Surf Smelt (*Hypomesus pretiosus*) in Burrard Inlet, British Columbia: Evidence of Recreational Overharvesting?

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Abstract
Surf smelt (*Hypomesus pretiosus*) occur throughout temperate coastal regions of the Northeast Pacific. Our understanding of the biology, distribution and abundance of this species is poor. Within Burrard Inlet, adjacent to the metropolitan area of Vancouver, small local fisheries have operated for more than a century. During the early 1900s, most smelt were taken in small, commercial fisheries for local consumption. Since then, commercial fisheries have diminished and have been replaced by a rapidly growing recreational fishery that peaks during spring and summer months on surf smelt spawning beaches. Some of the catch in this unmonitored recreational fishery may enter commercial markets. Because of the many uncertainties associated with this species, concerns about the sustainability have been raised. No previous stock assessments have been made for surf smelt in British Columbia. We develop methods to (1) estimate spawning biomass of based on measurements of spawn deposition and (2) estimate recreational catches based on favorable fishing times, as creel surveys are not available. These analyses indicate that recent surf smelt catches in Burrard Inlet may remove 39% of their potential spawning biomass, a high level for a short-lived, iteroparous species. Coupled with an estimated natural mortality rate of 46%, our analyses indicate that the Burrard Inlet surf smelt population may be overharvested. Reduction in recreational harvest levels and preservation of spawning substrate are identified as priorities for this stock.

Introduction
Surf smelt are small, silvery, pelagic schooling fish belonging to the family Osmeridae. They are an important prey item for many marine fish, birds, and mammals, but little research has focused on their basic biology or distribution. Surf smelt are a coastal marine species distributed from Prince William Sound, Alaska to Long Beach, California. Adults are nearshore pelagic fishes,and it is hypothesized that juveniles remain nearshore as well. The failures of offshore acoustic and ichthyoplankton surveys to collect or report surf smelt at any age, including juveniles, supports this hypothesis. Data on the distribution of surf smelt in British Columbia is sparse. Limited observations have been made during spawning events (Loosanoff 1937) with reports from fishery inspectors supplementing observations (i.e., Mowat 1890). Historical reports suggest surf smelt were abundant and could be easily caught nearly year-round in the southern part of their range. This includes the Strait of Georgia and Whiterock, with additional reports from Rivers and Smith Inlets and near the mouth of the Skeena River (Hart and McHugh 1944). Other spawning sites in British Columbia included beaches between Port San Juan and Point no Point on the West Coast of Vancouver Island (H. Dunn, pers. comm.) and Prince Rupert Harbour from inside Digby Island to the mainland (K. Kristmanson, pers. comm.). McAllister (1963) examined individuals from Vancouver, Saturna Island, Goose Island, and Barkley Sound (Vancouver Island). In Washington State, detailed shoreline surveys have revealed many previously unknown surf smelt spawning locations over the last 25 years (i.e., Penttila 1978; 1982; 1995; 1997; 2001; Moulton and Penttila 2001). The initiation of systematic surveys in British Columbia might reveal previously unknown surf smelt spawning beaches. Currently, due primarily to logistical constraints, most surf smelt data for British Columbia come from popular fishing beaches of the Lower Mainland (Hart and McHugh 1944; Levy 1985). It is probable that more than one genetic population of surf smelt is found in British Columbia given the large geographical range of this species. Differences in spawning time, parasite incidence, meristic and morphological characteristics, and serological analyses each support this hypothesis (Kilambi 1965; Kilambi et al. 1965; Kilambi and DeLacy 1967).

Both recreational and commercial fisheries coincide with spawning during spring and summer at spawning beaches. The largest commercial catches occurred during the early 1900s with catches exceeding 200mt. Since then the fishery has steadily declined such that current commercial catches rarely exceed 10mt. Thus, it is unclear whether current harvest levels are sustainable in British Columbia since there has been little research and no formal assessment to estimate current catch or spawning biomass. Wildermuth (1993) estimated catch and biomass for a small research area in Washington State, but data for Canadian beaches is lacking. The purpose of this paper is to provide an estimate of spawning biomass and harvest levels for surf smelt, with special reference to Burrard Inlet, British Columbia.

Estimates of Spawner Biomass

A time-series of egg density deposition, combined with data from recreational catches could be useful as general indicators of surf smelt abundance in specific regions, such as the heavily fished beaches of Burrard Inlet. Penttila (2001) developed a method to determine presence/absence of eggs and the related spawning biomass. This method was adapted from herring egg density surveys conducted by Fisheries and Oceans Canada for herring spawn surveys in British Columbia (Wildermuth 1993).

Egg density surveys are based on three independent estimates: (a) spawning area;(b) egg density; and (c) relative fecundity. Due to considerable variability in the limited data available, we report the mean and range, minimum and maximum, for each variable used in the model. To estimate spawning area we used information from commercial fishermen and published reports (i.e., Levy 1985) to identify spawning beaches and the corresponding length of spawning shoreline around Burrard Inlet (Department of Fisheries and Oceans Canada (DFO) Statistical Management Area 29). Also, we used data from biophysical surveys of Burrard Inlet to estimate the approximate width of spawning locations with suitable spawning substrate (Casher and Roberts 1992). The estimated total potential spawning area is provided in Table 1 and represents the maximum area available. Furthermore, geographical information systems (GIS) corroborate our estimates of available habitat within 20%, a range we will use in our example calculations. It is believed that surf smelt only use approximately 20% of available substrate (D. Penttila, pers. comm.). Therefore, the estimate of actual spawning area used in any year would be about 5967.51m^2 (or 20% of 29 837.57m^2) ranging between 4774.01m^2 and 7161.02m^2. Based on Washington State surveys, the estimated egg deposition depth is about 0.0254m so the corresponding volume of spawning substrate would be 151.57m^3 (5967.51m^2 x 0.0254m). However, eggs might be deposited shallower or deeper depending on actual beach conditions. Thus, we assume a range between 0.0127m and 0.0381m, a range that allows eggs deposited too shallow to die due to limited protection from the elements and those deposited too deep to die due to physiological stress. The corresponding volume of spawning substrate then ranges between 60.63m^3 and 272.83m^3. Egg density surveys have not been conducted for British Columbia populations but in Puget Sound, Wildermuth (1993) observed an egg density around 1.24 eggs cm^{-3} at Ross Point. Penttila (1978) reported much higher densities in other areas, between 15 and 150 eggs cm^{-3}. Due to changes in spawning activity over time (see above) we assume the mean density of eggs to be 75 eggs cm^{-3} ranging between 1.24 and 150 eggs cm^{-3}. It should be noted this variable introduces considerable uncertainty due to the wide range of measured egg densities reported in the literature. The corresponding egg deposition would be 1.14 x 10^{10} eggs, ranging between 7.52 x 10^7 eggs (based on smaller available area, shallower egg deposition depth, and minimum egg density) and 4.09 x 10^{10} eggs (based on larger available area, greater deposition depth, and maximum egg density).

Table 1. Estimated surf smelt spawning areas in Burrard Inlet. Spawning lengths and widths are indirect and approximate.

Spawning Location	Length (m)	Width (m)	Area (m^2)
Point Gray to Jericho	1666.8	4.63	7717.28
Spanish Banks to Jericho	3426.2	4.54	15554.95
Jericho to Kitsilano	4074.4	1.02	4155.89
Stanley Park	2037.2	0.20	407.44
Capilano to Ambleside	926.0	0.83	768.58
Ambleside to Dundarve	1666.8	0.74	1233.43
Potential Total Area			29 837.57

Relative fecundity for Fraser River surf smelt was estimated as 556.5 eggs g^{-1} (Table 2) for females, data that corresponds to 278.25 eggs g^{-1} for both sexes assuming a 1:1 sex ratio and approximately equal weights for each sex. The observed range in relative fecundity was 454.51 eggs g^{-1} female to 670.99 eggs g $^{-1}$ female (Table 2), which corresponds to a range of 227.26 eggs g^{-1} to 335.50 eggs g^{-1} for both sexes based on the above assumptions. Therefore, the estimated spawn deposition would correspond to a spawning biomass of 41mt (1.14 x 10^{10} eggs/278.25 eggs g^{-1}), ranging between 0.2mt (minimum number of eggs deposited and maximum relative fecundity) and 180mt (maximum number of eggs deposited and minimum relative fecundity). Admittedly this range is very large and of limited use to a fisheries manager but it shows the methodology is sound and a priority of future research should be to measure parameters for variables used in the model.

Table 2. July female surf smelt fecundity estimates from the Lower Fraser River Estuary.

Sample Location	Weight (g)	Standard Length (mm)	Fork Length (mm)	Total Fecundity (eggs)	Relative Fecundity (eggs/g)
Fraser River	42.7	148	--	23766	556.59
Fraser River	49.3	159	168	27174	551.20
Fraser River	34.7	138	147	20570	592.80
Fraser River	35.9	144	--	19470	542.35
Fraser River	29.0	133	141	15286	527.11
Fraser River	34.3	142	152	20315	592.29
Fraser River	44.5	146	155	23408	526.02
Fraser River	38.6	148	155	21282	551.34
Fraser River	35.1	139	148	23552	670.99
Fraser River	44.3	142	150	20135	454.51
Mean					556.52

Surf Smelt Fisheries

Commercial Catch

Landings from British Columbia commercial fisheries between 1886 and 2001 have been variable over time. Catches increased during the late 1800s and early 1900s with a maximum catch of 230 158mt in 1904 (Figure 1). Since this peak, the fishery has steadily declined, most notably since the mid-1950s. A combination of increased fishing pressure and habitat loss due to increased human population and industrialization (i.e., oil refineries, mills) have contributed to the reduction of surf smelt around the Lower Mainland, especially English Bay and Burrard Inlet since the 1920s (Figure 1; Motherwell 1922). Also the percentage of smelt landed from the Vancouver area has changed over time. Early in the fishery, large quantities of surf smelt were landed from areas other than Vancouver (Figure 1), but between the 1920s and present, almost the entire catch comes from this area (Figure 1). Recent commercial landings in Burrard Inlet have not exceeded 2mt.

Estimates of Recreational Harvest

Currently, there are no estimates of recreational harvest, likely a significant portion of surf smelt landings. Thus, we provide a working estimate of the recreational harvest using some general assumptions. High evening and weekend tides attract the greatest number of fishermen (D. Levy, pers. comm.). There are 77 evening and weekend high tide events (Monday to Friday, 3 pm to 8 pm, Saturday and Sunday 8 am to 8 pm), between mid May and the end of September in Burrard Inlet. Of those 77 fishing opportunities, 27 fall during the fishery closure leaving 50 possible fishing opportunities. Weather also affects the ability and desire to fish. Assuming that an additional 25% of these opportunities will be lost due to weather, 37.5 fishing opportunities remain. There is an estimated 13 800m of shoreline used by recreational fishermen. On a good night, nets are set every 2m (D. Levy, pers. comm.). However, not every location is used equally, as some locations are very popular while others are less popular. Thus, we assume one fisherman every 50m. Using an average catch of 56 fish per trip (D. Levy, pers. comm.) and an average weight of 22.67g per fish, the estimated recreational harvest would be 13.2mt. It is important to note that this estimate does not take into account several important elements. First, average catches used in this estimate come from an area known to be one of the most productive for recreational fishing and it is unknown whether this level off fishing success would be equalled in all areas. Also, this estimate assumes no fishing opportunities during the conservation closure and there are many reports by fishermen, the GVRD, and Conservation and Protection (DFO) that fishing during the closure is common so estimated landings likely underestimate the actual landings. And, it is likely many users are fishing outside of the preferred fishing areas used in our harvest estimate, an assumption that would tend to underestimate the actual recreational harvest in British Columbia.

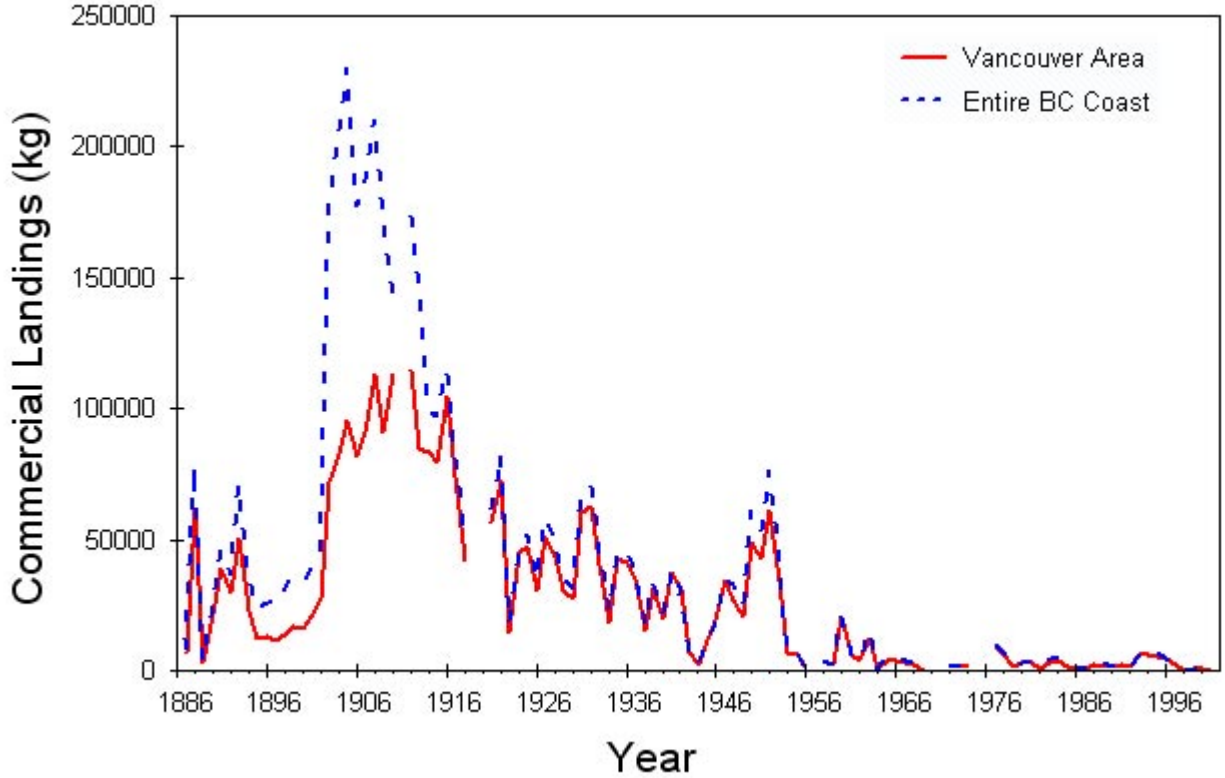

Figure 1. Reported surf smelt catches for Statistical Areas 28 and 29 (Vancouver Area) and for the entire British Columbia coast between 1886 and 2000.

Discussion

Our knowledge and understanding of surf smelt in British Columbia is extremely limited. To make proper assessments for this species, basic biological data is required. Major data deficiencies for surf smelt include limited information on distribution, biomass and spawning biomass, fishing and natural mortality rates, and the impact of commercial and recreational fishery gear, including by-catch of non-target species (i.e., salmon, perch). The most extensive surf smelt fisheries in British Columbia occur in Statistical Management Areas 28 and 29 where harvester impacts are unknown. We advocate the adoption of a precautionary management plan for both commercial and recreational users (Fisheries and Agriculture Organization 1995). Such a plan should include strict enforcement of regulations, limited effort and catches for both commercial and recreational users, and the inclusion of a biologically based sampling program.

The Burrard Inlet stock has decreased dramatically since its peak in the early 1900s with landings less than 2mt in recent years (Figure 1). Due to limited available data, it is unclear if this drastic decline is due to decreases in biomass or effort, unreported catches, or a combination. Hart and McHugh (1944) also noted decreased catches and believed the demand was high but fish abundance was low. Since 1963, reported catches have averaged 2.6mt, with a maximum harvest of 9.5mt in 1976. There are several management implications due to the current policy for surf smelt in British Columbia. Currently, this fishery operates as an unlimited entry commercial fishery with no catch limits, poor enforcement, no by-catch management, and poor compliance to the harvest log submission requirement (average 38%). In addition, although there is perceived limited commercial demand for the product, there is a high incidence of illegal fishing both recreationally and commercially. One management option is to reduce fishing pressure on females. Altering the current regulations on mesh size could accomplish this due to size differences between sexes (Levy 1990).

Commercial catch data, estimated recreational harvest, and estimated spawner biomass for Burrard Inlet indicate potential over-utilization of the resource. Admittedly these values are approximate and caution should be exercised for management decisions, but continuation of both commercial and recreational fisheries under the current management strategy in Burrard Inlet is not recommended. The current management plan is inconsistent with the precautionary approach to fisheries management. In accordance with the guidelines for new and developing fisheries in British

Columbia, insufficient data exist to reasonably manage the resource. It should be noted that these guidelines apply to ongoing data limited commercial fisheries, an example of which is the current surf smelt fishery. Thus, it is necessary to gather pertinent data for future resource development. Currently, there is no biological basis to support an unlimited entry, unlimited quota fishery where biological data are sparse or non-existent and formal assessments are not possible.

For successful management of Burrard Inlet surf smelt additional biological and fisheries data are required. Better estimates of spawning biomass and refined catch data are essential. With the introduction of Area Based Management, there exists an opportunity to include local stakeholders. For example, interest groups could easily collect spawn data and user effort data via creel surveys. Data collected would provide much needed information on inter-annual variability in population biomass, spawning biomass, and catch, data that could be used by managers and scientists for assessment decisions. Burrard Inlet is geographically compact, lending itself to implementation of these suggestions. Also, the GVRD maintains a security patrol that operates throughout Pacific Spirit Park, including Point Gray and Spanish Banks, two of the most popular fishing areas in Burrard Inlet. Staff has expressed interest in collecting and supplying user information to the Department of Fisheries and Oceans Canada.

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