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Research Document 2002/115

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Document de recherche 2002/115

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Review of Surf Smelt *(Hypomesus pretiosus*) biology and fisheries, with suggested management options for British Columbia

Examen de la biologie et des pêches de l'éperlan argenté (*Hypomesus pretiosus*) et options de gestion suggérées pour la Colombie-Britannique

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ISSN 1480-4883

Canada

Abstract

Surf smelt (*Hypomesus pretiosus*) occur throughout temperate coastal regions of the northeast Pacific. Despite small local fisheries operating for over a century, primarily in Washington State and British Columbia, notably Burrard Inlet, San Juan Inlet and Prince Rupert Harbour, the distribution and abundance of this species has been poorly described. During the early 1900s most smelt were taken in small, commercial fisheries for local consumption. The commercial fishery peaked in 1904 with a coastwide catch of over 230mt. Since then the commercial fishery has largely disappeared and is being replaced by a growing recreational fishery that peaks during spring and summer months at surf smelt spawning beaches. This rapidly expanding recreational fishery has raised concerns that the fishery might not be sustainable, especially if an increased proportion of the recreation catch is intended for commercial markets. Therefore, we provide a precautionary management strategy for surf smelt in British Columbia including recommendations.

Résumé

L'éperlan argenté (*Hypomesus pretiosus*) est présent dans l'ensemble des régions côtières tempérées du Pacifique nord-est. On ignore largement la répartition et l'abondance de cette espèce malgré le fait qu'elle fasse l'objet de petites pêches locales depuis plus d'un siècle, surtout dans l'État de Washington et en Colombie-Britannique (notamment dans les bras de mer Burrard et San Juan et le havre de Prince Rupert). Au début des années 1900, on capturait surtout l'éperlan pour la consommation locale dans le cadre de petites pêches commerciales, lesquelles ont atteint leur apogée en 1904 lorsque les captures ont dépassé 230 tm pour l'ensemble de la côte. Depuis, la pêche commerciale a largement disparu, et une pêche récréative qui se pratique surtout les mois d'été et d'automne sur des plages de fraie de l'éperlan argenté gagne en popularité. L'expansion rapide de cette pêche récréative soulève des préoccupations selon lesquelles elle ne serait pas durable, surtout si une fraction accrue des prises récréatives est destinée à la vente commerciale. Par conséquent, nous proposons une stratégie prudente et des recommandations pour la gestion de l'éperlan argenté de la Colombie-Britannique.

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 occur throughout coastal regions of the eastern Pacific Ocean from Prince William Sound, Alaska to Monterey Bay, California but little is known of their distribution in British Columbia. Penttila (1978; 2001) surveyed bays and inlets of northern Washington State and Levy (1985) conducted similar surveys in Burrard Inlet, British Columbia to better understand their regional distribution. No biological or distribution data for surf smelt is available for regions of British Columbia outside of Burrard Inlet despite active recreational fisheries in the Lower Mainland, San Juan Inlet and Prince Rupert Harbour and a minor localized, commercial fishery in Burrard Inlet. 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, operating with a Category Z8 licence or a vessel based Schedule II licence, has steadily declined such that current commercial catches rarely exceed 10mt.

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 report is to provide managers with a source of information for surf smelt, with special reference to British Columbia populations. We review surf smelt biology and the history of commercial and recreational fisheries for this species. The policy governing new and developing fisheries is to proceed through three developmental stages (Perry et al. 1999). This report represents “Phase 0”: a review of the available biological and fisheries information on the target species (or similar species elsewhere) using a variety of sources. Thus, the three main objectives of this report are:

1. review relevant biological and fisheries data for surf smelt, with emphasis on populations in British Columbia and Washington State;
2. identify data deficiencies relevant to management needs, especially in British Columbia; and
3. recommend alternate management strategies based on available biological and fisheries data.

A Review of Surf Smelt Biology

Surf smelt (*Hypomesus pretiosus*) belong to the family Osmeridae, a small family distributed throughout cold and temperate waters of the Northern hemisphere whose center of origin is thought to be the eastern Pacific Ocean (McAllister 1963). Osmerids are small, soft-rayed fishes with an adipose fin living in marine, estuarine, and freshwater habitats. The Osmeridae is composed of 6 genera and 15 species with 7 species found in British Columbia: whitebait smelt, *Allosmerus elongatus;* capelin, *Mallotus villosus*; rainbow smelt, *Osmerus mordax*; night smelt, *Spirinchus starksi*; longfin smelt, *S. thaleichthys*; elachon, *Thaleichthys pacificus*; and surf smelt. Surf smelt are beach spawning fish with cycloid scales reaching a maximum length of 22.2cm in British Columbia, although they are slightly larger in California, 30.5cm (Hart 1973). Diagnostic characteristics include a small mouth, presence of a dark bar down either side of the body, a small, curved adipose fin, an incomplete lateral line, and the insertion point of the pelvic fin beneath or behind the dorsal fin (Hart 1973). This species displays sexual dimorphism. Males have numerous nuptial tubercles on the sides, head and fins, a brown back and yellowish belly while females have no tubercles, a bright green back, and white belly (Schaefer 1936; Hart and McHugh 1944). Kilambi (1965) hypothesized that coastal ocean and estuarine populations from Puget Sound were genetically distinct based on glacial movements and resultant division and distribution of osmerid populations over 13 000 years ago. Spawning time, parasite incidence, meristic and morphological characteristics, and serological analyses each support this hypothesis (Kilambi et al. 1965; Kilambi and DeLacy 1967).

Fertilization occurs immediately after spawning. The first stage of incubation is marked by the rupture and folding back of the outer egg membrane. This fold forms an extremely adhesive 'peduncle' that attaches to the beach substrate. Adherence of only the peduncle is a unique characteristic of surf smelt eggs that make them easily distinguishable from other demersal fish eggs that are adhesive all around. Subsequent wave action buries the eggs to a depth between 2–15cm in the upper tidal zone. Development can take up to 56 days depending on spawn timing and water and air temperatures (Penttila 1982). Key developmental stages and their timing are summarized for summer spawned individuals. After 7 hours rudimentary organs become visible. Between 92 and 97 hours embryo length has increased such that it wraps once around the yolk. By 145 hours eyes of the larvae are visible. At 8 days movement may be detected with agitation. Around 10 days eggs detach from beach substrates and hatching starts. Most larvae hatch after 11 days. Newly hatched planktonic larvae are approximately 3mm long and active. They have a small yolk sac and a transparent continuous medial fin that stretches from the back of the head to the anal fin. Pelvic and pectoral fins are undeveloped at this stage. Some evidence exists to suggest larvae might move into estuaries during this stage to complete their development (Yoklavich et al. 1991). Larval and juvenile growth is fairly rapid, attaining lengths between 45 and 100mm by late fall or early winter when scales begin to develop (Loosanoff 1937). By late winter all scales have developed, but remain small.

Scales are generally used to estimate length-at-age of smelts from 1–5 years (Penttila 1978). Two year old smelt dominate all populations studied to date in both Washington State and British Columbia, with average standard lengths of 138mm for males and 146mm for females. No other aging structures (i.e., otoliths) have been validated, and to our knowledge, surf smelt have not been aged in British Columbia.

Surf smelt feed on a variety of zoobenthos and zooplankton (i.e., amphipods, copepods, crab larvae, shrimp, aquatic insects, worms, fish eggs and larvae, and jellyfish). Surf smelt are important prey for larger predatory fish (i.e., salmon), marine mammals (i.e., harbour seals), and birds (i.e., mallards, blue herons and bald eagles) (Penttila 1995).

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 Fishery Inspector reports 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. Molecular markers could be developed to test this hypothesis.

Populations have an approximately equal sex ratio (i.e., 1:1), except when spawning. During spawning (see below) a single female may be pursued inshore by up to five males resulting in higher captures of males (maximum 9.5:1, average 8:1) in both recreational and commercial fisheries (Schaefer 1936; Loosanoff 1937; Penttila 1978; Levy 1985). In Puget Sound, surf smelt spawn throughout the year with heaviest spawning between June and September (Thompson et al. 1936; Schaefer 1936; Loosanoff 1937; Penttila 1978). Winter spawning populations also occur throughout Juan de Fuca (Hart 1973; Penttila 1978) with several locations supporting both winter and summer spawns. In contrast, surf smelt of the Lower Mainland spawn only during the summer months from early May until the end of September (Hart and McHugh 1944; Levy 1985). The San Juan population in southern British Columbia also spawn during summer but specific spawning times are not available (H. Dunn, pers. comm.). Evidence from Fishery Officers and commercial fishermen indicate the Prince Rupert population spawns during the spring, between mid-February and April. Winter spawning does not occur on beaches exposed to open ocean surf (Hart and McHugh 1944).

Spawning activity has been observed and described extensively (Schaefer 1936; Thompson et al. 1936; Loosanoff 1937; Yap-Chiongco 1941). Spawning time is affected by tidal and lunar cycles with marked increases in the number of spawners during high evening tides during full moons (Levy 1985). During the spawning season, surf smelt concentrate just offshore, adjacent to spawning beaches of fine to coarse gravel (1–7mm in diameter) (Schaefer 1936; Penttila 1978; 2001). Approximately one to two hours prior to high tide, single ripe females begin swimming onshore (0–5cm depths). Several males pursue each female and position themselves parallel to and slightly behind the female. Nuptial tubercles on the male help maintain its position relative to the female (Thompson et al. 1936). Milt and a small number of eggs are released, at which time the female, followed by the males, rejoins deeper water schools adjacent to the spawning beach. This process takes less than 20 seconds with each female repeating the process over several days until all eggs have been spent. It is unknown whether males spawn once or several times. Between 1440 and 29 180 eggs (each 1.0–1.2mm in diameter) are released by a single female during the spawning period (Schaefer 1936). Spawn densities tend to be higher on beaches with afternoon shade and freshwater seepage, generally on or near the mouth of a river (Penttila 2001). Surf smelt eggs have moderate resilience to prolonged periods of exposure or warm temperatures (Loosanoff 1937), but overexposure will desiccate and kill developing embryos as will mechanical compression (i.e., walking on the spawning beach). Eggs that are kept moist and cool during low tides and/or high temperatures and have increased water circulation around developing embryos have improved egg to larvae survival rates (D. Penttila, pers. comm.). Some Burrard Inlet beaches (e.g., Kitsilano, Jericho) have little afternoon shade and this may increase egg and larval mortality rates.

Schaefer (1936) reports the only data on spawning frequency and fecundity for surf smelt. Multiple modes of egg maturity (immature, intermediate and maturing) were observed and it was suggested that smelt might spawn more than once during the season. However, it was not possible to determine whether the intermediate mode developed to maturity and was spawned or was reabsorbed. Fecundity estimates were based on counts of maturing, but not fully ripe, eggs. Females produced between 1440 and 29 180 eggs, corresponding to length and ages of 105mm and 2 years and 175mm and 4 years, respectively. This data is consistent with Hart and McHugh (1944) that suggest most surf smelt produce between 15 000 and 20 000 eggs (with a range between 2500 and 37 000). Schaefer (1936) showed fecundity increased linearly with weight as:

$$\text{Fecundity} = 396.2 \bullet (\text{length [in mm]}) - 402$$

Also, longer females produce larger eggs such that a negative correlation exists between the number of eggs per gram and length (Schaefer 1936).

Using scales for age determination, Penttila (1978) concluded that recruitment to the fishery and spawning population may occur as early as age one, but only late in the season, when the fish would be entering their second year. Early in the spawning (and fishing) season, catches consist mainly (> 90%) of 2-year-olds, almost all males and juveniles. As the season progresses, the age profile shifts to reflect a larger influx of 1-year-old males and some 1-year-old females (Table 1). This apparent age distribution matches the length frequency data from 531 surf smelt collected at 3 different locations and times: 132 from June 2001 and 218 from October 2001 from the Fraser River estuary, 40 from Spanish Banks spawning beaches in September 2001 and 141 from Alaska in October 2001. Using length-weight data, these samples cluster into distinct categories, regardless of origin or time of catch (Figure 1A). In all samples there is one peak around 120mm, a second around 150–160mm and a third around 180mm (Figure 1B). If these 3 peaks correspond to age classes, they would correspond to age 1+, 2+, and 3+ fish, respectively. Thus, another peak corresponding to age 0+ should occur at sizes less than 100mm. Such a peak has been identified for other species collected in the Strait of Georgia using fine mesh nets (Fulton et al. 1982). The observed size modes correspond closely to size modes observed for another smelt, the eulachon, collected from rivers and adjacent offshore locations (Hay and McCarter 2000).

Estimates of Spawning Biomass

There is insufficient data to estimate spawning biomass for any location in British Columbia. However, using available data (published reports from Washington State, research collections, and personal communications) and making some general assumptions, a methodology is presented that could be used for future assessments of surf smelt spawning biomass. The following is not intended to provide “usable” estimates, but rather to show how the procedure could be used if appropriate data were available and how uncertainty in measured parameters affect final estimates of spawning 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. For more than 20 years this approach has been used to monitor spawning patterns of surf smelt in Washington State. The method for collection and analysis of substrate for estimating egg density for known surf smelt spawning beaches is provided in Appendix 1. 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. For this sample calculation, 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 (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 2 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).

Relative fecundity for Fraser River surf smelt was estimated as 556.5 eggs g^{-1} (Table 3) 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 3), 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.

A Review of Surf Smelt Fisheries

Historical First Nations Use

There is a long history of First Nation's usage of surf smelt throughout the Pacific Coast. Patchedat First Nation on the West Coast of Vancouver Island historically fished surf smelt for food, social, and ceremonial purposes. They continue to utilize this species today and have made a request to Fisheries and Oceans Canada to commercially harvest surf smelt (H. Dunn, pers. comm.). Dipnets and gillnets were used historically but, more recently, a recreational gillnet is used. Haida First Nations of

Massett (*qaian*) and Skidegate (*kiina*) also harvested surf smelt although historically a rake was used rather than a net (Jones 1999). A number of small pelagic forage fishes, including anchovy, perch and eulachon have been identified from archaeological sites in Nuu-Chah-Nulth territories on the West Coast of Vancouver Island, but surf smelt has not been identified from samples collected to date (D. Hall, pers. comm.). However, given the extensive utilization of marine resources by Nuu-Chah-Nulth First Nations, and the ease of capture of surf smelt, it is likely Nuu-Chah-Nulth First Nations harvested surf smelt in the past.

Quillihute First Nations of northern Washington State also relied heavily on surf smelt. Historically, the Qullihute people used a parallelogram shaped dipnet with a curved handle, a frame that was 2m long by 1.25m wide and a net of 2–3m deep (Swan 1880). The netting itself was composed of fiber derived from stinging nettle. The shape of the net and handle were designed for use in the surf. Fishing involved placing the net firmly in the sand while waves broke onto the beach, forcing smelt into the net. As the wave receded, the net was pulled up and turned around, to catch additional smelt in the falling water. These smelt were strung and dried, similar to salmon.

Historical Fishery

Although no sales or catch records exist until 1886, evidence of the popularity of surf smelt as a local delicacy was mentioned frequently prior to this date. Beginning in 1876, Fisheries Inspectors noted “The smelt of this coast is a valuable fish, highly esteemed for the table, and produced in incredible numbers” (Anderson 1880). Based on historical accounts, we assume fishing for smelt has occurred since the settlement of Vancouver in the mid-1800s. There was a lack of export demand for smaller fish species, such as smelt, so catches were used primarily for personal consumption or local demand (Motherwell 1923). The British Columbia smelt fishery was not as commercially important as the Atlantic coast smelt fisheries, especially those in New Brunswick (Kendall 1926).

Current Fisheries

An Integrated Fisheries Management Plan (IFMP) has been initiated for smelt in the Pacific Region (http://www.pac.dfo-mpo.gc.ca/ops/fm/mplans/plans02/Smelt02pl.PDF). Currently, there are two fisheries for surf smelt in British Columbia, a recreational fishery and a commercial one. Recreational fishing for surf smelt has increased significantly over the last decade, especially on beaches of the Lower Mainland, rivers of Alberni Inlet, and docks in the Prince Rupert area (C. Nelson, pers. comm.). In Canada, the laws governing foreshore rights provide the public unlimited access to most beaches in British Columbia. Easy access and ample fishing opportunities make gillnetting for surf smelt a popular recreational fishery. Sport smelters will line the more popular sections of south shore Burrard Inlet beaches, including Kitsilano, Jericho, Wreck, and Spanish Banks, every 1.5m on summer evenings with a high tide (D. Levy, pers. comm.).

The recreational fishery is regulated through the ‘British Columbia Tidal Waters Sport Fishing Guide’. All smelt species, excluding eulachon, are classified together. A Tidal

Sport Fishing Licence is required which permits a coastal daily limit of 20kg and a possession limit of 40kg. Permitted gear are dipnets (no restriction on mesh size or frame size) and gillnets (maximum length of 7.5m, mesh size greater than 25mm and less than 50mm) with no maximum on the number of nets fishing at a time. The preferred gear is a 'smelt net' which is 7.5m hung length with a 60mm-mesh depth and a mesh size of 30.2mm. It is common practice for recreational fishermen on the Lower Mainland beaches to 're-rig' the regulation size gillnets after a 'cast' net or string multiple nets together. This allows fishers to harvest spawners further offshore, thereby increasing their catch since smelt school just offshore with only a small percentage coming inshore with each wave cycle to spawn (D. Penttila, pers. comm.).

There are seasonal closures in Statistical Management Areas 28 (Howe Sound and northern shores of Burrard Inlet, including Gambier and Bowen Islands) and 29 (Southern shores of Burrard Inlet, and all mainland beaches south to the Canada–US border) from June 15 to August 15. Recreational fishing is further restricted to four days per week from 8:00am Thursday to 8:00am Monday. The remainder of the week is reserved for commercial fishing. Prior to 1982, Statistical Management Areas 28 and 29 were open seven days a week with a seasonal closure from July 5 to August 5. Both fishery officers and recreational users of the resource established the stricter regulations due to increased fishing pressure and conservation, and salmon by-catch concerns.

There is no harvest log system or creel in place to estimate catches. A creel was conducted in late May–June of 1981 and summarized by Levy (1985). Unfortunately, weaknesses in the sampling design (i.e., multiple surveying of individuals, uneven sampling distribution over time) limit the usefulness of the data collected. There is no data and sparse anecdotal information regarding recreational harvests outside Statistical Management Areas 28 and 29. For example, the commercial surf smelt fishery in Prince Rupert has been closed for several years despite repeated requests to re-open this fishery while a successful recreation fishery operates in this region.

Vessels with a Schedule II Part II Other Species or a Category Z8 smelt licence eligibility can commercially harvest surf smelt in British Columbia. Schedule II species include spiny dogfish, flounder, sole, pacific cod, sturgeon, eulachon, skate, lingcod, tuna, and smelt (all species). The Schedule II privilege is issued in respect of a commercial fishing vessel and any vessel that holds a vessel based licence (e.g., salmon, halibut or groundfish trawl) is authorized to fish for smelt using a gillnet. Currently, approximately 4000 vessels hold Schedule II privileges. Management protocols stipulate that a vessel wishing to harvest Schedule II species make a formal request to the Department of Fisheries and Oceans Canada by variation order. Licence conditions allow for the unlimited capture of smelts by unspecified gillnets but there is a harvest log requirement when fishing for smelt.

The second type of commercial licence for surf smelt in British Columbia is a Category Z8 licence. This is an unlimited entry, person based licence and permits harvest without a vessel using either seine nets (maximum length of 275m and minimum mesh size of 19mm) or gillnets (maximum length of 275m and mesh size between 25 and 50mm). There is no maximum number of licenses issued under this category. Individuals who apply for issuance of a smelt licence also must apply to obtain a Fishers Registration Card (FRC).

The Z8 fishery is closed all year in Statistical Management Areas 0–27 opened only by variation order. A variation order for those areas has not been issued for several years. Statistical Management Areas 28 and 29 are closed June 15 to August 15 due to the same conservation concerns raised by the recreational fishery, and open the remainder of the year Monday 8:00am until Thursday 8:00am (alternate days with the recreational users). All fishers are required to maintain logs of daily harvest operations and submit them to Fisheries and Oceans Canada according to licence conditions. Harvest logs have been collected since 1984 with limited success (see below).

Washington State

Recreational harvest of smelt in Washington State is regulated by the 'Forage Fish Management Plan' that also includes herring, eulachon, and sand lance and encompasses both recreational and commercial fisheries (Washington State Department of Fish and Wildlife 1998). In contrast to Canadian law, in Washington State, foreshore rights belong to the property owner and not the citizen. As a result, there is a lack of suitable access to many known surf smelt spawning beaches and this has resulted in poor knowledge and utilization of the resource as a whole. Conservation concerns stem from proposed shoreline development, not over-utilization of the resource as in British Columbia. Recreational guidelines for surf smelt fall under the category of 'Forage Fish' that also covers Pacific herring, northern anchovy, Pacific sardine and Pacific sand lance. There is a coast-wide possession limit of 4.5kg and due to salmon by-catch concerns, gear is restricted to jig (maximum 3 treble or 9 single hooks) or dipnet (no mesh size restriction, bag frame not to exceed 0.9m). In addition to the recreational fishery, there is a commercial fishery (not regulated by Washington Department of Fish and Wildlife, WDFW) that use primarily drag (beach) seine or dipnet, but other gears include round haul, purse seine, gillnet and otter trawl. This commercial fishery harvests approximately 45mt per year from northern Washington State with most landings from inside Puget Sound (Washington State Department of Fish and Wildlife 1998).

Surf Smelt Fisheries

Historical Catch Records 1886–1981

Various provincial and federal agencies have been responsible for the collection and reporting of surf smelt catch data in British Columbia since 1886 (all sources used in this report). Fishery information from Fisheries Inspectors was reported in Annual Fisheries Reports between 1886 and 1967. Catch and sales information was recorded by Fishery Statistics of Canada between 1920 and 1970. Catch has been reported by British Columbia Catch Statistics based on sales slips submitted to Statistics Canada between 1971 and present. Additional catch data has been reported in various documents including Canada Department of Fisheries (1887–1918), Dominion Bureau of Statistics (1922–1949 and 1952–1972), Department of Fisheries and Environment (1977–1979), Department of Fisheries and Oceans (1980–1982), and Department of the Environment (1972–1973).

Historically, data were recorded as combined “smelt” catches, excluding eulachon for which a distinct fishery existed. Surf smelt were the only targeted smelt species in British Columbia during these fisheries (Hart 1973), thus; we assumed that all reported smelt catch was surf smelt. Therefore, our bias is in overestimating commercial catches since other species might have been classified as “smelt”. Levy (1985) refined existing catch data and suggested smelt catches from Statistical Management Areas 28 and 29 could be confidently identified as surf smelt while those from other management areas could contain additional smelt species. Therefore, for clarity, we present data separately for Statistical Management Areas 28 and 29 and those from the entire British Columbia coast. Also, some harvest records were converted to pounds when actual catch estimates reported by harvesters were in pieces. Without having any method of determining which records were piece counts versus weights, we maintained catch data as recorded, in pounds, contributing to potential overestimation of actual catches. We converted imperial measures to metric and all catch data are reported in kilograms. For a few records, the weight unit was ‘unknown’ so we assumed these weights to be pounds since pounds were used more frequently, and we converted these to kilograms.

Current Catch/Sales Records 1984–1999

Since 1984, commercial fishermen (Z8 licence) are required to submit harvest logs to fisheries managers. These logs provide catch data (weight) by area. In addition, when fish are sold, there is a requirement to submit a record of each transaction to the Catch Statistics Branch of Fisheries and Oceans Canada. However, there is no relationship between sales records and harvest logs for the surf smelt fishery. For example, examination of sales records indicated commercial sales to processors but no record of these catches in harvest logs. Similarly, review of harvest logs indicated catches but no record of sales slips were identified.

To estimate total catch for the years 1984 to 1999 harvest logs were reviewed noting date, catch weight, and comments regarding sale of the catch. Sales records also were reviewed and catch records with no licensee information compared to harvest records. To avoid “double-counting” catches, we examined both harvest logs and sales slips for potential overlap. For cases where weight, date, and location were identical between records, overlaps were eliminated. It is not uncommon for catch to be sold one or two days after harvest such that sales slips correspond to multiple harvest logs. Where buyers were indicated in harvest logs, we matched the relevant data in sales records thereby eliminating “overlapping” reports of the same catch.

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 (Table 4, Figure 2). 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 (Table 4, Figure 2; 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 2) but between the 1920s and present, almost the entire catch comes from this area (Figure 2).

There is a clear discrepancy between catch data from sales slips and catch data from harvest logs (Table 5). There is a significant difference between the number of Z8 licenses issued and the number of harvest logs received. Between 1984 and 2001 compliance averaged 37.9%. Thus, the current data collection method makes it impossible to accurately estimate commercial surf smelt catches for British Columbia. Furthermore, there is no method to determine recreational landings for this species. No commercial licenses have been issued for Statistical Management Areas 0–27 since the early 1980s but catches are routinely made in these areas, either via the Schedule II licence, for First Nations food, social, ceremonial (FSC), or illegally (Table 6).

Estimates of Recreational Harvest

Since the current management plan does not estimate recreational harvest, likely a significant portion of surf smelt landings, we provide a working estimate of the recreational harvest using some general assumptions. As with estimating spawning biomass, this is a methodological approach and parameters must be measured to provide reasonable estimates of the recreational harvest. 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, 3:00pm–8:00pm, Saturday and Sunday 8:00am–8:00pm), 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.

Interviews

Formal interviews were conducted with commercial Z8 licence holders from the Lower Mainland of British Columbia to supplement data not included in harvest logs using a standard questionnaire (after Nakashima and Clark 1999; Appendix 2). Five of 25 licence holders contacted agreed to be interviewed. These individuals had different backgrounds and experience in the fishery. Questions were designed to ascertain knowledge about regulations, general trends in catch and effort over time, and comment on the overall state of the surf smelt fishery in the Lower Mainland. Informal interviews were conducted with retired commercial fishermen and Fishery Officers in the Prince Rupert area and with Lower Mainland and GVRD Parks staff.

Surveys provide information on general trends and views but can not be used quantitatively in management decision making. Results suggest enforcement is inadequate, with many users abusing regulations (i.e., illegal gear, fishing during close times, and fishing without a licence). Currently, surf smelt are often captured only for personal consumption; almost none is sold commercially. Individuals purchased commercial licences to avoid competition with recreational fishers rather than to profit from this fishery. Fishers indicated the average length of fish caught was approximately 140mm, with larger fish captured earlier in the season and smaller ones later. Also, there is concern about by-catch, especially juvenile salmon near the Capilano hatchery.

Limitations in manpower have resulted in reduced knowledge of the surf smelt fishery due to decreased monitoring efforts. Fishery Officers in the Lower Mainland make limited observations while the GVRD (no enforcement capability) monitor the fishery in Pacific Spirit Park (Spanish Banks, Wreck Beach) and the University of British Columbia Campus beaches. Fishery Officers confirm serious compliance issues with this fishery, notably 1998 when many charges were laid for fishery violations including multiple gear use, fishing without a licence, and fishing during fishery closures. Fewer complaints and charges have been noted in more recent years. Unfortunately, enforcement opportunities are limited as the surf smelt fishery peaks during evening hours when Fishery Officers and park staff are off duty.

Discussion

Burrard Inlet

Due to current commercial and recreational fisheries in Burrard Inlet, management of this stock should be a priority. This stock has decreased dramatically since its peak in the early 1900s with landings of only 51kg in 2000 (Figure 1; Table 4). 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. This is one of the management issues outlined in the IFMP for surf smelt. 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 (see Appendix 1) 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.

Other Coastal Areas

There is negligible biological and fisheries information available for surf smelt in all other Statistical Management Areas in British Columbia. Thus, sound management decisions cannot be made at the current time. We recommend continued restricted commercial access in these areas until adequate assessments can be made.

Recreational fishing pressure is probably small based on human population concentrations and recreational fishing for surf smelt might be possible. Opportunities exist to collect data from potential commercial users, by providing limited fishing in return. This exchange could benefit both commercial users and scientists if properly implemented (i.e., scientists would have biological data and fishers would have an opportunity to test potential markets for surf smelt) and should be considered for Statistical Management Areas outside of Greater Vancouver where resources are limited.

Recommendations

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.

There is some indication that surf smelt stocks in British Columbia have been declining for four decades and a precautionary management plan should be initiated, especially given inadequate assessment data. Although estimates of spawning biomass and recreational harvest were provided only as working examples, there is some indication that surf smelt are currently being over-harvested in British Columbia. Therefore, we suggest the following recommendations for the current surf smelt fishery.

1. Determine the number of populations of surf smelt in British Columbia. In order to make informed management decisions, genetic studies should be undertaken to determine the amount of gene flow between putative populations in British Columbia given the confined fishing locations (isolated by considerable geographic distance). Also, early studies in Washington State suggested the Puget Sound populations of surf smelt were reproductively isolated.
2. The current surf smelt fishery should be limited given a high probability of overexploitation and limited biological data for surf smelt in British Columbia. Given that current management is based on unlimited entry, the current fishery could rapidly expand with potentially devastating consequences.
3. Develop an assessment program to determine the status of surf smelt in British Columbia, especially with respect to biomass and distribution. Initial data collection should focus on determining baseline data that will need to be interpreted with caution as a fishery is currently in operation.

4. Establish a monitoring program to determine both commercial and recreational harvest of surf smelt in British Columbia and any associated by-catch, especially potentially vulnerable species such as juvenile salmon or herring.
5. Establish a long-term program capable of evaluating the effects of harvest strategies on growth and recruitment of surf smelt in British Columbia. This would be consistent with a “Phase 1” report based on the guidelines of Perry et al. (1999) and could be initiated via a switch to scientific licenses.
6. Consult with various user groups, including First Nations, to determine the expected use and potential interest in surf smelt fisheries in British Columbia. Current effort has focused on the greater Vancouver area, but surf smelt would likely attract interest from other areas in British Columbia, notably Prince Rupert and the West Coast of Vancouver Island.

Acknowledgments

We would like to thank all the participants in the 2002 surf smelt workshop. These individuals prompted meaningful discussions and raised valid fishery concerns that led to the completion of this Phase 0 report. D. Trager assisted with clarification of licence conditions for surf smelt.

References

Anderson, A.C. 1880. Report of the Inspector of Fisheries for British Columbia, for the year 1879. *In* Annual report of the Department of Fisheries, Dominion of Canada, for the year 1879. Queen’s Printer, Ottawa.

Canada Department of Fisheries 1877-1878. Annual report of the Department of Fisheries, Dominion of Canada, for the year [1876-1877]. Queen’s Printer, Ottawa. 2 vols.

Canada Department of Fisheries 1880-1889. Annual report of the Department of Fisheries, Dominion of Canada, for the year [1879-1888]. Queen’s Printer, Ottawa. 10 vols.

Canada Department of Fisheries 1890-1891. Annual report of the Department of Fisheries, Dominion of Canada, for the calendar year [1889-1890]. Queen’s Printer, Ottawa. 2 vols.

Canada Department of Fisheries 1892. Annual report of the Department of Fisheries of the Dominion of Canada, 1891. Queen’s Printer, Ottawa.

Canada Department of Fisheries 1893. Twenty-fifth annual report of the Department of Marine and Fisheries for the fiscal year ended 30th June 1892. Queen’s Printer, Ottawa.

Canada Department of Fisheries 1894-1900. [Twenty-sixth–Thirty-second] annual report of the Department of Marine and Fisheries: Fisheries [1893-1899]. Queen's Printer, Ottawa. 7 vols.

Canada Department of Fisheries 1901-1914. [Thirty-third–Forty-seventh] annual report of the Department of Marine and Fisheries: [1900–1913-14] Fisheries. King's Printer, Ottawa. 14 vols.

Canada Department of Fisheries. 1915-1918. [Forty-eighth–Fifty-first] annual report of the Fisheries Branch, Department of the Naval Service [1914-15–1917]. King's Printer, Ottawa. 4 vols.

Casher, B.J. and Roberts, J.F. 1992. Biophysical surveys of twenty Burrard Inlet shore units utilizing Department of Fisheries and Oceans description and assessment procedures II Map set. Envirowest: 45p.

Department of the Environment 1972. Summary of fishing in British Columbia: [June, Aug, Sep., Dec.] 1972. Queen's Printer, Ottawa. 4 vols.

Department of the Environment 1973. Summary of fishing in British Columbia: [May, June, July, Nov.] 1973. Queen's Printer, Ottawa. 4 vols.

Department of Fisheries and Environment 1977-1979. British Columbia catch statistics [1976-1978]. Queen's Printer, Ottawa. 3 vols.

Department of Fisheries and Oceans 1980-1982. British Columbia catch statistics [1979-1981]. Queen's Printer, Ottawa. 3 vols.

Dominion Bureau of Statistics (Fisheries Division) 1922-1949. Fisheries statistics of Canada [1920-1948]. King's Printer, Ottawa. 29 vols.

Dominion Bureau of Statistics (Fisheries Division) 1952-1972. Fisheries statistics of Canada [1949-1970]. Queen's Printer, Ottawa. 21 vols.

Fisheries and Agriculture Organization. 1995. Precautionary Approach to Fisheries. Part 1: Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions. FAO Fish Tech Paper 350 (1)

Fulton, J., Arai, M.N., and Mason, J.C. 1982. Euphausiids, coelenterates, ctenophores, and other zooplankton from the Canadian Pacific Coast ichthyoplankton survey, 1980. Can. Tech. Rep. Fish. Aquat. Sci.1125: 1-75.

Halladay, A.P. 1917. Report on the fisheries of District No. 1. *In* Fiftieth annual report of the Fisheries Branch, Department of the Naval Service 1916-17. King's Printer, Ottawa. pp. 241-244.

Hart, J.L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Board Can. No. 180.

Hart, J.L., and McHugh, J.L. 1944. The smelts (Osmeridae) of Britsh Columbia. Bull. Fish. Res. Board Can. No. 64.

Hay, D., and McCarter, P.B. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. CSAS Res. Doc. 2000/145.

Jones, R.R. 1999. Haida Names and Utilisation of Common Fish and Marine Mammals. *In* Back to the future, Reconstructing the Hecate Strait Ecosystem. *Edited* by N. Haggan and A Beattie. Fisheries Centre Research Reports 7(3). University of British Columbia Press, Vancouver, BC.

Kendall, W.C. 1926. The Smelts. Fish. Bull. US 42: 217-375.

Kilambi, R.V. 1965. Heterogeneity among three spawning populations of the surf smelt, *Hypomesus pretiosus* (Girard), in the State of Washington. Ph.D. thesis, University of Washington, Seattle, Washington.

Kilambi, R.V., and DeLacy, A.C. 1967. Heterogeneity of surf smelt, *Hypomesus pretiosus* (Girard) in the State of Washington, as judged by incidence of larval *Anisakis* (Nematoda). J. Fish. Res. Board Can. 24: 629-633.

Kilambi, R.V., Utter, F.M., and DeLacy, A.C. 1965. Differentiation of spawning populations of the surf smelt *Hypomesus pretiosus* (Girard) by serological methods. J. Mar. Biol. Assoc. India 7: 364-368.

Levy, D.A. 1985. Biology and management of surf smelt in Burrard Inlet, Vancouver, B.C. Westwater Research Centre Tech. Rep. No. 28.

Levy, D.A. 1990. Sex ratio variation in surf smelt, Hypomesus pretiosus, gillnet catches due to differences in mesh size. J. Fish. Biol. 37: 493-494.

Loosanoff, V.L. 1937. The spawning run of the Pacific surf smelt, *Hypomesus pretiosus* (Girard). Int. Rev. Gesamten Hydrobiol. 36: 170-183.

McAllister, D.E. 1963. A revision of the smelt family, Osmeridae. Bull. Nat. Mus. Can. No. 191 (Biol. Series No. 71).

McNab, J. 1892. Annual Report on the Fisheries of British Columbia for the year 1891. *In* Annual report of the Department of Fisheries of the Dominion of Canada, 1891. Queen’s Printer, Ottawa.

McNab, J. 1898. Annual Report on the Fisheries of British Columbia for the year 1897. *In* Thirty-First Annual report of the Department of Marine and Fisheries: Fisheries 1898. Queen's Printer, Ottawa.

Motherwell, M.J.A. 1922. Report of the Chief Inspector, M.J.A. Motherwell, Western Fisheries Division (British Columbia), for 1921. *In* Fifty-fifth report of the Fisheries Branch, Department of Marine and Fisheries for the year 1921-22. King's Printer, Ottawa. pp. 47-55.

Motherwell, M.J.A. 1923. Report of Chief Inspector, Major J.A. Motherwell, Western Fisheries Division (British Columbia) for 1922. *In* Fifty-sixth annual report of the Fisheries Branch, Department of Marine and Fisheries for the year 1922. King's Printer, Ottawa. pp. 44-60.

Moulton, L.L. and Penttila, D.E. 2001. San Juan County forage fish assessment project: forage fish spawning distribution in San Juan County and protocols for sampling intertidal and nearshore regions: final report. San Juan County Marine Resources Committee.

Mowat, T. 1887. Annual Report on the Fisheries of British Columbia for the year 1886. *In* Annual Report of the Department of Fisheries, Dominion of Canada, for the year 1886. Queen's Printer, Ottawa.

Mowat, T. 1887. Appendix to Mr. Thomas Mowat's report, with remarks on the deep sea fisheries, fishing grounds, harbours, etc., of the coast of British Columbia. *In* Annual report of the Department of Fisheries, Dominion of Canada, for the year 1886. Queen's Printer, Ottawa. pp. 259-269.

Mowat, T. 1888. Annual Report on the Fisheries of British Columbia for the year 1887. *In* Annual Report of the Department of Fisheries, Dominion of Canada, for the year 1887. Queen's Printer, Ottawa.

Mowat, T. 1889. Annual Report on the Fisheries of British Columbia for the year 1887. *In* Annual Report of the Department of Fisheries, Dominion of Canada, for the year 1886. Queen's Printer, Ottawa.

Mowat, T. 1890. Annual Report on the Fisheries of British Columbia for the year 1889. *In* Annual Report of the Department of Fisheries, Dominion of Canada, for the calendar year 1889. Queen's Printer, Ottawa.

Mowat, T. 1891. Annual Report on the Fisheries of British Columbia for the year 1890. *In* Annual Report of the Department of Fisheries, Dominion of Canada, for the calendar year 1890. Queen's Printer, Ottawa.

Nakashima, B.S., and Clark, M.C. 1999. Results of a telephone opinion survey of fixed gear capelin licence holders for 1998. *In* Capelin in SA2 + Div. 3KL. DFO Can. Stock Assess. Sec. Res. Doc. 99/206. pp. 1-37.

Penttila, D. 1978. Studies of the surf smelt (*Hypomesus pretiosus*) in Puget Sound. Wash. Dep. Fish. Tech. Rep. No. 42.

Penttila, D. 1982. The LaConner baitfish sport jig fishery: January 1978 – March 1981. Wash. Dep. Fish. Prog. Rep. No. 176.

Penttila, D.E. 1995. Baitfish Resources and Habitats of Fidalgo Bay, Skagit County, WA. Wash. Dep. Fish. Wildl. Man. Rep.

Penttila, D. 1997. Investigations of intertidal spawning habitats of surf smelt and Pacific sand lance in Puget Sound, Washington. *In* Forage fisheries in marine ecosystems. Univ. Alsk. Sea Grant Program Sea Grant Rep. AK-SG-97-01. pp. 395-407.

Penttila, D. 2001. Documented spawning areas of the Pacific herring, *Clupea*, the surf smelt, *Hypomesus*, and the Pacific sand lance, *Ammodytes*, in Whatcom County, Washington. Wash. Dep. Fish Wildl. Man. Rep.

Perry, R.I., C.J. Walters, and J.A. Boutillier. 1999. A framework for providing scientific advice for the management of new invertebrate species. Reviews in fish Biology and fisheries. 9:125-150

Schaefer, M.B. 1936. Contribution to the life history of the surf smelt (*Hypomesus pretiosus*) in Puget Sound. Wash. Dept. Fish., Biol. Rep. 35B:1-45.

Swan, J.G. 1880. The surf-smelt of the northwest coast, and the method of taking them by the Quillehute Indians, West Coast of Washington Territory. Proc. U.S. Nat. Mus. 3: 43-46.

Sword, C.B. 1903. Annual report on the fisheries of British Columbia for the year 1900. *In* Thirty-Sixth Annual report of the Department of Marine and Fisheries: 1903 Fisheries. King's Printer, Ottawa. pp. 208-219.

Sword, C.B. 1905. Annual report on the fisheries of British Columbia for the year 1903. *In* Thirty-Seventh Annual report of the Department of Marine and Fisheries: 1904 Fisheries. King's Printer, Ottawa. pp. 214-224.

Thompson, W.F., Bell, F.H., Dunlop, H.A., Schultz, L.P., and Van Cleve, R. 1936. The spawning of the silver smelt, *Hypomesus pretiosus*. Ecology 17: 158-168.

Washington State Department of Fish and Wildlife. 1998. Forage fish management plan: a plan for managing the forage fish resources and fisheries of Washington. Olympia, Washington.

Wildermuth, D.A. 1993. Estimates of the recreational harvest and spawn deposition for surf smelt (*Hypomesus pretiosus pretiosus*) at Ross Point, Washington in 1991 and 1992. Wash. Dep. Fish. Wildl. Prog. Rep. 309: 45p.

Whitcher, W.F. 1879. The fisheries of Canada. *In* Supplement no. 4 to the eleventh annual report of the Minister of Marine and Fisheries for the year, 1878. Queen's Printer, Ottawa.

Yap-Chiongco, J.V. 1941. *Hypomesus pretiosus*: its development and early life history. Ph.D. thesis, University of Washington, Seattle, WA.

Yoklavich, M.M., Cailliet, G.M, Barry, J.P., Ambrose, D.A., and Antrim, B.S. 1991. Temporal and spatial patterns in abundance and diversity of fish assemblages in Elkhorn Slough, California. Estuaries 14: 465-480.

Table 1: Seasonal changes in surf smelt spawning abundance as percentage of total fish at a surf smelt spawning beach in LaConner Washington in 1978 (after Penttila 1982).

Fish	June	July	August	September	October
Age-1 male	0.0	0.1	17.1	49.5	56.9
Age-2 male	70.6	77.5	62.6	31.5	30.3
Age-3 male	1.0	0.4	0.2	0.2	0.2
Age-4 male	0.1	0.1	0.1	0.0	0.0
Age-1 female	0.0	0.0	0.2	4.9	3.7
Age-2 female	12.5	11.6	17.4	12.3	7.8
Age-3 female	2.3	1.0	1.7	1.0	0.9
Age-4 female	0.2	0.3	0.5	0.7	0.2
Juvenile	13.4	9.0	0.2	0.0	0.0

Table 2: 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

Table 3: 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

Table 4: Recorded smelt catch data for Statistical Management Areas 28 and 29 (Vancouver area) and all other Statistical Management Areas combined (entire British Columbia coast) between 1886 and 2001. Data from: Mowat 1887-1891; Whitcher 1879; McNab 1892; 1898; Sword 1903; 1905; Canadian Department of Fisheries 1877-1918; Halladay 1917; Dominion Bureau of Statistics 1922-1949; 1952-1972; Department of the Environment 1972-1973; Department of Fisheries and the Environment 1977-1979; Department of Fisheries and Oceans 1980-1982.

Year	Catch (kg)		
	Areas 28 and 29	All Other Areas	Total
1886	6 893	1 724	8 617
1887	62 206	15 551	77 757
1888	2 902	726	3 628
1889	21 361	2 222	23 583
1890	38 889	6 803	45 692
1891	29 932	6 803	36 735
1892	50 612	20 408	71 020
1893	22 676	13 605	36 281
1894	12 653	11 338	23 991
1895	12 698	13 606	26 304
1896	11 338	13 605	24 943
1897	13 605	18 141	31 746
1898	17 007	18 594	35 601
1899	15 873	17 687	33 560
1900	20 408	18 821	39 229
1901	27 211	18 821	46 032
1902	71 655	104 989	176 644
1903	82 794	121 315	204 109
1904	95 238	134 921	230 159
1905	81 633	96 054	177 687
1906	90 703	96 372	187 075
1907	113 379	96 916	210 295
1908	90 703	83 401	174 104
1909	113 379	29 342	142 721
1910	N/A	N/A	N/A
1911	114 739	58 957	173 696
1912	84 535	64 082	148 617
1913	83 220	16 100	99 320
1914	79 683	17 233	96 916
1915	104 444	10 431	114 875
1916	74 150	9 025	83 175
1917	42 231	10 558	52 789
1918	N/A	N/A	N/A
1919	N/A	N/A	N/A

1920	56 508	5 669	62 177
1921	72 517	9 887	82 404
1922	14 286	3 855	18 141
1923	45 215	1 769	46 984
1924	47 075	4 626	51 701
1925	30 476	4 898	35 374
1926	51 610	6 485	58 095
1927	43 356	6 712	50 068
1928	30 249	5 216	35 465
1929	27 528	4 218	31 746
1930	60 091	5 895	65 986
1931	63 039	8 208	71 247
1932	40 408	6 667	47 075
1933	18 322	4 762	23 084
1934	43 175	2 766	45 941
1935	41 315	3 129	44 444
1936	35 011	3 946	38 957
1937	15 102	2 358	17 460
1938	31 655	1 769	33 424
1939	20 272	1 860	22 132
1940	37 868	499	38 367
1941	31 111	0	31 111
1942	7 211	0	7 211
1943	1 995	0	1 995
1944	11 156	0	11 156
1945	19 048	0	19 048
1946	34 467	998	35 465
1947	26 485	6 622	33 107
1948	20 317	5 080	25 397
1949	48 980	12 244	61 224
1950	42 812	10 703	53 515
1951	61 315	15 329	76 644
1952	34 104	8 526	42 630
1953	7 256	0	7 256
1954	5 896	453	6 349
1955	1 361	453	1 814
1956	N/A	N/A	N/A
1957	4 082	0	4 082
1958	2 721	0	2 721
1959	20 862	0	20 862
1960	6 349	0	6 349
1961	3 628	0	3 628
1962	12 336	3 084	15 420
1963	726	181	907
1964	3 991	998	4 989
1965	3 991	998	4 989

1966	2 902	726	3 628
1967	2 177	544	2 721
1968	363	91	454
1969	N/A	N/A	N/A
1970	N/A	N/A	N/A
1971	1 451	363	1 814
1972	1 633	408	2 041
1973	2 268	566	2 834
1974	N/A	N/A	N/A
1975	N/A	N/A	N/A
1976	9 524	453	9 977
1977	6 009	1 020	7 029
1978	1 361	0	1 361
1979	2 748	0	2 748
1980	2 748	0	2 748
1981	707	91	798
1982	2 761	1 730	4 491
1983	3 580	902	4 482
1984	1 690	139	1 829
1985	592	610	1 202
1986	853	147	1 000
1987	2 477	0	2 477
1988	1 578	1 649	3 227
1989	1 440	446	1 886
1990	1 987	175	2 162
1991	1 884	9	1 893
1992	6 340	18	6 358
1993	5 971	144	6 115
1994	5 513	1 552	7 065
1995	4 529	0	4 529
1996	1 976	68	2 044
1997	195	22	217
1998	750	18	768
1999	1 061	0	1 061
2000	51	0	51
2001	N/A	N/A	N/A

Table 5: Commercial landings of surf smelt between 1982 and 2001 in British Columbia and Washington State. Canadian reporting compliance also is shown.

	Total Recorded Catches (kg)			Canadian Compliance		
	Canada		Washington*	Number of Z8 Licences	Number of Harvest Logs	Percent Compliance
Year	Sales Slips	Harvest Logs				
1982	4491	--	40 659	--	--	--
1983	4482	--	28 060	--	--	--
1984	1734	94	41 677	40	3	8
1985	1078	123	41 382	30	3	10
1986	988	12	60 405	34	1	3
1987	1870	597	61 698	44	8	18
1988	1187	2010	72 273	67	17	25
1989	467	1397	45 221	66	22	33
1990	337	1796	27 047	54	22	41
1991	110	1756	32 613	58	26	45
1992	2124	4168	34 278	93	58	62
1993	1504	4542	76 047	120	71	59
1994	3171	3268	107 689	120	46	38
1995	966	3421	71 027	112	48	43
1996	1115	835	77 600	42	18	43
1997	9	215	55 292	23	6	26
1998	131	631	67 924	15	9	60
1999	5	1040	61 789	17	5	29
2000	N/A	55	65 121	16	2	13
2001	N/A	N/A	16 942	25	5	20
Total	16 796	25 960	1 084 741	976	370	38

* M. Stanley, Washington Department of Fish & Wildlife (pers. comm.)

Table 6: Landings of surf smelt between 1982 and 2001 in British Columbia reported by Statistical Management Area. 0) West Coast of Queen Charlotte Islands; 1) North Coast of Queen Charlotte Islands; 2) East Coast of Queen Charlotte Islands; 4) Skeena; 17) Nanaimo; 18) Cowichan; 20) Juan de Fuca; 23) Barkley Sound; 28) Howe Sound; and 29) Fraser River.

	Total Catch (kg)										
Year	0	1	2	4	17	18	20	23	28	29	Total
1982		39		1691			39			2761	4491
1983					163		699		112	3468	4482
1984	96				10	34			254	1436	1829
1985					270			340	434	158	1202
1986					147				164	689	1000
1987									1327	1150	2477
1988	989						660		1188	390	3227
1989	313						132		681	759	1886
1990		175							1512	475	2162
1991	9								1191	693	1893
1992	18								4937	1402	6358
1993	43		95		5				4401	1571	6115
1994	1552								3562	1951	7065
1995									4015	514	4529
1996	68								1904	71	2044
1997				23					195		217
1998				19					704	45	768
1999									1061		1061
2000									51		51
Total	3088	214	95	1732	595	34	1530	340	27694	17534	

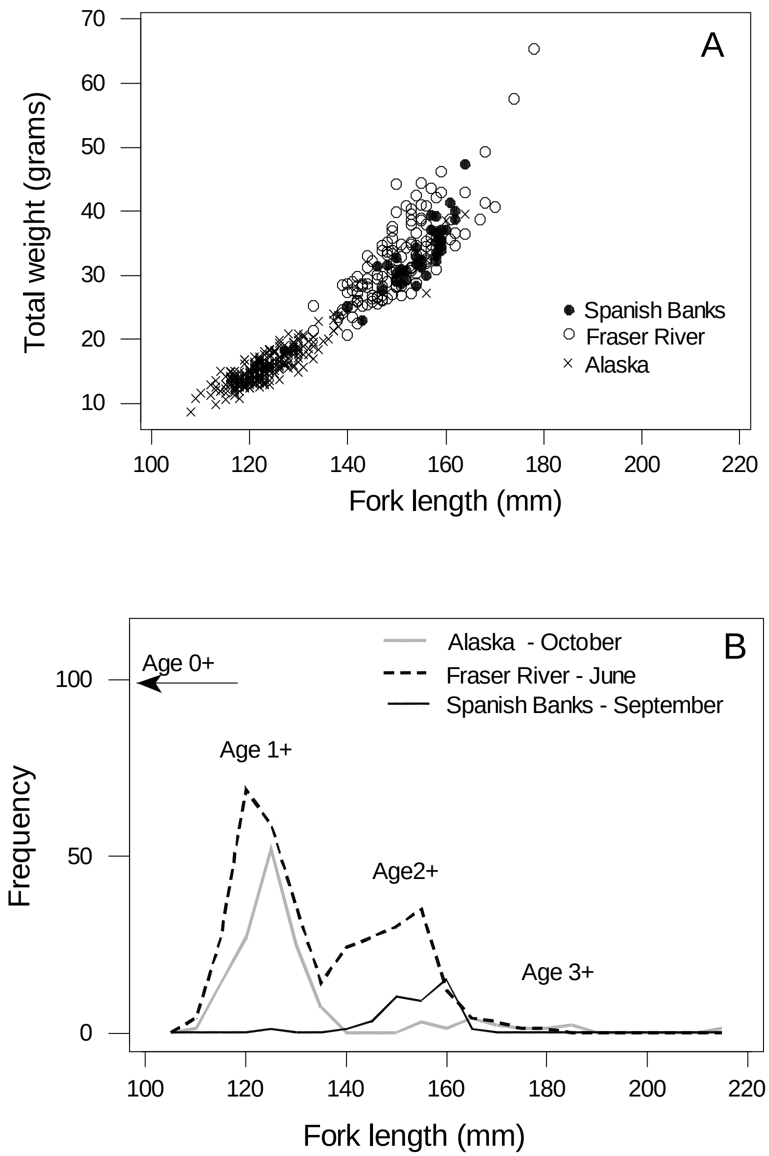

Figure 1: Length-weight relationships between three populations of surf smelt (A) and their corresponding size-frequency distribution (B).

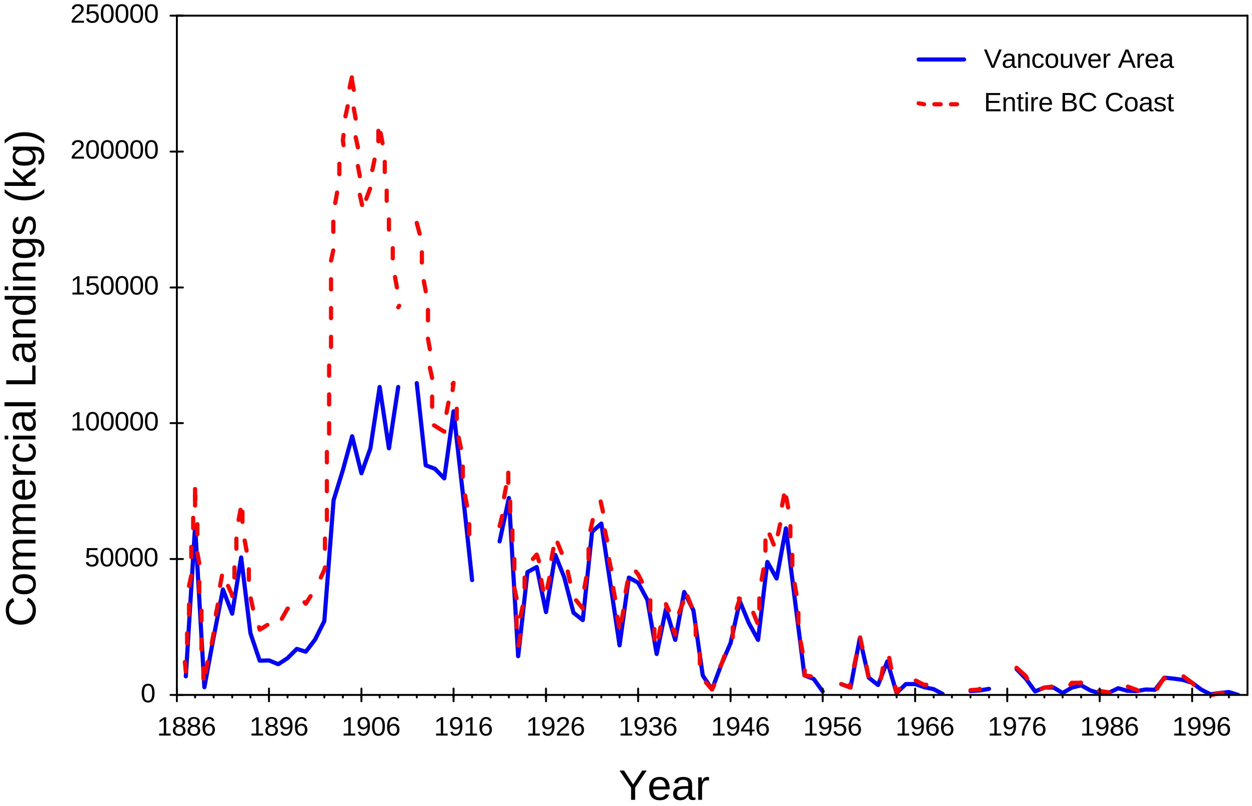

Figure 2: Reported surf smelt catches for Statistical Areas 28 and 29 (Vancouver Area) and for the entire British Columbia coast between 1886 and 2000.

Appendix 1: Protocols for Sampling Intertidal and Nearshore Regions in British Columbia (modified from Penttila 2000 for Washington State).

Objectives

1) To identify and map areas that are being utilized as spawning areas by surf smelt.
2) Collection of bulk egg samples to estimate egg density and spawner biomass.

Note: Planning will need to consider spawning time when designing surveys intended to identify spawning locations.

Site Selection

Not all beaches represent ideal spawning conditions for surf smelt. However, several indicators can be used to effectively predict which sites are most suitable. First, look for sand or gravel (pea sized) with crushed shell fragments. Egg incubation and spawning sites are generally located 2–3m above mean low tide level. Although areas that are protected from direct sunlight are often preferred for spawning, this will not apply to Burrard Inlet beaches, as there is little or no hanging vegetation.

Required Field Equipment

Collection of Samples:

- 250 ml plastic jar
- Extra large freezer bags (sealable)
- Waterproof labels

Condensing Samples:

- Nalgene sediment screens, sizes 4, 2 and .5mm
- 2 X 25L buckets (modified to act as drain for screen rack)
- wash bucket
- plastic dishpan
- 250ml plastic sample jar
- Stockard's solution (50ml formalin (37% formaldehyde), 40ml glacial acetic acid, 60ml glycerin, 850ml distilled water)

Records to Maintain (Completed at Time of Sampling)

Name of beach sampled, date of sampling, Statistical Management Area and Sub-Area, station number, latitude and longitude (if GPS available)

Beach Substrate type:

0–mud
1–sand (<2mm)
2–gravel (2-64mm)
3–cobble (64-256mm)
4–boulder (>256mm)
5–rock, no habitat (>4000mm)

Uplands Character:

1–0% impacted (natural)
2–25% impacted

3–50% impacted
4–75% impacted
5–100% impacted (development, housing, breakwaters)

Sample Zone: Distance of collection parallel to landmark (in m to nearest cm). Used to determine tidal elevation of the spawn deposit.

Landmark for Sample Collection:
1–down beach from the last high tide mark
2–up beach from the last high tide mark
3–down beach from second to the last high tide
4–down beach from upland toe
5–up beach from the waterline at the time noted in comments

Tidal Elevation: To be determined in the lab using data based on landmark, average beach slope, and tidal height.

Width: Width of potential spawning substrate.

Length: Length of potential spawning substrate OR measured from maps if greater than 50m.

Shading: Shading of spawning substrate averaged over the 50m station and best interpretation for the entire day:
1–fully exposed
2–25% shaded
3–50% shaded
4–75% shaded
5–100% shaded

Smelt, sand lance, rock sole, herring: subjective field assessment of spawn intensity:
0–no eggs
1–light
2–light-medium
3–medium
4–medim-heavy
5–heavy
6–very heavy

Comments: Any additional information.

Prepare a map of each location sampled using a 1:20 000 or 1:40 000 scale Canadian Hydrographic Service nautical chart or 1:50 000 scale National Topographic System topographic map. Mark each sample located on the map with the appropriate sample number so that the exact site can be re-visited, if needed. If possible, use a GPS to obtain latitude and longitude of each sampled location, but priority should be placed on an accurate map.

General Guidelines for Collecting Bulk Beach Samples

Examine the beach to evaluate the most likely zone to contain eggs (2–3m MLLW). This zone will be in the upper third of the beach, near the upper tidal limit. Typically, this zone is less than 1m below the log line but for surf smelt eggs it can extend into pure sand. Gravel is the only acceptable substrate for surf smelt.

Each sample is composed of four (4) scoops of gravel evenly spaced along a 50m stretch of beach.

- identify approximately 50m of beach to be sampled
- obtain location information for the transect by reading position information from a GPS or marking the location carefully on the appropriate map
- prepare a sampling label (location, date, time, etc.) and place the label in the collection bag
- starting at one end of the transect, scoop a jar full of sand from the top 2–5cm of beach and dump into the plastic bag. Note: the scooped area will likely be 1–2m long—the idea is to skim the eggs developing in the surface substrate.
- move 15m along the transect and obtain the second scoop of the sample and place in the bag with the previous scoop
- repeat this procedure until the four scoops have been obtained—this constitutes the bulk sample for the transect
- seal the bag securely and place in a cool location (i.e., cooler). This is particularly important in warmer weather since high temperatures can cause mortality and speed the decomposition of eggs
- carefully transport the bulk samples from the field to the laboratory for further examination or proceed with condensing the bulk samples prior to transport depending on time and weather

Condensing Bulk Samples

Bulk egg samples can be processed in the field to remove most of the sand and reduce the volume transported. Eggs are washed from the sediment such that only the eggs (and any residual sediment) are transported to the laboratory. Eggs are lighter than the sand and gravel and will rise to the surface during the washing process, thus allowing the eggs to be skimmed from the surface. Washing is conducted as follows:

- assemble the Nalgene screens on top of the drain bucket, with the largest mesh on top and the smallest mesh on the bottom
- remove the sample label and place it in the sample jar
- place a portion of the bulk sample on the top screen and thoroughly wash the sediment through the screen set with available water
- discard sediment retained in the top screens and retain only material on the bottom (0.5mm) screen
- transfer this material into a dishpan
- add water until the material is covered by 3–5cm of water
- swirl the water around the pan, adding rocking and bouncing motions to allow eggs to migrate to the top of the sediment. The idea is similar to gold panning, try to winnow the eggs to the surface of the material.
- after swirling for 1–2 minutes, work the lighter fraction of material to one corner of the pan. Carefully dry up the lighter fraction by tipping the pan so that excess water drains away and skim the lighter fraction from the surface of the sand with the sample jar.
- repeat the winnowing process two more times

- process the remainder of the bulk sample the same way, each time adding the retained lighter fraction to the sample jar
- fill the sample jar with Stockard's solution and seal the jar securely
- invert several times to ensure that preservative penetrates the entire sample

Laboratory Examination

Laboratory examination begins with a further condensing of the sample. The winnowing process conducted in the field is repeated using a shallow tray to separate eggs and sand. Final separation is performed under a dissecting microscope where eggs can be separated from any remaining beach material using fine-tipped forceps or dissecting needles. Eggs are then identified and counted using available keys.

Eggs found during the surf smelt/Pacific sand lance spawn assessment should be archived for species confirmation and additional analyses. Up to 100 random eggs of each species present should be labeled and preserved in Stockard's solution in a small vial, to be forwarded to DFO staff or other knowledgeable experts for confirmation. A number of non-egg objects may be encountered in preserved upper intertidal substrate samples that may be misidentified as forage fish eggs or empty egg shells, including invertebrate eggs, algal fruiting bodies, flatworms and their egg cases, certain thecate or arenaceous forminifera, decalcified gastropods, and fragments of annelid worm tubes. Relative abundance of all forage fish eggs encountered in the samples should be recorded since this data provides information of the relative frequency and intensity of spawning activities.

Appendix 2: Survey questions for commercial surf smelt licence holders

1. How long have you been fishing for smelt?
2. Have you caught fish with your commercial licence this year?
3. If so, which areas? If not, do you plan on fishing for smelt this year and why?
4. In which areas have you fished for smelt in the past?
5. How successful was each area? Why did you change?
6. Are there any other beaches that you know of where smelt spawn?
7. How late into the year do you fish for smelt and/or notice smelt spawning?
8. Do you fish prior to June 15?
9. Would you fish for smelt if the season were open between June 16 and August 15?
10. How would you describe the abundance of smelt this year/last year compared to when you first started fishing for smelt?
11. If there are changes, how? (size, density, distribution)
12. What gear have you been utilizing? (gillnet or seine)
13. Have you ever used another type of gear?
14. Do you or have you fished from a boat or onshore? Mesh size of net? (*Minimum is 19mm for seine, some may be using larger, ask why if they are. Size range for gillnet is 25mm – 50mm*).
15. Do you fish smelt in order to sell it or for personal use, or both?
16. If you've fished this year, approximately how much have you caught?
17. Approximately how much do you usually catch per year?
18. What is the average size of smelt being caught?
19. When fishing, how many smelt do you return to the water?
20. If yes, what percent of the returned smelt do you think survive?
21. If yes, why were smelt returned?
22. While fishing for smelt, did you catch any other species?
23. If yes, what species were they, and how old were the individuals?
24. If yes, what is the condition of these species when you released them?
25. Do you also fish for smelt using a tidal waters sport fishing licence? Why?
26. If yes, do you use a gillnet or a dipnet? What is the mesh size?

Any other comments: