0.74, 0.98 for even years from 0.89, and 0.94 for odd and even years combined from 0.85. None of the slopes differed from a slope of one ($p>0.05$)

Year	**DMF Catch '000**	**This Report Catch '000**
1926	13,604	14,151
1928	14,334	14,311
1930	23,873	20,384

10. 100(w-W)/W = estimated percent underestimate.

1936	12,114	10,786
1945	14,454	12,566
1947	12,334	9,327

and the intercepts were not significantly different from zero. This suggests that our average weights were reasonable except in years of high pink abundance when they were too high. This might reflect a density-dependent effect on pink growth in years of high abundance (Welch 1994MS, 2002MS, Bigler *et al.* 1996), which would not be accounted for by using average weights. Regardless, we conclude that ours and DMF's data for pink salmon measure the same commercial catches.

3.2.4. Comparison of Numbers Estimates for Coho, Chinook and Steelhead

In this section we test the hypothesis that the two independent data sets for coho, chinook and steelhead measure the same commercial catch. Figure 24 compares the estimates derived by us (solid line, 1875 to 1950) with the DMF numbers (solid squares, 1920 to 1948) for coho, chinook and steelhead.

For the 1920 to 1948 period the DMF catches of coho and chinook were generally much less than catches in this report (24 of 29 years for both species). Based on paired sample t-tests, average catches of coho and chinook from DMF were significantly less than corresponding average catches from this report ($p < 0.01$). In Figure 25 it can be seen that, prior to 1933, the ratios of catches from the two sources were consistently much greater than one for coho and chinook, and varied from 1.2 to 0.2 for steelhead. From 1934 onward the ratios for all three species varied around one, becoming closer to one towards 1950. For this later period, the average catch-in-numbers for coho and chinook from this report were not significantly different from those by DMF ($p>0.05$). It is clear from these results that, except for a few isolated years, catch estimates from the two data sets differed.

The DMF steelhead estimates differed from those we developed, but for the most part the DMF numbers were higher than ours (20 of 29 years). In general, however, the steelhead catches were small and more variable than catches for the other salmon species (less than 0.5% of the total landings were steelhead). As a result minor errors in species composition of products for chinook, coho and chum, the species most commonly used for products may have resulted in relatively large errors in the estimated proportions of steelhead. Data with this type of error are difficult to analyze; there are no further analyses of steelhead data.

Regression of coho and chinook catches from DMF on catches from this report were significant only for coho ($p < 0.01$) (Figure 26). The slope of the coho regression was 0.402, significantly less than 1.0 ($p < 0.01$), $\mathbf{R}^2$ was only 0.339, and the 95% confidence interval for the positive intercept, a, did not bracket zero.

From the above results we conclude that for coho and chinook, the DMF Annual Report data and the data from this report do not measure the same catches.

There are various circumstances that could have produced these results. For example, many coho and chinook that were recorded as fresh/frozen in the government statistics may have simply been in temporary storage before canning or processing into other products, hence these fish might have been double counted in the DMF product and canned pack statistics, and as a result also in our analyses. Therefore our coho and chinook catches would overestimate true catches. Alternatively, counts of coho and chinook that were used for products other than canned might not have been fully included in the DMF catch-in-numbers statistics, hence the DMF numbers data would underestimate the true catch. Another possibility is that catches by trollers, who were known to harvest substantial numbers of coho and chinook (but few of the other species) were inaccurately tallied in the numbers data (perhaps some coho and chinook were omitted or double counted). For example, in FRC-Ottawa files for 1922 and 1926, the authors found tables of numbers of salmon caught in Districts I and III with footnotes stating that:

> *The shortage* (in numbers caught) *consists of fish caught by trollers and which are not included in the numbers caught, having been exported. Considerable quantities of red springs were also disposed of to the fresh fish trade* [noted on Schedule II records], *and these, also, are not included in the numbers reported caught.*

Such underreporting could explain why the two sets of sockeye, pink and chum catches were closely correlated, but the coho and chinook catches were not.

For several reasons we consider the first hypothesis (double counting) to be unlikely. The landings presented in this report were derived from product and canned pack weights reported by companies to the Dominion government. It is unlikely that these statistics involved extensive double counting, as hypothesized, since such a practice would have had to remain undetected by government and company bookkeepers for decades. Certainly Burton (1949) didn't consider this to have been a significant problem in his review of the pre-1951 DMF statistical system when he concluded that:

> *... the statistics on output of products, in terms of product weight, are accurate. The method now used to collect these data, viz. schedules completed by processors, is the most satisfactory one available.*

In light of Burton's conclusions, it is not surprising that there was no evidence in the historical material that double counting was a major problem. If anything the opposite situation occurred as companies often had to be reminded to submit the required statistical forms. Since the available evidence does not support the hypothesis that coho and chinook landings from this report are overestimates, it will not be considered further.

In the next two sections we explore the hypothesis that the DMF Annual Report data underestimate the coho and chinook catch. Since the relationship between the coho and chinook data from this report and from DMF changed quite markedly after 1933 (Figure 25), the year that DMF officially began to account for transfers in the published statistics, the analyses that follow are divided into two time periods, 1920-1933 and 1934-1948.

3.2.4.1. Comparison of 1920-1933 data sets

During the 1920 to 1933 period the DMF numbers were consistently less than the numbers

generated by our analyses (all points are above the dashed one-to-one line in Figure 27) implying that some data may be missing from the DMF data series.

To test whether the 1920-1933 DMF catches were missing some or all of the fish used for products other than canned salmon, regressions of DMF numbers on numbers from this report were compared. The numbers of coho and chinook we estimated to have been used for fresh/frozen salmon prepared by fishermen, for fresh/frozen salmon prepared by companies, for mild cured (chinook only) and for remaining products, were successively subtracted from the total numbers of coho and chinook calculated from our analyses. For coho, $\mathbf{R}^2$ values were all significant and improved in each case (Table 59). In the fourth regression in Table 59 for coho (total numbers from this report less product numbers) the slope was not significantly different from one, the intercept was not significantly different from zero, and $\mathbf{R}^2$ was 0.677 ($p < 0.01$) (upper graph, Figure 28). For chinook, $\mathbf{R}^2$ values were all statistically significant and increased until mild cured chinook were subtracted (eighth regression in Table 59). At this point $\mathbf{R}^2$ dropped from 0.759 (middle graph, Figure 28) to 0.602; when numbers of chinook from all products were subtracted $\mathbf{R}^2$ was 0.617 and the 95% confidence interval for the intercept did not bracket zero (lower graph, Figure 28).

On the basis of these results it would appear that for years prior to 1934, the DMF catch-in-numbers data underestimated the true catch of coho due to omission of coho that were used for products other than canned salmon. This mainly involved fresh/frozen product since coho were not extensively used for other non-canned product forms (Appendix E). For chinook, it also appears that the DMF catch-in-numbers data for 1920 to 1933 underestimate the true chinook catch due to omission of chinook used for products other than canned salmon. However, the fact that the goodness of fit statistic decreased and the DMF numbers exceeded our numbers when mild cured chinook were removed suggests that chinook used in mild curing were included in the DMF catch-in-numbers data. Because the slopes of the "best" regressions, number four for coho and number seven for chinook, did not differ significantly from one and the intercepts were not significantly different from zero, we infer that possible trends in average weight, and our use of 1951-1954 average weights, did not seriously distort our estimated catch-in-numbers data between 1920 and 1933.

3.2.4.2. Comparison of 1934-1948 data sets

The purpose of this section is to try to determine why the two data sets for coho and chinook differed for the 1934 to 1948 period. Figure 29 presents the relationships between the DMF numbers and the total numbers from this report for this period. Unlike the 1920 to 1933 period, the DMF numbers for 1934 through 1948 actually exceeded the numbers from this report in five of fifteen years for coho and chinook (points below the dashed lines in Figure 29). Figure 30 presents the relationships between the DMF numbers and the canned pack numbers from this report. In this figure virtually all the DMF numbers exceed the numbers from this report. Clearly some of the salmon used for products must have been included in the DMF data for 1934 to 1948, but no matter how the numbers based on various product data from this report and the DMF data were combined, the regressions were not statistically significant. The 1934, 1935 and 1936 data points have been identified in Figure 30 because, as discussed in more detail below, troll catches in those years were anomalously high.

An examination of the troll catch component of the DMF Annual Report numbers (Table 60) shows that there was a large increase in the troll catches of coho and chinook in 1934, 1935 and 1936, whereas there was scarcely any change in the numbers of licensed troll vessels (Table 60), and hence presumably little change in troll effort. The troll catches of chinook for 1934 through 1936 were almost an order of magnitude higher than troll catches in the previous three years; coho catches for these years were about double previous catches. In contrast, chinook and coho catches from nearby Pacific north west states were near average for these years (Shepard *et al.* 1985). In his review of the B.C. troll fishery, Milne (1964) considered the 1934-1936 troll catches of coho and chinook to be "grossly overestimated". These observations suggested that the problem we had with the post-1933 data was with the troll catch component.

To test whether the problem really was with the troll catch, we repeated the regressions after attempting to eliminate the troll catch from both data sets. For coho, we regressed estimated numbers used for canning from this report (our total numbers less our product numbers) on the DMF numbers less the total troll catch of coho and blueback (small coho) from DMF Annual Reports (Table 60). By using our numbers from the canned pack we are in effect assuming for our data that all of the troll catch went into non-canned products. The value for $\mathbf{R}^2$ for this regression was 0.252; the regression was not significant (Figure 31, upper graph).

Blueback was a term the processors used for small coho (<3 lb round weight) that were mostly only of suitable quality for canning; so in the next regression we assumed that troll-caught bluebacks were in fact all canned. When bluebacks were added back into the DMF numbers and the regression repeated, $\mathbf{R}^2$ increased to 0.483 ($p<0.01$), the slope of 1.503 was not significantly different from a slope of one ($p>0.01$), and the intercept was not significantly different from an intercept of zero. The fit improved ($\mathbf{R}^2 = 0.524$) without the 1941 outlier (lower graph, Figure 31). We conclude that DMF numbers data did reasonably accurately account for troll caught bluebacks that were used for canning, but did not accurately account for troll caught coho that went into other products.

There was only one DMF category of troll catch for chinook to compare with our chinook data. To be consistent with our approach for coho, we examined the relationship between the DMF numbers less the troll catch of chinook, and our numbers based only on canned chinook (i.e. total numbers less the numbers of chinook that we computed from other products). Numbers for canned chinook were consistently well below the DMF numbers less troll caught chinook (Figure 32, upper graph) . As noted in the previous section, this may have resulted from a substantial proportion of the troll chinook catch being used for products other than fresh/frozen. Our historical research had demonstrated that that product could only be mild cured chinook (see Appendix E). Therefore the final relationship we examined for chinook was between numbers from this report for canned plus mild cured (i.e. total numbers less numbers from other products except mild cured) and the DMF numbers less troll caught chinook (Figure 32, lower graph). Two outliers, 1936 and 1943, were excluded from the regression because in these years the gillnet catch from the DMF reports was more than double gillnet catches in the five years before or after. In fact these two gillnet catches were by far the highest on record between 1920 and 1948 and we consider them to be in error. For this regression $\mathbf{R}^2$ was 0.301 and the slope was 0.553. The regression was significant ($p<0.05$), the slope was not significantly different from a slope of one, and the intercept was not significantly different from zero.

On the basis of the above results we conclude that the troll catch was inaccurately accounted for in the DMF data for coho and chinook between 1934 and 1948. There also would appear to be a problem with the gillnet catches reported by DMF for 1936 and 1943.

3.3. Comparison of Landings Before and After Introduction of Sales Slips

As a further check on the degree of accuracy of estimates we derived from product information, we compared the magnitude of catches recorded for different areas immediately before and immediately after the introduction of the sales-slip system in 1951. It will be recalled that a major concern of Burton (1949) with the pre-1951 system was its ability to account for transfers of salmon between areas, a shortcoming largely overcome by the new system. The analysis outlined below hypothesises that if the pre-1951 statistics inadequately accounted for transfers in a significant manner, one would expect there to be an abrupt change in the magnitude of recorded catches before/after 1951/1950.

The annual catches by species and area for 1941 through 1960 show no obvious evidence of such shifts in landings (Figures 33-36). Going further, we calculated average catches by species and area for five- and ten- year periods before and after sales slips were introduced (Table 61). We submitted the average catches to a simple test to examine whether or not there were distinct shifts in estimated catch levels. As outlined earlier, in the years before the new statistical system was put in place, we found evidence of salmon being brought from outlying areas such as the North Coast and the west coast of Vancouver Island (WCVI) to the Skeena and Fraser Rivers where fish processing establishments were concentrated. We hypothesize that the higher averages should be evenly split between years before and years after sales slips if there were only random variations in abundance and exploitation affecting catch (null hypothesis, H_0). Alternately, if there were problems tracking transfers then catch averages for outlying areas should be lower before and higher after sales slips were introduced, and averages for central processing locations (i.e. Skeena River and Fraser River) should be higher before and lower after (alternate hypothesis, H_A). Below we use the pairs of five-year averages and one-tailed Chi-square to test these hypotheses. In the analysis, sockeye, pink, chum and steelhead, which were caught primarily by net gears, are treated separately from coho and chinook because the latter species were caught primarily by troll gear and trollers' landings were more difficult to account for (see previous section). The data below are the number of average comparisons that supported either hypothesis.

	Sockeye, Pink, Chum and Steelhead			**Coho and Chinook**		
	H_0	**H_A**	**X^2**	**H_0**	**H_A**	**X^2**
North Areas	8	12	0.8	4	6	0.4
South Areas	10	10	0.0	2	8	3.6*
Combined	18	22	0.4	6	14	3.2*

The null hypothesis is supported for the net species suggesting that the change in statistical system did not result in an abrupt change in catch. This appears not to be the case for the species caught by trollers - coho and chinook. Similar results were obtained when we classified the ten-year averages.

Trends in abundance or exploitation could have given rise to significantly higher catches post-1950 for coho and chinook. For example, the troll fishery grew substantially between 1940 and 1960 (Milne 1964) increasing many outside area catches and undoubtedly contributing to decreased terminal area catches. Since the largest troll fisheries developed on the WCVI and around the Queen Charlotte Islands (QCI), these areas were examined more closely as they would be most likely to show the effects of improved catch accounting. We combined chinook for WCVI and QCI because fisheries in these areas have similar stock compositions (Pacific Salmon Commission 1994).

In our view catches in Figure 37 demonstrate significant increasing trends (WCVI coho, WCVI+QCI chinook) or no trend (QCI coho) rather than steep changes between the two time periods (1941-1950 and 1951-1960). Similarly, Skeena River and Fraser River coho and chinook show significant decreasing trends rather than an abrupt change over the same pre/post sales slip period (Figures 38 and 39).

It would appear that the growing troll fishery was largely responsible for these trends. The close relationship between total WCVI catches for coho and chinook and WCVI troll catches for coho and chinook from Milne (1964) and Argue *et al.* (1987) (Figure 40), lends support to this interpretation, as does the significant ($p<0.01$) inverse relationship ($\mathbf{r} = -0.628$) between total Fraser River chinook catches and WCVI chinook catches by trollers.

4. DISCUSSION

Commercial harvest statistics are important building blocks for biological studies of the production of Pacific salmon and the factors affecting their production. Such studies require reliable measures of numbers and weights of salmon harvested by species, area and over a long period of time. For British Columbia, such information has only been available in comprehensive form since the sales slip system started in 1951. In contrast, prior to 1951, statistics were prepared primarily for economic purposes, concentrating on the volume and value of the canned pack and other products processed in an area rather than on quantities harvested. The production statistics were available to us for each area back to 1828, however until now these data had not been converted to landed weights and numbers of fish in the commercial harvest. In the discussion following we provide our perspective on the reliability and completeness of the data we have developed in this paper (Intermediate Tables 4-37 and Summary Tables 44-54)), observations on trends in British Columbia salmon production using pre and post-1951 data, and suggestions for further historical research.

4.1. Reliability and Completeness of Landed Weights

4.1.1. 1828-1875

Our estimates of commercial harvests for this period were based on fragmentary records of products by the Hudson's Bay Company (mainly for overseas trade), occasional records of economic activity in the Colonies of Vancouver Island and British Columbia, and a few

historical papers (e.g. Shepard and Argue 1989). As such, for most years the harvest records were probably incomplete and, aside from clear-cut evidence that sockeye salmon predominated in production and that pink and chum salmon were not used commercially, assessments of the species composition of harvests were based mainly on our professional judgement. Because commercial production was limited almost entirely to the Fraser River and its approaches, determining the location of the harvests, which presented vexatious problems in later years, was not an issue.

In general, for this early period, estimates of commercial harvests must be considered underestimates and assessments of species composition approximate.

4.1.2. 1876-1900

From 1876 through the turn of the Century growth of salmon fisheries accelerated, spurred on by the development of canning, which overcame the problems of preserving salmon products for shipment to distant markets. Most processing establishments were relatively large enterprises and their records of production, on which Department of Marine and Fisheries (DMF) compilations were based, were complete in terms of total weights of canned, pickled, fresh/frozen, smoked and salted product. These production data, supplemented by historical records, allowed us to develop estimates of green landed weights of products for each of ten broad coastal areas.

Fresh and frozen salmon were used for subsistence as well as commercial purposes. We carefully reviewed the DMF records, excluding those that we considered were used for subsistence purposes, and including those we considered were commercial sales. However, these early records were admittedly confusing in the DMF reports. Since it is likely that fishermen have always made direct sales of salmon, particularly coho and chinook salmon, and direct sales are notoriously hard to document (even today), we feel this is reason to question the fresh/frozen product tallies.

On the basis of the foregoing considerations, we concluded that during 1876-1900 the recorded amounts of canned, pickled, smoked and salted salmon, which, in total, accounted for 95% of the recorded harvest, were quite complete, whereas the recorded amounts of salmon sold as fresh or frozen fish likely were incomplete (further details in Section 3.3 of Appendix D).

To convert product weights to green landed weights, we used conversion factors developed after 1900 by DMF; we did not find these in the published records until 1933. For canned products, archival data show that during the late 1800s, when the canning industry was well established, that a conversion factor of 1.75 lb of raw fish to one lb of canned product, the same as DMF used in later years, was appropriate. For products other than canned, production methods have remained essentially the same throughout the history of the fishery through 1950. We verified this by using 1933 conversion factors to recreate the published DMF green landed weight (GLW) data from the product amounts for 1932 back to 1910 (Section 4.3 in Appendix D), the first year DMF published GLW for each area. On this basis we consider that the conversion factors used during the Twentieth Century were appropriate for converting product forms to harvest during 1876-1900.

Next in our analysis we allocated estimated GLWs among species. There were few records of actual quantities of each species used during the period. We therefore had to make a number of assumptions in reaching estimates of catches on a species by species basis. For canned products, forming the bulk of the harvest, it is known that sockeye salmon predominated. However, archival material shows that chinook and coho also contributed. We estimated the proportions of the latter two species mainly on the basis of fragmentary information available for the early 1900s. Such estimates must be considered approximate. For salted products, it is clear in the archival record that virtually all dried and salted salmon were prepared for Asian markets and comprised chum salmon. Chinook have always predominated in the smoking process. It was therefore considered that species designations for these products were reliable.

In contrast, there is considerable uncertainty regarding the species used in production of pickled products. From the early 1870s onward, pickling was carried out mainly as an offshoot of canning operations. In this report we made our estimates of the species composition of salmon used for pickling by assuming that the same mix of species were used for pickling as for canning. We know of no way to test this assumption, and estimates of weights of salmon based on it must therefore be considered approximate. However, during 1876-1900, pickled salmon formed a minor proportion of the harvest (<3%) and errors in estimation of species composition would introduce little bias to trends in total salmon production during this period.

There were no records of species composition for fresh and frozen fish during the 1876-1900 period. In developing our estimates, we assumed that salmon used for fresh and frozen products by companies were limited to sockeye, coho, chinook and steelhead and that the relative proportions of each were the same as during 1923-1930, the earliest period during which extensive records of species composition of non-canned salmon were available (see Appendix E). For salmon sold directly by fishermen, we assumed a broader mix of species based on species composition data for directly sold salmon during 1923-1930. Whereas the assumptions made are not unreasonable, we are not aware of any way they can be tested.

Since fresh and frozen salmon were estimated to have formed only about 5% (Table 55) of the total commercial harvest (mostly sockeye), errors in their estimation should not introduce significant bias into overall trends. However, a higher proportion (15-25%) of chinook and coho salmon landings in 1876-1900 originated from fresh/frozen product. In this case, errors in estimates of quantities and species compositions of fresh/frozen landings could introduce larger errors in estimates of landings for these species.

In summary, 1876-1900 was a period of rapid development in the fishery. DMF reporting of salmon production was steadily improving. Records for quantities of salmon canned were probably quite complete. Sockeye salmon predominated in the catch (approximately 80 %), but species other than pink and chums (these species entered the canned pack in small amounts late in this period) also contributed to the canned pack. Information on the proportional contribution of these species (chinook and coho) is lacking and our estimates therefore must be treated with caution. For the 12% of salmon production not accounted for by canning, information on quantities and species composition must be considered as approximate, but considerably more complete than in the 1828-1875 period. Assessments

of species composition for other products for 1876-1900 are weakest in respect of chinook and coho salmon.

With regard to transfers of fish between areas for processing, in the 19th Century it is known that fishing vessels did not travel far from the places where they eventually sold their catches. Therefore, we considered it reasonable to assume, unless documented to the contrary, that the fish were caught in the same area as they were reported to have been processed or sold to the public. In the few instances during this period when small amounts of transfers were reported we adjusted the landings data on the summary tables (see Appendix F, Sections 6.1.3 and 6.1.4).

4.1.3. 1901-1922

Based on historical material revealing a proliferation of reporting forms and exchanges of correspondence about the production statistics, we believe that DMF devoted increasing care and attention to obtaining full and accurate accounts of the quantities of salmon canned or processed into other products. When DMF began converting data on quantities of salmon processed by all methods to GLW in 1910 it gave us the opportunity to confirm the appropriateness of our using the conversion factors we uncovered for 1933 to convert canned packs and products to GLW for earlier years.

The biggest change in terms of availability of data began in 1901 when annual data on the species composition of the bulk (about three quarters from 1901 to 1922) of the salmon harvest, namely the portion of the harvest used for canning, became available. The principal reason for this change was that the industry began to can all six species of salmon and to label them by species. Since there were price differentials between species in the marketplace, government decided to include a species breakdown of canned salmon in the published reports, but usually only for the province as a whole.

Provincial Government reports and Yearbooks of the Pacific Fisherman provided breakdowns of species compositions for canned salmon packs of individual canneries throughout the Province. These data, which we considered to be reliable, were used as samples to estimate the species composition for the total pack that DMF and DBS reported for each area in the province. The location of each cannery was determined and their packs assigned to one of the ten broad areas (see Table E24 in Appendix E). These totals were usually equal to or very close to the DBS totals, thus giving us confidence that species compositions for canned packs in each area are accurate.

It is very difficult to assess the accuracy and completeness of amounts of salmon prepared in fresh or frozen form by fishermen. From approximately 1920, and likely for several years before, the numbers of troll vessels was in the thousands (Table 60) and they were scattered coast-wide. This contrasted with the companies which numbered in the hundreds and which were becoming concentrated in fewer and fewer places. Since DMF depended on information provided by the processors or sellers of fish, it is likely that coverage of production by companies was far more complete and accurate than coverage of production by individual fishermen. We see no easy way to assess the degree to which this surmise would have introduced a bias into the results of our analyses.

Overall, we conclude that improvements in recording of species composition of the canned pack contributed to much more reliable estimates of landed weights by species and area than had been available before. Uncertainties remained regarding species composition of salmon sold in fresh and frozen form, however quantities of such fish remained a relatively low percentage (5%-17%) of the total GLW (Table 55). Studying fragmentary data and narratives for earlier years, we concluded that it was reasonable to assume that the species composition of the other product forms prior to 1923 would not be substantially different than during 1923-1930 when we had species compositions by product and area from the historical record.

Prior to 1910 we assumed that transfers of fish from one area to another for processing were insignificant. There was, however, a documented transfer of small quantities of salmon from the Sooke traps to the Fraser River in 1904-1905, the first two years of trap operation. The fish were of poor quality at the destination so the practice was discontinued.

After 1910, motorization, changes in fishing techniques and the desire of processors to centralise their operations led to increasing instances where salmon caught in one area were landed and processed in another. This trend probably started in earnest around 1915 with the expansion of the motorised troll fleet whose vessels tended to travel relatively long distances and to move between areas.

As a result of transfers between areas, GLW based on estimates of the quantities of various products in various areas do not provide an accurate measure of the quantities of salmon caught in that area. DMF recognised this deficiency and spent major efforts to address the problem. However, it was not until 1933 that DMF/DBS Annual Reports took transfers of raw product between areas into account when providing estimates of landings by area.

We reviewed available narrative accounts and some fragmentary records of transfers from DMF historical files in order to assess and correct for biases that had been introduced as the result of the transfers. Such information was most complete for the northern areas. For the most part the adjustments we made for transfers prior to 1923 in each area were minor.

In summary, during 1901 to 1922 the completeness and accuracy of production records by area, and their conversion to GLW by species were substantially improved over earlier years. However, with the mobility of the fleet increasing and with transport networks developing, increasing amounts of salmon were transported from areas in which they were harvested to different areas for processing and sale. As a consequence, the statistical system, which recorded only quantities of fish by area of processing, provided somewhat less reliable information on the actual quantities of salmon harvested in different areas. We did not correct for transfers in the tables of canned packs (Tables 7 to 16) or products (Tables 17 to 26) in order to be consistent with the published DMF production data. However, we were able to identify areas and years where transport of fish would affect landings estimates, to establish measures of biases due to these transfers, and finally to effect adjustments to the landings data for transfers. These adjusted data are shown in bold and italicized font in Summary Tables 44 to 53.

4.1.4. 1923-1929

DMF's statistical system steadily evolved through the 1920s, with increasing emphasis on

completeness and accuracy; systems were developed for estimating production in terms of landed weights rather than product weights. Of importance, 1923 marked the first year that comprehensive species composition data were available for all product forms. Bookkeepers at processing plants compiled these data and submitted them to government. We consider this a major advance in the quality of the production data we had to work with as it eliminated any uncertainty we had in the species composition for products, particularly for fresh/frozen salmon prepared by companies and fishermen. We conclude that, on a Province-wide basis, estimates of landed weights by species became increasingly complete and accurate.

The year 1929 was the last that transfers were unaccounted for in northern British Columbia. We are confident that our adjustments for transfers amongst northern areas for 1929 and earlier years are reasonable and an improvement over unadjusted data. There is more uncertainty surrounding our adjustments for transfers amongst southern areas of District III and District I during this period because the earliest government adjustments for transfers were in 1933 (compared to 1930 in District II). However, there is no doubt that in the south transfers were substantial and had to be accounted for. We view our adjusted data in the summary tables as more accurate than the unadjusted data.

4.1.5. 1930-1950

In general, our tabulations of the annual commercial harvest data for 1930-1950 are considered to be complete and accurate. However, for 1933 to 1944 for the areas of District III, we had to correct the GLW by species and area for transfers. This entailed using data in GLW or product amounts from DMF forms in the historical record (e.g. Appendix F, Tables F24 and F27) for each area that were collected by Fishery Officers from information provided by processing establishments (e.g. Table F28). Because available data were sparse for some years and areas, some of our results for individual areas in these two Districts may contain inaccuracies. However, total GLWs are consistent with those in DBS publications, and DMF statisticians had adjusted the DBS totals for transfers. Our analysis in Section 3.3 of harvests in these areas for ten years before and after sales slips were introduced (1951) gives us further confidence that our adjustments for transfers were reasonable.

We introduced minor inaccuracies into the total provincial landings for 1930 to 1932 by assuming there were no northern BC - southern BC transfers. This assumption was necessary because we lacked southern transfer data for these years. We feel that most uses of aggregated northern or southern data could absorb this bias (±2.5%). However, transfer of northern production to southern areas and vice versa may have introduced more sizeable biases in landings for some individual southern areas (over 10%) in these years (see Section 6.4 in Appendix F).

For District I, our adjustments for transfers hinge on the assumption that DMF's transfer adjustments for salmon used in canning (from Anonymous 1958) are appropriate for salmon used in products. We see no clear way to test this assumption due to a lack of historical material for District I in the DMF files.

4.1.6. The Need by 1950 for a New Statistical System

The production-based statistical system for the British Columbia salmon fishery ended in

1950. Complex and numerous forms had burdened it. Furthermore, the data collected were unsuited to the needs of federal government biologists who were charged with researching the status of the stocks, and providing advice to fishery managers.

As processing became increasingly centralized, keeping track of transfers within a year became a major bookkeeping exercise for company and government officials that was fraught with data gaps and analytical pitfalls. As a result, there was increasing concern about the accuracy of the procedures used by DMF, particularly when the use of these data was for biological purposes on a much finer area and time scale. This was the main reason that, in 1948, Professor G.L Burton was called upon to review the production-based statistical system and to make proposals for its improvement (Burton 1949).

Although Burton felt the basic annual production statistics were accurate and their equivalent GLW was reasonably precise, his final report was quite critical of the accuracy of DMF's estimates of the landed catch by species and area. In his conclusion, he stated that:

> *The statistics on catch of salmon by area of capture are inadequate, not because of any lack of diligence on the part of the statistician assembling them, but rather because of inherent weaknesses in the statistical method employed. There are too many inter-plant shipments of salmon, too many salmon processed in areas other than those in which they were caught,* [and] *too much inter-mixture of salmon from different areas in packer boats and cold storage plants, to permit of accurate statistics being secured ....*

These criticisms were not new. Throughout the post-1932 files, DMF personnel often commented to the effect that weekly and monthly returns for an area seldom corresponded with the "final and correct annual returns", and that transfer data received from "the field" during the fishing season were difficult to reconcile amongst areas.

Burton did not provide detailed analyses to quantify the extent to which he concluded that faulty information on transfers might have biased the pre-1951 data. Since his proposals for improvements would overcome any substantive transfer problems, there perhaps was no need for him to provide precise measures of past shortcomings.

It will be recalled that his proposals for revamping the statistical system dealt with providing very detailed information on a weekly or monthly basis for much smaller areas than we used. Provision of such detailed data would be very vulnerable to transfer errors. All things considered, we believe that by our using an annual time period and large areas (i.e. combinations of DBS/DMF areas), the data in this report are less subject to error than data for shorter time periods and smaller areas. It is our view that at this level of detail the DMF statistics, adjusted for transfers, provide reasonably accurate measures of annual catches for each of the ten areas.

4.2. Numbers of Salmon in the Annual Commercial Harvest

The foregoing discussion dealt with estimation of landed weights of salmon. Biological analyses more often rely on numbers of salmon rather than on weights. Prior to 1951 DMF did not provide data on numbers of salmon caught in each area. As outlined in detail

earlier, we developed estimates of numbers of salmon caught by species and area during 1828 to1950 by applying average weights for each species in each area during the first four years of the sales slip system (1951-1954) to our pre-1951 GLWs. The question is, just how appropriate are these average weights?

4.2.1. Sockeye, Pink, Chum

For 1920-1948, DMF Annual Reports provided estimates of numbers caught, by species and gear, for the Province as a whole. We compared the provincial totals from our analyses with the DMF data. We concluded that for sockeye, pink and chum, Province-wide catch-in-numbers data from DMF and from this report estimate the same commercial catch. Based on this analysis, our use of 1951-1954 average weights to estimate numbers of these species from the landed weights appears not to have introduced any systematic bias during the 1920-1948 period, as would be expected if there had been trends in average size such as Ricker (1981) documented for the 1951-1980 period. This result is consistent with the analysis of pre-1951 time series for trends in average size.

We can't rule out the possibility that there were trends in average size during this period in some areas and at certain times, and we note the lack of average size data for the 1800s (except for Fraser sockeye), but on balance we are comfortable that trends in average size have not seriously distorted our numbers of sockeye, pink and chum landed prior to 1951.

Careful comparison of the average size of salmon from 1951-1954 with average weights from earlier and later years suggested that for some species in some areas, 1951 to 1954 might have been a period of above average size. For example, our Fraser River sockeye average round weight of 6.95 lb is definitely at the high end of the historical range in size, averaging about 6 lb. And for pinks we believe our average sizes were too high in years of exceptional pink abundance.

Our analyses of the appropriateness of 1951-1954 average weights gave us few insights into how a better conversion to catch-in-numbers could be effected. For example it is unclear whether adjustments should be across the board, different in some/each area, and in any case how would we objectively determine the levels of correction? And what about accounting for inter annual variability in size? This often exceeded the differences that we have reported between averages for 1951-1954 and earlier years (compare Figures 6 and 20). In the final analysis we made no adjustment to our numbers data for these possible biases since we could see no obvious way to make consistent corrections across species, areas and years.

4.2.2. Coho, Chinook, Steelhead

For coho and chinook, the comparative analysis showed that prior to 1934 the DMF catch-in-numbers were consistently less than ours. For 1934 to 1948, the degree of underestimation decreased towards 1948, and for several years (e.g. 1934, 1935, 1936), the DMF catch estimates greatly exceeded our estimates. We conclude that the pre-1934 DMF numbers were biased mostly by omission of fish (possibly mostly troll caught fish) that were used for products other than canned salmon. In contrast, our analyses suggested that the problem with the post-1933 DMF data lay mainly with estimates of the troll catch. Troll caught coho and chinook were purchased by weight by many small fish buyers, the

public, as well as by the large companies. Many troll caught fish were held in cold storage before being sold perhaps a year or more later. Such widespread buying in weight rather than numbers, and long periods of storage before processing must have made it extremely difficult to estimate the annual coho and chinook catch-in-numbers. We conclude that the post 1933 DMF catch estimates of coho and chinook salmon were biased by troll caught salmon that were inaccurately reported on troll licenses and that may have been double reported, perhaps as much as a year later by cold storage facilities. The net result - DMF published biased numbers caught, particularly for 1934 through 1936 (gross overestimates).

There are further considerations relevant to the chinook and coho data. Although we lack direct evidence, it is logical that the average weight of chinook and coho from 1951 to 1954 was less than in the years before the troll fishery became a major harvester (after 1910-1915). Commercial fisheries developed first near and in the rivers on the spring and summer spawning runs, and then further and further offshore and over a longer season as market demand increased for later timed runs, the troll fishery for coho and chinook grew, and fishing vessels were equipped with increasingly more powerful engines allowing them to operate further from fish plants and still deliver an acceptable product. This implies that the average size of coho and chinook should have been decreasing over time since fishing in rearing areas takes a higher proportion of immature fish, at generally younger ages and smaller sizes than the terminal net fisheries that target mature chinook and coho on spawning runs. So 1951-1954 average weights for these two species could be significantly less than their average weights in, for example, the period 1880 to 1930, especially for multi-aged chinook. Therefore our estimates of catch-in-numbers for chinook and coho could well be overestimated prior to 1930.

However, there also is the possibility that many of the troll caught chinook and coho sold in fresh/frozen form were actually marketed dressed head-on, which was the practice in the 1940s (Burton 1949). Since neither DMF statisticians nor we adjusted the fresh/frozen product weight for dressing, the numbers (and GLW) in this report for chinook and coho may be underestimated for some areas and years by as much as 15%, the industry standard reduction in weight for dressing salmon with the head on (see also Section 3.3 in Appendix D).

These considerations indicate that for coho and chinook, care should be taken in using our catch-in-numbers data for biological analyses, although we consider our data more accurate than that summarised in the DMF Annual Reports and reported by Kasahara (1963).

Because a high proportion of steelhead harvest went into non-canned products (over 70%, mostly fresh and frozen) and the percentage they formed of the total fresh and frozen product was low (< 3%), we judge the steelhead data most prone to bias and hence least reliable for biological analyses.

4.3. Trends in Salmon Harvests

Having made our best efforts to develop and explain the methodological basis for our estimates of British Columbia salmon harvests in ten areas from 1828 to 1950, it would be desirable to analyze these data to deduce trends and to examine hypotheses regarding

causes for such trends. However, on a comprehensive basis such further explorations are beyond the scope of this paper. Nevertheless, some preliminary observations would seem appropriate.

4.3.1. Canned Pack

In presenting long term trends in salmon catches, some authors used only canned pack statistics to represent salmon catches prior to 1951 (e.g. Pearse 1982, Fraser *et al.* 1982). To examine the potential bias in such presentations, the contribution of products other than canned salmon to the landings of each species was examined (Table 62).

On a province-wide basis, sockeye clearly would be well represented prior to 1951 by catches based solely on the canned pack. Sockeye landings that went into products other than canned fish were never more than 9 percent of the total sockeye landings prior to 1951, and usually were under one percent. For pink salmon, there were ten years when non-canned products accounted for more than 10 percent of total landings prior to 1951 (note that pinks were not canned prior to 1899), otherwise the remaining percentages were all under eight, and so the canned pack would also be representative of the total pink salmon harvest. For the remaining species, relying solely on canned packs would result in significant underestimates of pre-1951 landings. For chum salmon, underestimates would generally amount to 4 to 100 percent of total landings; for coho, from 7 to 100 percent of total landings; for chinook, from 33 to 100 percent of total landings; and for steelhead, between 15 and 100 percent of total landings.

4.3.2. Fraser River Sockeye

Walters and Staley (1987) postulated that the great cyclic (four-year) swings in abundance in some Fraser River sockeye stocks, wherein production every four years greatly exceeds that in the intervening years, is maintained by commercial fishing at higher rates of exploitation in "off" years, tending to prevent the production blooms in those years. They also speculated that cyclic variations in the abundance of Fraser salmon could have arisen from an earlier intensive Aboriginal fishery.

Other authors have suggested that natural mechanisms such as predation (Ward and Larkin 1964), genetics (Walters and Woodey 1992) and lake rearing capacity (Jim Woodey, Senior Scientist, Pacific Salmon Commission, pers. comm.) maintain cyclic dominance. The abundant late Adams River sockeye stock, which exhibits strong cyclic dominance, was seldom fished by the pre-1940 commercial fishery (Gilhousen 1992) or by Aboriginals due to its late timing and poor flesh quality (Jim Woodey, pers. comm.). This observation supports some form of natural mechanism.

Cyclic dominance is apparent from the early Fraser sockeye production statistics that we compiled. With only two exceptions between 1849 and 1916, landed weights for Fraser sockeye for the combined 1901 dominant cycle and the 1902 subdominant cycle exceeded landed weights for the intervening two off years (Figure 41). Prior to the advent of intense commercial fisheries in the 1880s dominant/subdominant landings were 2.2 times landings in the two off years; the ratio was similar, 2.6 times, from 1880 to 1916. This would seem to rule out the commercial fishery as the mechanism maintaining cyclic dominance since

prior to 1880 the harvest was large enough to have exerted such an effect on Fraser sockeye production.

The appropriate escapement targets for most stocks depend heavily on whether cyclic dominance is natural or man-induced (Cass *et al.* 2003). For decades this debate has challenged managers in setting the upper limits for Fraser sockeye production (Ricker 1950; Anonymous 1988). We believe that the above observations, coupled with experimentation since 1985 with high escapements for some stocks on off and dominant years, and a wealth of juvenile sockeye, lake productivity, and adult returns data provide fertile grounds for further research of cyclic dominance hypotheses.

4.3.3. Coastwide Salmon Abundance

Salmon populations are subject to wide swings in abundance. After almost a century of research, the root causes for such fluctuations are still only partially understood. Over the years many authors have speculated on man-made and environmental reasons for salmon catch fluctuations (e.g., Rounsefell and Kelez 1938, Hoar 1951, Milne 1955, Shepard and Withler 1958, INPFC 1962, Milne 1964, Ward and Larkin 1964, Fraser *et al.* 1982, Mysak 1986, Nickelson 1986, Beamish and Boullion 1993, Hare and Francis 1995). A few authors believe that harvest levels in pre-contact times were substantial enough to have affected the productivity of the stocks (Hewes 1973, Glavin 2000). Hewes suggested that following contact with Europeans there was a substantial decline in Aboriginal fishing thus creating a surplus of production that facilitated rapid development of the commercial fishery.

It is apparent that much remains to be discovered about abundance shifts for salmon stocks, and the mechanisms are bound to be more complex when climate and ocean effects are included (Beamish and Bouillon 1993, 1995; Hare and Francis 1995; Hare *et al.* 1999; Mueter *et al.* 2002).

The salmon fishery has a long history in British Columbia. To portray that history we graphed our 1828-1950 commercial data and data from the sales slip statistical system for 1951-2001 (Table 63), providing a record of commercial landings throughout the 174 year history of the fishery (Figure 42). Starting in 1828, the figure illustrates the slow growth of commercial fishing over the first fifty years followed by a rapid expansion, spurred by the advent of the canning industry, over the next 30 years. Then for over 80 years ending in 1997, catches were variable, averaging approximately 65,000 mt per year, but without a long-term trend. Peak total catches occurred in the late 1920s and again in the mid 1980s, before falling to pre-1900 levels since 1997 as a result of substantial changes to the management regime (e.g. management for small stocks/stock aggregates, in particular coho, and selective fishing).

The smoothed data in the lower panel of Figure 42 suggest a periodism with major peaks in landed weight occurring every 15 years or so. Disaggregated north and south coast data show similar periodism (Figure 43). This pattern is repeated for sockeye, pink, chum (Figure 44) and coho (Figure 45), but not as well for chinook (Figure 45). It is tempting to pursue this line of investigation further but that is beyond the scope of our investigation.

What struck us most in presenting the historical harvest data was the long period – 1910 to 1997 – during which total British Columbia salmon harvests fluctuated between approximately 40,000 and 110,000 mt each year. Although rates of harvest that were sustained for this long period are purely speculative, we believe it conceivable that through the 1950s the thousands of fishing vessels fishing five to seven days per week could have consistently harvested 40% and perhaps as high as 60% from most stocks. Since then harvest levels probably exceeded 50% in most years and 80% for some species and stocks in some areas. The question is, what is the biological basis for such a long period of high harvests and sustained production?

In this regard we believe a line of research, suggested some years ago by a colleague (John Sibert, University of Hawaii, pers. comm.) has merit. Given that Pacific salmon and humans colonized the Pacific coast soon after the retreat of glaciers some 10,000 or more years ago, salmon and Aboriginals could be said to have co-evolved on this coast – humans as major predators on adult salmon and adult salmon as providers of food and nutrients for humans and the ecosystem that humans depended on (Cederholm *et al.* 1999; Schmidt *et al.* 1998). With a population of Aboriginal peoples in British Columbia numbering at least 100,000 (Duff 1964), and perhaps much more (Richard Inglis, Royal British Columbia Museum, pers. comm.), it is not inconceivable that pre-contact Aboriginal harvests rivalled those of the post-1910 commercial fishery, as Glavin (2000) speculated for Fraser River stocks. Thus we postulate that built into the genes of salmon is the ability for these species, and the ecosystem to which they are a key part, to withstand substantial human exploitation without significant loss of biodiversity or production.

Conversely, the long period of sustained but variable production could simply reflect that fluctuating ocean conditions, not freshwater escapements largely determine salmon productive capacity. We hope that the data we have assembled here can be used to shed light on these and other hypotheses concerning Pacific salmon dynamics.

4.4. Concluding Remarks

Our research and analyses resulted in preparation of British Columbia commercial salmon harvests for 1828 through 1950 for ten areas (Summary Tables 44 – 53). This is the first coastwide set of area-based statistics that we are aware of for the pre-1951 salmon fishery in the province. We are confident that the landed weights in these tables are as complete and reliable as possible for each salmon species in ten broad coastal and riverine areas along the British Columbia coast. This conclusion is supported by our examination of levels of harvests in each area for ten years before and after the sales slip system was introduced. The annual total landed weights of all salmon species in Table 54 are consistent with published provincial GLW in the DMF and DBS Annual Reports. Small differences between our totals and those in the government publications are due to rounding errors and minor adjustments for transfers. In short, we believe our records of the weight of each salmon species caught in each area are appropriate data for most scientific uses.

Kasahara (1963) compiled total provincial catches in numbers for each salmon species from the DMF Annual Reports for 1920 to 1948. Our numbers of salmon were based on GLW divided by average weight. Our use of 1951-1954 average weights likely introduced a small degree of systematic bias in our numbers data. The bias may be towards

overestimating chinook and coho catches for early years and underestimating pink and possibly sockeye catches, at least in certain areas in most years (e.g. District I – Fraser River sockeye). We encountered data series in the historical records from which more appropriate fish weights (average or annual) may be able to be constructed on an area by area basis. This is beyond the scope of our report but should not be viewed as an insurmountable task by those who wish to develop their own catch-in-numbers data. We note, however, that there was close correspondence between our annual sockeye, pink and chum numbers and those in Kasahara. This was not the case for coho, chinook and steelhead. For these species our numbers generally were higher because we included GLW that would appear to have been underrepresented in the published data that Kasahara compiled.

Our failure to find comprehensive records of salmon catch-in-numbers in the Department of Marine and Fisheries archival and historical records was disappointing. It meant that, unlike for GLW, we had no way to reconstruct and verify the numbers data compiled by Kasahara. Because, at times, federal taxes were levied on quantities of fish harvested, we attempted to find Revenue Canada files providing details of numbers of fish caught, unfortunately with no success. In the end this left us with the close correspondence between Kasahara's sockeye, pink and chum numbers and ours, and the clear evidence that Kasahara's coho and chinook numbers were in error, from which to conclude that our data likely are the most comprehensive estimates of numbers caught that will be produced from the historical records in the foreseeable future.

Whereas we feel that further, wide archival searches would be largely unproductive, there are a number of lines of investigation that could be followed using data we uncovered but did not analyse exhaustively. For example, we found annual harvest records for northern British Columbia that were more detailed by area than those for southern parts of the Province. As outlined at the beginning of the report, we aggregated harvest data for ten rather large areas because we wanted a consistent set of geographical areas that we could report on for the whole history of the fishery. The finer northern data cover 1930 to 1950 landings by species, adjusted for transfers, for geographic divisions that are consistent with each of today's statistical areas in northern B.C. These data may prove useful for those investigators needing more detailed northern landings.

In a similar vein, our search of archival and historical records revealed much information that, because the information was not found over sufficient periods or in sufficient detail, or was not collected in a consistent manner between areas, it was not of use in developing our estimates of annual harvests. Such fragmentary data included forms which recorded the numbers of each salmon species caught by seines in certain areas, forms submitted annually by troll vessel license holders showing numbers caught, tables of daily trap catches, statements showing monthly quantities of salmon purchased by cold storage facilities, weekly purchases of troll caught salmon, and the numbers of each species that it took to make a case of canned salmon. There were also tables showing numbers of each species caught by drag and purse seines for some areas. Such data could be useful for studies of fisheries in particular areas or studies of more fundamental biological nature. As well, weekly or daily data scattered in the files for fisheries in places like Rivers Inlet and Sooke in Juan de Fuca Strait might prove useful for examining run timing.

Finally, as a historical footnote, it might be interesting to gain more information on the commercial fisheries and trade activities of the Hudson's Bay Company operations at posts other than Fort Langley, for example on the United States San Juan Islands. The waters surrounding these islands teem with salmon during the fall spawning migrations and there are a number of sites where Aboriginals and early settlers could fish close to shore for salmon.

5. ACKNOWLEDGEMENTS

Over the years we worked on this report many dedicated public servants helped us search for and understand the historical data records. Maureen Kostner and Mary Weibe, staff with the then Catch Statistics Division of the Department of Fisheries and Oceans, helped us locate company Schedules. Laurie Young, a retired DFO economist, helped us understand the product-based statistical system. Gordon Miller, head of Library Services at the Pacific Biological Station in Nanaimo, directed us to important historical records. Hilda Vanstone, past head of the DFO Records Division in Vancouver, and her now retired successor, Judy Graham, provided us with important background material to the DFO archives at Federal Records Centres in Burnaby and Ottawa. At the Federal Record Centre in Burnaby, Harry Chapin and his staff patiently helped us with our countless requests for archive boxes.

Fred Wong provided us with encouragement to complete this paper and insight into the post-1950 salmon catch database at the Pacific Biological Station (PBS) in Nanaimo. We were greatly impressed by his pioneering work to make post-1950 salmon harvest data easily accessible by computer for stock assessment; Brenda Adkins provided us 1951 to 2001 commercial catches of salmon from the PBS database. Diana Campbell, our senior research assistant, is thanked for reviewing and copying thousands of archive documents. We are appreciative of Bud Graham, scientific authority in the earlier stages of this project, for his patience as this paper passed through many drafts. Finally, we are particularly grateful to Dick Beamish whose extensive review and comments greatly improved the document, to Philip Symons for editorial comments, and to Brian Riddell who reviewed the final report.

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