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Information in Support of a Recovery Potential Assessment of Eulachon (*Thaleichthys pacificus*) in Canada

L'information a l'appui de l'évaluation du potentiel de rétablissement de l'eulakane (*Thaleichthys pacificus*) au Canada

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ABSTRACT

Eulachon (*Thaleichthys pacificus*) are a culturally important, anadromous smelt species that has experienced significant population declines in British Columbia, Canada. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) currently is reviewing the status of eulachon populations in Canada to assess their conservation status but due to the noted population declines, a listing under the *Species at Risk Act* (SARA) is possible. Should eulachon be assessed by COSEWIC as Threatened or Endangered, Fisheries & Oceans Canada (DFO) undertakes a number of actions required under SARA. In advance of potential listings for aquatic species, DFO's standard practice is to conduct a recovery potential assessment (RPA) for the species to help inform the SARA listing process. Thus, this document provides background information on eulachon in Canada in support of a RPA.

RÉSUMÉ

L’eulakane (*Thaleichthys pacificus*) est une espèce d’éperlan anadrome d’importance culturelle ayant connu des déclins démographiques importants en Colombie-Britannique (Canada). À l’heure actuelle, le Comité sur la situation des espèces en péril au Canada (COSEPAC) examine la situation des populations d’eulakane au Canada pour évaluer leur situation de conservation, mais en raison des déclins démographiques indiqués, une inscription en vertu de la *Loi sur les espèces en péril* (LEP) est possible. Dans l’éventualité où le COSEPAC désigne l’eulakane menacée ou en voie de disparition, Pêches et Océans Canada (MPO) prendra un certain nombre de mesures prescrites en vertu de la LEP. En vue de l’inscription éventuelle d’espèces aquatiques, la pratique courante du MPO consiste à réaliser une évaluation du potentiel de rétablissement (EPR) de l’espèce pour servir à éclairer le processus d’inscription sur la liste de la LEP. Le présent document fournit ainsi des renseignements généraux sur l’eulakane au Canada pour appuyer une EPR.

BACKGROUND

This document provides background information on eulachon (*Thaleichthys pacificus*) in Canada in support of a recovery potential assessment (RPA). The completion of an RPA is a standard process used by the Fisheries and Oceans Canada (DFO) for species being considered for listing under the *Species at Risk Act* (SARA) as either Threatened or Endangered. It is anticipated that after eulachon are assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) an RPA specific to each Designatable Unit (DU) will be developed and will reference this document as critical background material. This paper includes existing information relevant to each phase of the revised RPA guidelines (DFO 2007a) and outlines the uncertainties, knowledge gaps and potential future analyses and data collections relevant to DU-specific RPAs that are expected to be developed once the DU structure and status has been decided by COSEWIC.

Information consolidated into this background report originates from both the primary and grey literature (including non-peer reviewed documents) and the collective efforts of many groups including: First Nations, industry, federal and provincial government, consulting companies, and academia. An informal 'Eulachon Research Council' (ERC) was formed in 1995 by DFO and the British Columbia forestry ministry to discuss eulachon research and issues. The ERC members expanded over time and have included participants from DFO, the forest industry, shrimp fishing industry, eulachon commercial fishery, First Nations, fisheries and habitat managers, academia, and non-government agencies. A series of informal meetings were held between 1995 and 2007 in many regions of the British Columbian coast including: Terrace, Kitamaat Village, Vancouver, Bella Coola and Prince Rupert. Many recent scientific reports on eulachon reference information from these meetings. First Nations' participation at these meetings and their traditional ecological knowledge has played an integral part in the collective knowledge and research on eulachon. In 2000 a report was completed that summarized the biology and status of eulachon in British Columbia (Hay and McCarter 2000). Moody (2008) recently completed a thesis on eulachon that synthesized information on the current and past status, fisheries, management and analyzed eulachon relative abundance and decline hypotheses. Subsequent to the ERC meetings there have been science-based workshops to discuss research, impacts, and potential recovery of eulachon. In 2000, DFO asked the Fraser Basin Council to organize and facilitate a forum involving all interests to provide an opportunity for discussion about how sustainability could be enhanced (Fraser Basin Council 2000). In 2007, participants met in Richmond to discuss research priorities and impacts on eulachon (Pickard and Marmorek 2007), and in 2009, participants met in Prince Rupert to review the status of eulachon, cultural importance, threats, and recovery (Murray and Therriault 2010).

SPECIES INFORMATION

Scientific Name – *Thaleichthys pacificus* (Richardson 1836)
Common Names – eulachon, ooligan, oolichan, oolachan, oolachon, olachen, oulachan, hooligan, candlefish
COSEWIC Status – scheduled for assessment in May 2011 (COSEWIC 2010a).
Range in Canada – British Columbia

The eulachon, *Thaleichthys pacificus* (Richardson 1836), is an anadromous fish, meaning they spend most of their life in the marine environment but return to freshwater to spawn. They are endemic to the north-eastern Pacific; distributed from the eastern Bering Sea, Alaska, to northern California. Eulachon is the only species in the genus *Thaleichthys* and is one of 31 smelt species in the Family Osmeridae (Nelson 2006) of which seven, including eulachon, reside in British Columbia (BC). The others include: whitebait smelt (*Allosmerus elongates*), surf smelt (*Hypomesus pretiosus*), capelin (*Mallotus villosus*), rainbow smelt (*Osmerus mordax*), night smelt (*Spirinchus starksi*), and longfin smelt (*Spirinchus thaleichthys*) (Hart 1973).

Morphologically eulachon resemble a small salmon, having an adipose fin and long anal fin, but a smaller head, more slender body, and no fleshy flap at the base of the pelvic fin (Hart and McHugh 1944). They also have distinctive striae on their operculum (Clemens and Wilby 1946). Spawning eulachon are generally no larger than 25cm standard length (SL) and 40-60g in weight. Spawning occurs in the lower reaches of select rivers on the mainland coast (Table 1, Figure 1). Eggs are small (<1.0mm diameter) and have a second ‘sticky’ membrane that anchors them to sediment particles (McHugh 1940, Hay and McCarter 2000). Eggs incubate and hatch in about four weeks at temperatures of 4-5°C, which is typical of most BC rivers (Hay and McCarter 2000). Newly hatched larvae are small (3-6.5mm) and elongated with a distinct yolk sac and oil globule, and are quickly flushed from their natal river into surrounding estuarine waters where they reside for 4-5 months (McCarter and Hay 1999). They then appear to disperse to offshore marine areas where they spend an estimated two years at sea before migrating back to spawn at an estimated three years of age (Hay and McCarter 2000, Clarke et al. 2007).

1. STATUS AND TRENDS

1.1 RANGE

Range includes information on the distribution of each life history stage. Specific locations utilized within this range will be provided in the “Habitat Extent” section (3.2).

1.1.1 <u>Freshwater</u>

1.1.1.1 Adult stage

Mature adult eulachon spawn in 25 known mainland coastal rivers in BC that have been confirmed by the presence of adults and/or eggs and larvae within the river (Table 1, Figure 1). There are potentially 15 other spawning rivers that were identified based anecdotal information and/or the density and lengths of eulachon larvae found in adjacent estuaries or inlets during ichthyoplankton surveys conducted in the Central Coast in 1994 and 1996-1997 (McCarter and Hay 1999). The estimated number of spawning rivers could be higher if the Nass and Skeena tributaries as well as every known river with a record of spawning were included. The upstream portions of the Stikine, Taku and Alsek Rivers in northwestern BC that drain into southeast Alaska are known to have eulachon spawning runs (Willson et al. 2006) and are not included as there are no confirmed reports of eulachon using the upstream BC portions of these rivers.

There are no known confirmed spawning rivers on coastal islands including Haida Gwaii and Vancouver Island (Hay and McCarter 2000). However, there are anecdotal accounts of eulachon spawning in these other areas including: the Nimpkish and Kokish Rivers on the north end of Vancouver Island (Hay and McCarter 2000), the Somass River (in 1955) that drains into the Alberni Inlet on the west coast of Vancouver Island (Hay et al. 1997), and unnamed rivers on Haida Gwaii (Willson et al. 2006). Additional reports have suggested eulachon will sometimes use other mainland rivers as well such as small streams close to Kitimaat Village (J.

Kelson, pers. comm. as cited in Hay and McCarter 2000). Regardless, it remains unclear if these spawning events are valid (correct species identification), ephemeral, or if these rivers once hosted regular runs that have since disappeared (or at least dissipated).

1.1.1.2 Larval stage

The larval stage includes the period after eulachon hatch from the egg and until they leave the ichthyoplankton. Larvae are flushed quickly (within minutes to hours) from rivers after hatching into surrounding estuaries or inlets (Hart and McHugh 1944, Hay et al. 2002). Thus, juvenile eulachon do not use freshwater.

1.1.2 Marine

1.1.2.1 Larval stage

Ichthyoplankton surveys conducted in the Central Coast indicate that larvae are retained in the low salinity surface waters and mix in the plankton after being flushed from their natal rivers (McCarter and Hay 1999). During the first few months after hatching (April to June) they grow from 3-4mm to 30-35mm and disperse from inlets (McCarter et al. 1986, McCarter and Hay 1999). In the Skeena River estuary eulachon remain in brackish waters until they reach 40mm (Metlakatla Fisheries Program and Kelson, pers. comm.). Within their first year they appear to disperse to open marine areas, maybe even after a few months. Some large larvae or small juveniles (12-34mm) have been found off Porcher Island and in the centre of Chatham Sound in plankton tows in July and early August (McCarter et al. 1986). No larval eulachon were captured during similar surveys in May of 1985 and 1986 in nearshore areas around Moresby or Porcher Islands (Hay and McCarter 1991), possibly because the earlier timing of sampling did not allow larvae to disperse to this area.

1.1.2.2 Juvenile stage

The juvenile stage is the period between the larval stage and when eulachon are observed offshore as the first age class (1+ year old). Information on the distribution of the juvenile stage for eulachon is very limited as they are too large to be collected in ichthyoplankton gear and too small to be captured in research surveys or commercial fisheries (Hay and McCarter 2000). Barraclough (1964) summarized data on eulachon distribution from catches in mid-water and shrimp trawl research surveys from the 1950s and 1960s. Eulachon from 17-135mm standard length (SL) were found in the Strait of Georgia and Juan de Fuca Strait in the winter and spring. In contrast, few eulachon have been observed in the shrimp fishery in these regions (Hay et al. 1999). However, the mesh size used in shrimp trawl gear is larger than that of the small experimental mesh used in tows described by Barraclough (1964, as cited by Hay and McCarter 2000). Juvenile eulachon also have been observed in Barkley Sound (Hay and McCarter 2000).

1.1.2.3 Sub-adult/adult stage

The sub-adult stage includes the period between age-1+ and age-2+. Generally, eulachon are considered adult when they begin their migration back to spawning rivers. Within rivers at age-3 mature eulachon spawn. Information on eulachon distribution in marine waters is based on relatively small, incidental catches from offshore research surveys directed at groundfish (1963-present), herring (1963-1999), and shrimp (1973-present). These surveys illustrate that eulachon occur within waters of the continental shelf along edges of offshore banks of Dixon

Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island (Figure 2). Largest catches occurred during the research surveys directed at herring when mid-water trawl nets were fishing close to the sea floor and off the west coast of Vancouver Island. A large catch of 1,173 kg of eulachon was captured during a 19 minute tow on the Swiftsure Bank on July 11, 1969 (Taylor 1970). An analysis of depth from these surveys indicates most were caught around 100m, however some were found near the surface and as deep as 420m. The maximum and minimum depths are uncertain due to limitations of the sampling, as eulachon may have been entrained in the nets either on deployment or recovery (Hay and McCarter 2000).

Eulachon catch records were extracted from all groundfish trawl surveys from the GFBio database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC) on August 31, 2010. An analysis of all eulachon catches in all groundfish trawl surveys indicates an average catch depth of 168m, with the shallowest catch record at 33m and deepest at 453m. An analysis of the Hecate Strait Species Assemblage Survey indicated an increase in the proportion of the survey area where eulachon were found over time, from the beginning of the survey in 1984 to a maximum spatial coverage in 2003 (Sinclair et al. 2007). Most catches were between 100m and 150m in depth; the highest catches occurred at the Two Peaks area, at the northeast edge of Hecate Strait near Dundas Island. Sinclair at al. (2007) calculated a relative biomass index for eulachon, which was higher at the end of the survey, and concluded the increased spatial distribution of eulachon during this time was likely related to an increase in biomass.

Eulachon found in these offshore marine areas are believed to be approximately 1 and 2 years old, based on length frequencies corresponding to a bimodal distribution (Hay and McCarter 2000, Figure 3). Eulachon presence in both bottom trawls and mid-water trawls fishing close to the bottom indicate eulachon occupy near benthic habitats during this phase of their life history. There is inter-annual variation in the spatial distribution and density of eulachon off the west coast of Vancouver Island, determined from an analysis of survey catches in multispecies small mesh bottom trawl surveys on the west coast of Vancouver Island (Hay et al. 1997).

1.2 POPULATION STRUCTURE

Five different methods have been investigated to identify eulachon stock structure and were summarized by Hay and Beacham (2005). They included: 1) life history characteristics (semelparity, distribution and spawn timing); 2) larval surveys; 3) meristic analyses; 4) chemical and elemental analyses of otoliths, and 5) genetics.

1.2.1 Life History Characteristics

There is geographic variation in spawn timing over the entire eulachon range with the northern rivers in Alaska having the latest spawn timing in June and the most southern runs in California and the Columbia River having the earliest, in late January. However, there is unexplained variation within this range. The Fraser River has one of the latest spawning runs (April/May) (Ricker et al. 1954) while most BC rivers support spawning runs in March (Table 2).

1.2.2 Larval Surveys

Some rivers share common estuaries where eulachon larvae may mix from different river sources. For example, ichthyoplankton surveys in Gardner Canal had small newly hatched larvae from the nearby Kemano or Kowesas Rivers and much larger larvae likely from the more distant Kitilope River. Mixing likely occurs between larvae originating from the Kimsquit and

Bella Coola Rivers as well as from many rivers in Johnstone Strait (McCarter and Hay 1999). It is unlikely that eulachon could home precisely to their natal river in these instances, as their duration in their natal rivers is relatively short and imprinting would have to occur quickly. In comparison, most salmon have a longer residency time as alevins within the riverbed and are relatively larger with presumably more biological capacity (larger tissue and sensory organs) to imprint. It is more likely that eulachon could imprint to the estuary in which they reside for much longer. However, the possibly that eulachon home to their natal rivers and imprint while within the river can not be ruled out. For these reasons, Hay and McCarter (2000) proposed that the smallest stock unit for eulachon may be the estuary in which one or more rivers drain. This would result in 16 groupings of adjacent spawning rivers in BC.

1.2.3 Meristic analysis

Analyses of inter-population differences in vertebral number were conducted for the Columbia River and its tributaries (DeLacy and Batts 1963) and BC rivers (Hart and McHugh 1944). The data were combined and re-analyzed by Hay and McCarter (2000) who determined no differences between the Columbia and Fraser Rivers but significant differences between these and the Nass, Knight-Kingcome and Rivers Inlet populations as originally determined by Hart and McHugh (1944). Inter-annual differences within the Fraser River were not significant but were small and significant within the Columbia River. Mean vertebral numbers were higher in northern rivers, which is consistent with trends for clinal increases of meristic series with latitude (Lindsey 1962). Tanning (1952) showed that meristic series vary as a function of temperature and that variation in vertebral number can be environmentally induced. Both late spawning Fraser River eulachon and early spawning Columbia River eulachon incubate in warmer temperatures compared to the northern spawning rivers. These results suggest that mixing of eulachon in offshore waters is not so great among all populations to obscure real differences in vertebral number (Hay and McCarter 2000).

1.2.4 Chemical and elemental analyses

Chemical and elemental analyses of otoliths were conducted by Carolsfeld and Hay (1998) (studies summarized by Hay and McCarter 2000). The study assumes that there are distinctive elemental compositions of estuarine waters close to spawning areas that leave a distinct signature on the otolith. Unfortunately, results were not conclusive due to instrumentation error. However, there was evidence of differences in otolith chemical composition among the following areas: north coast (Kitimat, Kemano and Kowesas Rivers); central coast (Klinaklini and Franklin Rivers); and the Fraser River.

1.2.5 Genetic analyses

Initial genetic studies based on mitochondrial DNA (mtDNA) determined that populations were weakly sub-divided and essentially a large single stock. There was, however, genetic differentiation among the most geographically separated populations (McLean et al. 1999). McLean and Taylor (2001) conducted the first microsatellite DNA study with 5 loci and identified more genetic differentiation than observed with mtDNA, but overall arrived at the same conclusion of little apparent genetic variation among eulachon populations. Beacham et al. (2005) examined eulachon variation using 14 microsatellite loci from populations collected from the following nine rivers: Columbia, Cowlitz (Washington); Fraser, Klinaklini, Bella Coola, Kemano, Skeena, Nass (British Columbia), and Twenty-mile (Alaska) and found genetic differentiation among rivers and an isolation by distance relationship. Recent genetic analysis in Alaska (Flannery et al. 2009) used the same 14 microsatellite loci as Beacham et al. (2005) and found the same isolation by distance relationship. However, within regions there was less fine scale genetic differentiation compared to BC rivers. These results are supported by post-glacial recolonization from a Pacific refuge in the Columbia River. Eulachon likely underwent a northward range expansion following deglaciation and the older southern population would have had more time for genetic divergence (Flannery et al. 2009).

There was a lack of temporal stability within three rivers (Nass, Bella Coola and Kemano) that had multiple years of samples; however, differences between regions were greater than divergence among sampling years (Beacham et al. 2005). Further analysis is needed to address whether eulachon have a temporally stable and geographically based fine-scale genetic population structure. Significant differences among rivers corroborate the biological differences noted previously (Hay and Beacham 2005).

Offshore mixed samples also have been analysed for genetic differentiation. Beacham et al. (2005) determined that microsatellite loci variation provided reasonably accurate estimates of stock composition (river specific origin) of eulachon from these samples. Maximum errors for individual populations were about 4%, which is modest and sufficient to allow reliable estimation of the origin of eulachon in mixed-stock samples. Offshore mixed samples were analyzed from: the west coast Vancouver Island, Queen Charlotte Sound, and northern BC (Chatham Sound) (Beacham et al. 2005). The samples from the west coast Vancouver Island consisted mostly of fish from the Fraser and Columbia Rivers; samples from Queen Charlotte Sound consisted of eulachon from all rivers, and the north coast consisted mostly of eulachon from the northern and central coast rivers (Nass, Skeena, Kemano and Bella Coola).

Not all eulachon rivers have had genetic samples taken (Table 1); thus, the baseline is incomplete for the mixed stock samples to be compared against. If eulachon in a mixed sample originate from a river not in the baseline the analysis will fit these fish to a river, but there is no indication when this occurs. Uncertainty around stock identification should be taken into consideration when interpreting results. For example, the mixed stock samples from the north coast contained a small percentage of Fraser River fish, but this may have been an error in the analysis that assigned a fish from an unknown source as it is unlikely, but unclear, that Fraser River fish migrate that far north and were actually part of that sample. The marine distribution of eulachon originating from different spawning rivers is still uncertain but the genetic analysis concludes that eulachon do not mix evenly from all rivers offshore and there is regional structuring of offshore eulachon populations.

1.3 ABUNDANCE

Eulachon river spawning populations have declined considerably throughout most of BC. In the mid 1990’s a sharp decline was observed in the Fraser, Klinaklini, and Columbia Rivers (Hay et al. 1997, Hay and McCarter 2000). In the same year, runs appear to have been lower in the Kemano River (A. Lewis, Triton Consultants, pers. comm.) and the Skeena River (Tom Pendray, DFO, pers. comm.) although there are no quantitative data to document this (as cited in Hay et al. 1997). Declines in other BC rivers were reported later and included: Skeena, Kitimat, Kildala, Kemano/Wahoo, Kowesas, Kitlope, Kimsquit, Kwatna, Dean, Bella Coola, Wannock, Chuckwalla, Kilbella, and Clyak Rivers.

Moody (2008) provided a comprehensive consolidation and review on eulachon status over its entire range. Moody (2008) used a fuzzy expert logic system to create an index of abundance, using similar methods as Cheung et al. (2007), to describe past and present eulachon abundance trends for 15 rivers, 9 of which are in BC: Nass, Skeena, Kitimat, Kemano, Bella

Coola, Wannock, Kingcome, Klinaklini, and Fraser Rivers. Data originated from a variety of sources including quantitative data: 1) First Nation, recreational, and commercial catches; 2) catch-per-unit-effort (CPUE); 3) spawning stock biomass; 4) test fishery catches; 5) larval survey catches, and semi-quantitative data; 6) annual run size report comments; 7) fishing effort comments, and qualitative data; and 8) interviews and local comments. All sources of data available for each river were combined based on designed heuristic rules and by adjusting weighting parameters to estimate the final annual abundance indices. The final index is scaled from 1 to 100 (low to high abundance) that spans different time scales up to 2006, depending on river-specific data. Overall results showed a decline in abundance for most eulachon river systems over the last 20 years, especially those in the most southern range, including the Fraser River. Smaller northern rivers such as the Wannock, Bella Coola and Kitimat Rivers have suffered a more dramatic and long standing period of decline. Details follow on the status of each eulachon river from north to south including abundance trends determined by Moody (2008).

1.3.1 North Coast

1.3.1.1 Bear River

The Bear River, near Stewart at the head of Portland Canal, is suspected to support eulachon runs; no other information is available (B. Stewart, pers. comm.).

1.3.1.2 Nass River

The Nass River supports one of the largest eulachon runs on the BC coast. A commercial fishery existed from 1877 to approximately 1950 and a First Nations fishery is still operating (Moody 2008, Nisga'a Fisheries 2011). Reports for the late 1800s and early 1900s indicate that thousands of tons of eulachon were caught. Moody (2008) cites that Collison (1916) reported that "Indian fishermen land[ed] thousands of tons" of eulachon a year for this time period; Gibson (1992) reported in the early 1840's that "the Tsimshians brought more than 30,000 gallons of oolachan oil to Fort Simpson annually". When Moody's (2008) conversion parameter of 14.1 gallons/ton of fresh eulachon is applied to 30,000 gallons, it equals approximately 2,100 tons of eulachon (Moody 2008). In recent years, the Nisga'a Fisheries and Wildlife Department of the Nisga'a Lisims Government has monitored catches of both the Nisga'a and Tsimshian. LGL Limited has been a technical advisor to the Nisga'a Lisims Government since 1992 (LGL Limited 2011) and catch and effort data have been collected annually since 1997 (Nisga'a Fisheries 2011). River conditions vary year to year between complete ice blockage to ice free and affect access to eulachon catch (Langer et al. 1977, Moody 2008). Today there also is a small catch taken for fresh consumption by local, non-native residents (Moody 2008). Only one biomass estimate has been made for the Nass using data from Orr (1984) where McCarter and Hay (1999) estimated 1780 metric tonnes for the 1983 season.

Moody (2008) concluded that the Nass River eulachon population was stable in recent years.

1.3.1.3 Skeena River

Tributaries that drain into the Skeena known to have eulachon spawning include: the Ecstall, Khyex, Kasiks, and Gitnadoix Rivers and Scotia and Khtada Creeks (Don Roberts as cited in Stoffels 2001). In addition to the Ecstall mainstem, eulachon have been noted spawning in the Exchamsiks, and Mud Creek and Sparkling Creek tributaries (Dave Rolston, Kitsumkalum Fisheries, pers. comm. 2011). Combined First Nations and commercial fishery landings are patchy between 1900 and 1946 and averaged 28t (low of 0.9t in 1935 and high of 136t in 1910) (Parliament of Canada 1900-1916 and Canadian Bureau of Statistics 1917-1976 as cited in NFMS 2010). There have been qualitative reports on eulachon status since then. Experienced eulachon harvesters reported that the run was historically small in magnitude and short-lived (Steve Roberts, Kitsumkalum Band Council pers. comm. as cited in Lewis 1997). Catching eulachon is challenging in part because of the large size of the river, turbidity, and floating ice (Lewis 1997). In 1997 spawning stock biomass was estimated at 3.0t and larval densities were significantly lower than in 1993, which also was significantly lower than 1992 estimates (Pendray 1993, Lewis 1997). Very few eulachon were observed or caught between 1997 and 1999 (Don Roberts, pers. comm. 2006 as cited in Moody 2008). Don Roberts, a Kitsumkalum member, was hired by the Tsimshian Tribal Council in 2000 to monitor the status of Skeena River eulachon. Roberts and his crew conducted plankton tows for the capture of eggs and larvae and set gillnets to capture adults (Moody 2008). In 2000, Roberts reported it was the worst year in 24 years (ERC 2000), 2005 was a good run, but only in comparison to the previous 10 year average and in 2006 there was virtually no run (Moody 2008). In 2008 the run was reported to be very small (Murray and Therriault 2010). In 2010 the run was reported to be the best since 2004 (Baker 2010).

Based solely on reports and interview/local comment information Moody (2008) concluded that the run has fluctuated from medium-high to a low level over the last two decades.

1.3.2 Douglas Channel

1.3.2.1 Kitimat River

Annual First Nations catches ranged between 27.2t and 81.6t from 1969-72 (DFO 1969-1972 as cited in Moody 2008). The run was harvested by the Haisla First Nation until 1972, after which they stopped because the taste was impaired by municipal and industrial effluent discharges, the latter from the Eurocan Pulp and Paper mill (Beak Consultants Ltd 1991 as cited in Pederson et al. 1995). Total spawning biomass was estimated in 1993 at 22.6t or 514,000 individual spawners (Pederson et al. 1995). Dennis Farara, BEAK International (as cited in ERC 2000) reported that the last strong run was in 1991 and from 1992-1996 runs were estimated at half the size of the 1991 run. Therefore, the spawning stock biomass estimate for 1993 may be lower than the longer-term average run size. From 1994-1996 and 1998-2010, eulachon CPUE data was collected by EcoMetrix (formally BEAK International) under investigations commissioned by the Eurocan Pulp and Paper Company (Ecometrix as cited in Moody 2008). From 1994-1996 the estimated abundance ranged from 527,000 to 444,000 individuals and since 1998 between 13,600 and <1000 (EcoMetrix 2006 as cited in Moody 2008). The CPUE was estimated between 50 and 60 fish per 24 hour gill net set from 1994-1996 but since 1998 has been less than 2 fish per 24 hour gill net set (EcoMetrix 2006 as cited in Moody 2008). Based on this data an abrupt decline occurred between 1996 and 1998. From 1998-2000 the run was non-existent (Ferrara 1995 as cited in ERC 2000).

The estimated abundance index declined in the mid 1990’s and has remained at a very low level (Moody 2008).

1.3.2.2 Kildala River

In 2000 a negligible run was reported by the Haisla Fisheries Commission (ERC 2000).

1.3.2.3 Foch Lagoon and Gilttoyees Inlets

These inlets may have eulachon spawning based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1996 (McCarter and Hay 1999).

1.3.3 Gardner Channel

1.3.3.1 Kemano/Wahoo Rivers

The Kemano River and its tributary the Wahoo River converge before draining into Gardner Channel. Annual First Nations fisheries catches averaged 44.3t and ranged between 18.1t and 81.7t from 1969-73 (DFO 1967-1973 as cited in Moody 2008). More recent reports from 1988-2002 indicate an average catch of 57t (range from 32.5t to 146.5t) (Lewis et al. 2002; Lewis and Ganshorn 2004 as cited in Moody 2008). Rio Tinto Aluminum Company of Canada (Alcan) operate a hydroelectric generation facility on the Kemano River. Alcan started the Kemano eulachon monitoring program in 1988. They commissioned Ecofish Research Ltd. to conduct the work and to work cooperatively with the Haisla First Nation to monitor the eulachon fishery (Lewis et al. 2002; Lewis and Ganshorn 2004 as cited in Moody 2008). Eulachon appeared to decline in 1999 when there were no returns and low catches and CPUE were reported between 2000 and 2002; however, in 2003 there was marked improvement in both catches and CPUE. No catches were taken in 2005 and 2006 (Lewis et al. 2002 as cited in Moody 2008). Eulachon were observed in the Kemano River estuary in 2007 but they did not ascend the river (comment made by Ken Hall, member of the Haisla Nation during the Eulachon Crisis Meeting, Bella Coola, 2007 as cited in Moody 2008).

The estimated abundance index remained above a medium level until the late 1990s. A low to medium-low abundance period occurred between 1999 and 2001 followed by a short three year recovery and since then a low level for 2005-2006 (Moody 2008).

1.3.3.2 Kowesas

Low returns were reported in 2000 by the Haisla Fisheries Commission (ERC 2000).

1.3.3.3 Kitilope

Low returns were reported in 2000 by the Haisla Fisheries Commission (ERC 2000).

1.3.4 Princess Royal Channel

1.3.4.1 Khutze and Aaltanhash Rivers

These inlets may have eulachon spawning based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1997 (McCarter and Hay 1999).

1.3.5 Mathieson Channel Area

1.3.5.1 Mussel Inlet

The Kitasoo-Xai'Xais of the village of Klemtu used to harvest eulachon out of the Mussel River, Head of Mussel Inlet, but adults have not been found in harvestable numbers since the late

1980s (Megan Moody, Nuxalk Fisheries, pers. comm. 2011). It is unclear how often the river was checked for runs. In 1997 during ichthyoplankton surveys a single eulachon larvae was found in Mussel Inlet (McCarter and Hay 1999).

1.3.5.2 Kainet or Lard Creek

These rivers may have eulachon spawning based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1997 (McCarter and Hay 1999).

1.3.6 Dean Channel

1.3.6.1 Kimsquit River

No runs were reported in 2000 (ERC 2000).

1.3.6.2 Dean River

No runs were reported in 2000 (ERC 2000).

1.3.6.3 Skowquiltz and Cascade Inlets

These inlets may have eulachon spawning rivers draining into them based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1997 (McCarter and Hay 1999).

1.3.7 Burke Channel

1.3.7.1 Bella Coola River

The average annual First Nations catch between 1944 and 1998 was 15t, however, there were catches as high as 70t (DFO 1944-1989, Tallio and Webber 1998 as cited in Moody 2008). Moody (2008) calculated past eulachon catches from grease production from 1980 to 1998, which filled in gaps in catch statistics records. The Nuxalk community has not conducted a food fishery since 1998 (Moody 2009). Egg and larval surveys have been conducted since 2001 to estimate spawning stock biomass (SSB); no significant runs have been documented during these studies or observed since 1999 (Moody 2008). From 2001-2007 SSB was estimated at less than 160 kg of spawners (Moody 2009).

Moody (2008) determined an overall declining trend in run size from 1945 to 2000 with complete absence in the late 1990s from interview responses of Nuxalk and DFO Fisheries Officer comments. The estimated abundance index began a slow decline in the mid-1970's and remained consistently above the medium level until the mid 1990's where it declined sharply and since 1999 has remained at a very low level (Moody 2008).

Several Bella Coola River tributaries including the Necleetsconay River, Paisla Creek, Noeick River, Taleomy River, and the Asseek River could have eulachon returns but status is unknown.

1.3.7.2 Kwatna River

No runs were reported in 2000 (ERC 2000).

1.3.7.3 Quatlena River

Run status is unknown.

1.3.8 Rivers Inlet Area

The Rivers Inlet area has four known eulachon bearing rivers: the Wannock, Chuckwalla, Kilbella, and Clyak Rivers at the head of Moses Inlet. Since 1997 no eulachon have been caught in the Rivers Inlet area (Moody 2008) and only small runs have been observed (Murray and Therriault 2010). Eulachon larval surveys in Rivers and Smith Inlets estimated the spawning biomass required to produce the numbers of eulachon larvae caught at 4.86t in 1994 and 6.46t in 1997 (McCarter and Hay 1999).

1.3.8.1 Clyak River

The Clyak River was identified as a possible eulachon spawning run from the distribution and size of larval samples taken in Moses Inlet during the ichthyoplankton surveys in 1994 and 1997 (McCarter and Hay 1999). The Clyak River previously had a large run but eulachon have not been observed since the 1940s (Winbourne 2002).

1.3.8.2 Wannock River

First Nation catches reported for 1967-1968 and 1971 were 1.81, 2.27 and 4.54t respectively (DFO 1967-68 and 1971, as cited in Moody 2008). The runs during the early 1960s also were described by the Fisheries Officers as being “sufficient” and “adequate” to meet the needs of the Wuikinuxv (formally Oweekeno) people. Community members interviewed in the 2002 Central Coast eulachon project reported that the Wannock run had been gradually declining since the 1970s (Winbourne 2002 as cited in Moody 2008). There was unanimous agreement amongst the Wuikinuxv that the current returns are at a fraction of historic returns (Berry and Jacob 1998). Moody (2008) reported that the last fishable run was in 1986 (Burrows 2006). According to Frank Johnson (pers. comm. 2007, as cited in Moody 2008) the run has been “poor” since 1994. A study was conducted in 1997 in an attempt to measure spawning biomass, however no eulachon eggs or larvae were found in any of the samples; this observation is consistent with in-field observations of eulachon entering the river mouth only to exit and possibly going to nearby Chuckwalla or Kilbella Rivers to spawn (Berry and Jacob 1998). Berry and Jacob (1998) felt a spawn likely occurred in the Wannock River prior to their sampling as a few juvenile fish suspected to be eulachon were collected in lower river samples. No runs were reported in the Wannock River in 1999 or 2000 (ERC 2000). Larval data from 1999 confirms a low run (<100kg) (Hay and McCarter 2000). The Wuikinuxv Fisheries Department conducted spawner abundance surveys in 2005 and 2006. Only 11 adults were captured in 2005, with an estimated 2,700 adults returning to spawn and in 2006 no adults were captured, although nets were removed early because of requests made by elders, and an estimate of 23,000 adults spawners was calculated based on egg and larval sampling (Burrows cited in Moody 2008).

The estimated annual eulachon index began to decline in the mid 1970s and since 1997 has dropped and remained at a low level (Moody 2008).

1.3.8.3 Kibella and Chuckwalla Rivers

Spawned out eulachon were observed in 1997 and the Wuikinuxv caught approximately 150kg on these rivers combined (Berry and Jacob 1998). Three adults were captured in 2006 in the Kilbella River (Burrows cited in Moody 2008). No runs were observed in 1999 or 2000 (ERC 2000).

1.3.8.4 Hardy Inlet

An unknown river source that drains into Hardy Inlet may have eulachon spawning based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1994 and 1997 (McCarter and Hay 1999).

1.3.8.5 Nekite River

Ichtyoplankton surveys indicated the presence of larvae in Smith Inlet in 1997 that most likely originated from the Nekite River located at the head of the inlet (McCarter and Hay 1999). This is further supported by a single larva found in the Nekite River during plankton tows for the 2002 Bella Coola eulachon study (Winbourne and Dow 2002).

1.3.9 Johnstone Strait

The Johnstone Strait Region has three known eulachon rivers: Kingcome River of Kingcome Inlet and the Klinaklini and Franklin Rivers of Knight Inlet. Ichthyoplankton surveys conducted in 1994 and 1997 estimated the approximate eulachon spawning biomass of the Johnstone Strait Region at 107.43t and 48.28t (McCarter and Hay 1999).

1.3.9.1 Kingcome River

In the early 1900s, the annual combined grease production of Kingcome and Knight Inlets was approximately 1,500 gallons (Curtis 1915 as cited in Moody 2008). Using Moody's (2008) parameter of 14.08 gallons/ton of fresh eulachon the catch equals approximately 100 tonnes of fresh eulachon, which is comparable with years of high catches recorded by DFO (Common Resources Consulting Ltd. 1998). Catch statistics and qualitative information on run size is available from 1943 to 1977 based on DFO records (Common Resources Consulting Ltd. 1998). Most of the catch data is reported for the Knight and Kingcome Inlets combined. When reported separately Kingcome Inlet catches were lower than Knight Inlet ones and were estimated at 10t for 1960 and 1966 (Common Resources Consulting Ltd. 1998). Declines in the run were reported in 1971, as a "very small run", in 1972 there were "light catches" and in 1973 "the population appears to be on the decline" (Common Resources Consulting Ltd. 1998). A spawning stock biomass was estimated in 1997 at a minimum of 14.35t (Berry and Jacob 1998).

Additional anecdotal reports are available and indicate a decline in run size in recent years. In 2000 a poor run was reported (Hay and McCarter 2000). Midori Nicolsen, a member of the Tsawataineuk First Nation and a participant in the Kingcome eulachon fishery, reports an improved run in 2001 and a "good" run in 2002, with approximately 330 gallons of grease produced; 2003 and 2004 were poor and only an average run was seen in 2005 and in 2006 the run was absent and only small returns were seen in 2007 (Moody 2008).

The Kingcome estimated annual eulachon index has fluctuated and from 1992 to 2006 and had periods of low abundance followed by years of medium returns (Moody 2008).

1.3.9.2 Kakweiken River

The Kakweiken River may have eulachon spawning based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1997 (McCarter and Hay 1999).

1.3.9.3 Knight Inlet (Klinaklini and Franklin Rivers)

Eulachon catches ranged between 18 and 90t annually from 1943 to 1977 in Knight Inlet (Common Resources Consulting Ltd. 1998). For the Klinaklini River a spawning stock biomass estimate was made in 1995 at approximately 40t, which according to an elder was thought to be approximately 15% the historic run size (Berry 1996 as cited in Berry and Jacob 1998). In 2000 “very poor returns” were reported (ERC 2000). Over the past few decades, the Klinaklini River has suffered years with low returns, although never a complete failure of the run (Fred Glendale pers. comm. 2007, as cited in Moody 2008). Robert Duncan, a member Da’naxda’xw/Awaetlala and an eulachon fisher witnessed low returns during the 2004 and 2005 seasons (Robert Duncan pers. comm. 2007, as cited in Moody 2008). In 2007, the Klinaklini returns improved and, overall, it appeared to be a “very good run” (Fred Glendale pers. comm. 2007, as cited in Moody 2008). Knight Inlet did not have a good run size in 2008; 2007 was higher (Murray and Therriault 2010). In 2009, spawning stock biomass was estimated at 0.3t for the Franklin River and 6.3t for the Klinaklini River (A. Lewis, pers. comm.).

The estimated annual eulachon index fluctuated between a medium-high and medium-low level from 1938 to 2006. There appears to have been a small decline in the 1970s and a larger decline more recently during the mid 1990s. The abundance trend appears to be improving and was estimated as medium for 2006 (Moody 2008).

1.3.9.4 Stafford and Apple Rivers

The Stafford and Apple Rivers in Loughborough Inlet probably have eulachon spawning based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1997 (McCarter and Hay 1999).

1.3.9.5 Homathko River

The Homathko River of Bute Inlet probably has eulachon spawning based on the presence of larvae found in the surrounding waters during ichthyoplankton surveys in 1997 (McCarter and Hay 1999).

1.3.10 Strait of Georgia

1.3.10.1 Squamish River

A single eulachon was captured in the Squamish River estuary in August 1976 (Levy and Levings 1978). There are references to a spawning run (Hay and McCarter 2000), but no other information is available.

1.3.10.2 Fraser River

The Fraser River once supported the largest commercial eulachon fishery in BC. It began in 1877 (McHugh 1941) and between 1900 and 1996 the catch averaged 60t and ranged from 4t to just over 400t (Figure 6). A portion of the eulachon catch was taken by First Nations and local residents for personal consumption and it is suspected that early records included this source of catch, whereas in later years the commercial catch was recorded separately (McHugh 1941). As with any catch data, it is important to interpret it with caution as catches are affected by many factors including omissions in the data and market demand, which are both factors influencing the Fraser River eulachon fishery (McHugh 1941, Hay et al. 1997). More recently, management has restricted harvest rendering catch data uninformative. However, in years prior to these restrictions, catches can be inferred as minimum estimates of spawning stock biomass.

The Fraser eulachon run has experienced fluctuations in abundance. Concerns were raised by fishermen of a decrease in abundance in 1939 (McHugh 1941), and an investigation of catch records concluded that a decline occurred from 1921 to 1939 (McHugh 1939). First Nations noticed a decline in run since 1952 (ERC 2000). From 1957-1961 the eulachon run failed to return east of Mission and Fisheries Officers expressed concern, which also was voiced by fishermen (DFO 1940-1979 as cited in Moody 2008). In 1994 participation in the commercial eulachon fishery was limited to about 20 participants and many fishers observed the run was low and the fishery was closed mid-season (Hay et al. 2002). This decline initiated monitoring programs within DFO, including the test fishery at New Westminster, which was used as an in-season indicator as well as a post-season perspective on run size and peak spawning time. An egg and larval survey was initiated in order to provide estimates of spawning stock biomass (SSB) (Hay et al. 2003). In general, SSB has been declining since the survey began in 1995 (Figure 7). There have been some large and small scale fluctuations in abundance (above and below an order of magnitude) (Figure 7). In particular, in 1996 a significantly high SSB was recorded, which was concurrent with high numbers of pieces caught in the test fishery (Figure 8). Since 2004 the biomass has only been in the tens of tonnes when it used to be in the hundreds of tonnes and the fluctuations have been smaller in magnitude. In 2010 the SSB reached a historic low of 4t.

Moody (2008) estimated an annual eulachon index that declined in the 1940s, followed by a steady decrease in abundance, with a more drastic decline in the past 15 years, except for the temporary, small increase in 1996.

1.3.11 Marine Environment

An index of eulachon abundance has been estimated annually from multispecies small mesh bottom trawl surveys for two offshore locations off the west coast of Vancouver Island (WCVI) since 1973, for Barkley Sound since 1996, and Queen Charlotte Sound (QCSD) since 1998 (Figure 2, Figure 4a,b, and refer to survey bulletins: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/surveys.htm). These indices suggest inter-annual changes as areas surveyed, survey dates, and capture methods are relatively consistent throughout the time-series. These indices, however, cannot be easily compared with the abundance indices from other eulachon feeding or spawning areas (i.e. WCVI versus QCSD). For the two offshore WCVI areas the indices were relatively low and variable without a clear trend from 1973-1993; then both decreased from 1994-1999. Estimates began in Barkley Sound in 1996 and also were low during this time. All three WCVI area indices increased dramatically from 2001-2003. This same increase was observed in QCSD (Figure 4b). In addition, a relative abundance index was calculated for Hecate Strait from the Hecate Strait Species Assemblage

Survey (Sinclair et al.2007), which also increased during this time period (Figure 4c). All survey areas began to decrease in 2004 and remained low from 2005 to 2009. The WCVI survey areas also remained fairly low during this period but increased gradually in 2009. In 2010, two WCVI indices dropped and one increased slightly. The QCSD index increased significantly in magnitude to the same level as observed in 2002-03.

The WCVI and QCSD multispecies small mesh bottom trawl surveys provide an index of abundance for eulachon for these specific locations, but eulachon can be found outside of these areas (Figure 2) and it is therefore unknown what proportion of the total offshore eulachon population these surveys capture. Noted trend changes in indices could be related to inter-annual changes in eulachon spatial distributions as previously documented (Hay et al. 1997). It also is unclear what proportion of each age class (1+, 2+ and maybe some 3+ year olds) make up the pooled biomass index for each area. The biomass proportions that comprise each age class are difficult to estimate accurately based on length frequency data alone. Small fish may not be measured in their represented proportions due to selectivity and physical damage. Also, growth is highly variable between areas and years and there is uncertainty in the ages of larger fish. Estimates of biomass indices-at-age have been determined in the past and are published in previous shrimp survey bulletins (http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/surveys.htm) but currently are not estimated.

2. LIFE HISTORY PARAMETERS

Many life history parameters have not been quantified for eulachon. See Table 3 for a summary.

There is strong evidence that eulachon are semelparous (die after spawning) in BC. Hay et al. (2002) present three lines of evidence. First, direct observation of dead spawned out carcasses in rivers. However, Barraclough (1964) states that “spent eulachon in good condition caught by trawlers in the Strait of Georgia off the mouth of the Fraser River suggest that eulachon recover after spawning, and may spawn a second time.” This is a vague statement and it is not clear whether these eulachon would have survived and been able to spawn again in a subsequent season. Second, toothless eulachon have only been found in rivers and not at sea. However, in Twenty-mile River, Alaska, a significant proportion of eulachon (84% and 97% of the females and 3% and 32% of the males in 2000 and 2001 respectively) retained their teeth (Spangler et al. 2003). Third, the largest fish are observed only in rivers. Early studies also noted that the outer edge of eulachon scales from the Fraser River had been absorbed creating a distinct margin called a ‘spawning check’. Only one check was observed suggesting that none of the eulachon had spawned in a previous year (McHugh 1939, Hart and McHugh 1944). No spawning checks were observed on the scales of eulachon from the Nass River (Langer et al. 1977) and none on otoliths from the Kemano River (Lewis et al. 2002).

Age determination has not been validated. Common aging techniques including the counting of rings on scales and otoliths has been attempted by McHugh (1939) and Ricker et al. (1954) for the Fraser River and by Smith and Saalfeld (1955) and DeLacy and Batts (1963) for the Columbia River, but the results may not be valid (Hay and McCarter 2000). Results of BC otolith analyses are suspect because length and weight did not increase with age estimations (Hay and McCarter 2000). The best method currently being used to estimate age is size. Length frequency data collected from eulachon observed offshore shows a biomodal distribution that likely corresponds to ages 1 and 2 (Figure 3). Spawning eulachon are the largest recorded size of fish. Together, these two observations indicate that eulachon spawn at age-3 in BC (Hay and McCarter 2000). There is size variation inter-annually as well as among locations. For example, in Barkley Sound eulachon are mainly smaller while further offshore of WCVI they are mainly larger (Hay and McCarter 2000). Investigations are currently underway on exploring the relationship of inter-annual growth with Pacific Decadal Oscillation (PDO) (DFO 2010g; h).

In recent elemental analyses of otoliths Clarke et al. (2007) examined the seasonal oscillations in the ratio of barium (Ba) and calcium (Ca) elements to estimate eulachon age. The number of peaks, indicative of a year spent at sea, increased with latitude suggesting that the age at maturity is older for northern populations. It was determined that only 3 year old fish were observed from the Fraser and Kemano Rivers, while the majority of fish from the Columbia, Skeena, and Cooper Rivers were composed of a single year class of age-2, -3, and -4 years respectively. There was a lack of a strontium (Sr) signal in otoliths of spawners, which also indicates they are semelparous. Repeat spawners would be expected to show a decrease in the Sr to Ca ratio representative of the time they spent in freshwater from previous seasons. The Sr to Ca ratio is higher for fish in the marine environment relative to freshwater (Clarke et al. 2007). The lack of an age validation method hinders other life history parameters from being accurately estimated including age of maturity, proportion mature at age, natural mortality, and life span.

An attempt was made to estimate unfished biomass and recruitment compensation for the Fraser River. A stock reduction analysis was conducted which describes the carrying capacity (or unfished biomass) and productivity (recruitment compensation) of the stock that must have existed to sustain the observed historical catches. However the analysis was inconclusive and has not been published.

3. HABITAT CHARACTERIZATION

The following section provides information on eulachon habitat considerations for recovery as outlined in the RPA guidance for “documenting habitat use for species at risk and quantifying habitat quality” (DFO 2007b). The term ‘habitat’ is used in the manner defined by the *Species at Risk Act* (SARA) for aquatic species as “spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced.” Freshwater and marine habitats also are addressed individually due to the natural separation in habitat use by eulachon during their life history.

3.1 HABITAT REQUIREMENTS

This section outlines the features of the habitat used by eulachon during all their life history stages in both freshwater and marine environments, as well as the mechanisms by which those habitat features play a role in the survivorship or productivity of eulachon, where known.

3.1.1 <u>Freshwater</u>

Eulachon utilize select rivers (Figure 1, Table 1) for spawning, egg incubation, and a brief larval period until they are carried to the estuary/ocean by river flow. Spawning rivers vary in size and physical characteristics; some are large and turbid (e.g., Fraser River) and others are small and clear (e.g., Kemano River) (Hay and McCarter 2000, Hay et al. 2002). They also vary in temperature during the spawning season, from close to 0°C in the Nass River in March, to 6-7°C in the Fraser River in April and May (Langer et al. 1977, Hay et al. 2002). All spawning rivers occur along the coastal mainland and virtually all have glacially or snow-pack fed runoff during a spring freshet (Hay and McCarter 2000). This may be why there are no spawning rivers on coastal islands, including Vancouver Island and Haida Gwaii, which have predominantly fall freshets following rains in November and December (Hay et al. 2002). The absence of eulachon larvae around Vancouver Island, the Strait of Georgia, and Haida Gwaii in April and May during herring larval surveys (Hay and McCarter 1997) supports the conclusion that eulachon spawning is mainly confined to mainland rivers (Hay et al. 1997).

3.1.1.1 Spawning Adults and Eggs

Migration timing and extent – Spawning occurs in a relatively limited extent of each river. Periods of high tides and associated low river discharge have been linked to peaks in eulachon migration for Twenty-mile River, Alaska (Spangler et al. 2003) and the Skeena and Nass Rivers in BC (Lewis 1997), but not the Fraser River (Langer et al. 1977).

Flow – Eulachon spawn in moderate flowing velocities (Smith and Saalfeld 1955). In the Kemano River eulachon preferred water velocities of 0.1 to 0.7m/s (Lewis et al. 2002 as cited in NFMS 2010). In the Fraser River 'mature' eulachon, determined by appearance and release of sperm or eggs in response to light pressure, were found in areas of moderate current speed (<0.6m/s) (Plate 2009). In the Nass River, eggs were not found in tributaries or side-channels with lower percent oxygen, likely from high levels of terrestrial organic input (Langer et al. 1977).

Depth – Most spawning likely occurs in relatively shallow waters (Hay et al. 2002). In the Fraser River the greatest concentrations of eggs were found at approximately 7.6m (McHugh 1940) and 'mature' eulachon were found in depths less than 7m (Plate 2009). In the Nass River, eggs were found in depths less than 4m (Langer et al. 1977). In the Columbia River eggs were found in waters that ranged in depth from 0.1m to over 6.1m (Smith and Saalfield 1955). In the Kemano River eulachon preferred depths between 0.5 and 2.3m, however they used available habitat from 0.2m to over 4m (Lewis et al. 2002 as cited in NFMS 2010).

Eulachon sperm may only be viable for a short period of time so both sexes must synchronize their spawning activities closely (Hay and McCarter 2000). Broadcast spawned eggs are small (<1.0mm diameter) and have a second 'sticky' membrane that anchors them to sediment particles (McHugh 1940, Hay and McCarter 2000).

Sediment – Eulachon appear to prefer clean coarse sand to small gravel sized sediments to lay eggs (McHugh 1940, Smith and Saalfeld 1955, Langer et al. 1977, Samis 1977, Plate 2009). Higher egg mortality has been observed for eggs laid in silt and organic matter when compared to sand and gravel (Langer et al. 1977).

Temperature – Egg incubation is variable and temperature dependent (Smith and Saalfeld 1955). Eggs incubate and hatch in about four weeks at temperatures of 4-5°C, which is typical of most BC rivers (Hay and McCarter 2000).

Salinity – Exposure to salinity causes increased mortality of eggs. Ferrara (1995) showed experimentally that eggs exposed to 22‰ salinity (marine waters) had 100% mortality, a finding consistent with eulachon spawning in freshwater.

3.1.1.2 Larvae

Currently, there is no evidence for retention of larvae within rivers. Due to their small size, most are passively swept downstream as estimated swimming speeds are no more than 0.1m/sec, which is much less than river velocities (Hay et al. 2002). Thus, it appears they are flushed quickly from rivers, likely within 24 hours (McHugh 1940, Hay et al. 2002).

3.1.2 Marine

Nearshore and offshore marine habitats are utilized by eulachon for the majority of their life history (95%) where they spend most of their larval period and juvenile and adult stages.

3.1.2.1 Larvae

After larvae are flushed from their natal rivers they concentrate in the freshwater-seawater interface of the surrounding estuarine waters. Most larvae are present in the low salinity surface layer in the top 15m of the water column and much fewer are found between 20 and 35m (McCarter and Hay 1999). Robinson et al. (1968) determined that almost all eulachon larvae in the Strait of Georgia were distributed in the top 6.5m of the water column, with the greatest density between 1.7 and 3.5m. For an 18-20 week period (April to August) larvae grow from approximately 3-4mm to 30-35mm in nearshore waters (McCarter and Hay 1999). Remaining in the low salinity surface waters of low productivity inlets may provide larvae a refuge from stenohaline predators while they absorb their yolk sacs and develop characteristics they need to survive in the marine environment (McCarter and Hay 1999).

3.1.2.2 Sub-adults/pre-spawning adults

The marine distribution and habitat requirements of eulachon are not well known. Eulachon prey has not been well described or quantified in BC. Eulachon have substantial teeth from several different jaw bones (Hay and McCarter 2000) as well as a relatively low gill raker count (Hart 1973), which suggest they are mainly particulate feeders and require teeth to grab and hold their prey (Hay and McCarter 2000). Low gill raker number indicates that filter-feeding, as seen in herring and other osmerids, may not occur in eulachon (Hay and McCarter 2000) or may be much less important. Stomach contents of eulachon larvae and post-larvae from about 25 to 51mm include phytoplankton, copepod eggs, copepods, mysids, ostracods, barnacle larvae, Cladocera and worm larvae, as well as larvae of their own species (Barraclough 1967a,b,c as cited in Hart 1973).

For offshore eulachon, limited stomach samples have been analyzed but those that have suggest the euphausiid *Thysanoessa spinifera* is their main prey (Hay and McCarter 2000). Barraclough (1964) reports mainly euphausiids were found in the stomachs of juveniles from the "echo scattering layer in coastal waters at various seasons". In Prince William Sound, Alaska, Sturdevant et al. (1999) found that 55-80% of eulachon stomachs from 33-115mm fork length (FL) in autumn of 1994-1996 were empty and the others contained euphausiids and unidentified malacostracans. Another Alaskan study in 2001 sampled 39 eulachon (160-210mm FL) stomachs and found that 10 were empty and the rest included euphausiids and fish as the main food (66% and 14% of the total stomach content weight, respectively). Other prey items from eulachon in Alaska include small invertebrates such as mysids, cumaceans, and hyperiid amphipods (Yang et al. 2006). Smith and Saalfeld (1955) report the only recognizable animals in gut contents were remains of the cumacean, *Cumacea dawsoni*, from 50 eulachon taken during May 1948 near Destruction Island off the coast of Washington.

Eulachon reabsorb their teeth before spawning in BC (Hay and McCarter 2000); therefore, there are no prey requirements in rivers.

3.2 HABITAT EXTENT

Information is provided on the geographic extent and geo-referenced locations of known and potentially important eulachon habitats. There is information, including traditional ecological knowledge, by individual rivers that could be incorporated into future river-specific documents that are expected to be developed. Examples of geographic areas used by eulachon for some rivers are provided below as a first attempt to assemble this information.

3.2.1 Freshwater

3.2.1.1 Fraser River

Direct observation of eulachon in the Fraser River has not been possible due to the muddy nature of the river; however, other methods have been used to determine locations utilized by spawners. Spawning may concentrate on the north side of the Fraser River where most drainages enter the river or in the vicinity of other tributaries as densities of eggs and larvae were found to be higher on the north side of the river versus the middle and south side for locations upriver of New Westminster (Hay et al. 2002).

The furthest eulachon have been recorded to spawn up the Fraser River is Hope (154km east of Vancouver) (DFO 1940-1979 as cited in Moody 2008). McHugh (1940) surveyed approximately 56km of river bottom between New Westminster and the mouth of the Sumas River near Chilliwack using a bottom dredge. Eggs were found between the towns of Mission and Chilliwack; the heaviest concentration of eggs was near Nicomen Island, about 6km upriver of Mission. Eggs were found in varying numbers from there to 1.6km above the mouth of the Sumas River, where the investigation ended. No evidence of spawning was found below the Mission bridge. Samis (1977) surveyed for potential spawning sites from lower Fraser River to Nicomen Slough, upstream of Mission, using a submersible pump and observed the highest concentration of eulachon eggs adjacent to Nicomen Island, as previously reported by McHugh (1940). Samis (1977) observed eulachon eggs at most sampling sites along the North and South Arms and the lower Pitt River in lower numbers than that at Mission, which indicated that these lower Fraser River locations may not be as suitable for spawning. Also, during the freshet some eggs would be carried downstream into areas not utilized for spawning (Samis 1977). Local Fishery Officers indicate many potential eulachon spawning sites exist in the Fraser River channels adjacent to Matsqui, McMillan and Barnston Islands; however these areas had not been positively identified at the time of the study (Samis 1977).

Results from egg and larval surveys conducted from 1995-2002 indicate that spawning primarily occurs in the lower 50km of the river, as far downstream as Deas Island and as far north as Mission (Hay et al. 2002). Long-time residents indicate they do not see eulachon spawning in the locations that were once utilized for spawning in the upper areas of the Fraser River (Hay et al. 2002), possibly due to reduced spawning biomass.

Spawning and egg incubation locations are not static. There are relative differences in egg and larval production between sampling areas in the Fraser River, which indicates inter-annual variation in spawning locations (Hay et al. 2002). For example, in some years most spawning was upriver of New Westminster and in other years most spawning was below in the South Arm, North Arm or both (Hay et al. 2002). Egg incubation is not confined to spawning sites as viable eggs have been found in the water column during ichythoplankton surveys (Pedersen et al. 1995, Hay et al. 2002).

Recent studies have identified migration corridors and potential and historical spawning grounds by sampling spawners (Plate 2009). Acoustic surveys recently have been used to locate aggregations of eulachon in the lower Fraser River (Stables et al. 2005).

3.2.1.2 Skeena River

In the Skeena River, most spawning occurred downstream of Selma Island based on adult and larval eulachon, however the exact location of eulachon spawning and egg incubation were not determined (Lewis 1997). Stoffels (2001) describes the spawning areas and use of tributaries of the Skeena River: “Historically the eulachon spawned as far upstream as the Shames Rivers during large runs (Don Roberts, Terrace, pers. comm.). Currently, an average run will extend upstream to the Kasiks and Gitnadoix Rivers areas. Eulachon spawn in the main stem of the Skeena River, with high value spawning grounds around the lower Skeena River Islands and around the mouth of the Kwinitsa River (D. De Leeuw, MWLAP, pers. comm.). Eulachon also spawn throughout the Ecstall River system, almost up to Johnston Lake and in the Khyex, Scotia, Khtada, Kasiks, Gitnadoix and other tributaries in the vicinity (Don Roberts, pers. comm.).” In 2007 there was a flood that moved the main channel of the Skeena River (Dave Rolston, Kitsumkalum Fisheries, pers. comm.). In 2010 spawning areas were identified in the mainstem of the Skeena River and included four sites below Selma Island: 1) between the boat launch at Kwinitsa Creek and Don’s Cabin across the Skeena River; 2) near km 73.7 of Hwy 16; 3) near Freak Point; and 4) at the mouth of Alder Creek. Another location is located above Selma Island upstream of China Bar to river km 81.5. The highest densities of eggs were found above Selma Island at 2,744,803 eggs/m^2, with eggs in a layer covering 2.5cm in depth (Dave Rolston, Kitsumkalum Fisheries, pers. comm.).

3.2.1.3 Kemano/Wahoo Rivers

In the Kemano River all eggs are found within a one kilometre stretch (Pickard and Marmorek 2007). Eulachon are normally located no further upstream in the Kemano River than river km 2.7, about 1.5km above saltwater, although rarely they have been observed up to river km 4.3 (Lewis et al. 2002). Eulachon spawning is limited to the lower 1.6km of the Wahoo River (Lewis et al. 2002).

3.2.2 Marine

3.2.2.1 Larvae

Oceanographic conditions may dictate the distribution of larvae in nearshore environments. In the Central Coast, where rivers (hence larvae) drain into inlets, they likely are entrained by estuarine circulation (McCarter and Hay 1999). In the Strait of Georgia, larval eulachon may disperse greater distances. Eulachon from 17-30mm SL have been found off Race Rocks in April, which may be attributed to rapid spring flushing of newly hatched larvae from the Fraser River and direct transport by surface water runoff across the Strait (Barraclough 1964), which is supported by lower salinities observed in the surface layer in the southern Strait during spring (Hollister 1960-1962).

3.2.2.2 Juveniles and sub-adults

The distribution of the juvenile stage is unknown. The extent of habitat used by juveniles and adults is described in detail in the "Range" section of this assessment. In general, offshore adult eulachon are found in near benthic habitats mostly from 50 to 200m in depth within waters of the continental shelf along edges of offshore banks of Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island (Figure 2). Genetic evidence indicates regional structuring of eulachon populations offshore, based on individual river stock identification from mixed stock samples (Beacham et al. 2005). The west coast of Vancouver Island consists mostly of fish from the Fraser and Columbia Rivers; Queen Charlotte Sound consists mostly of Central Coast fish and the North Coast mostly eulachon from the northern rivers (Beacham et al. 2005). Catches in the Strait of Georgia are rare and are correlated with spawn timing of the Fraser River Population (Hay and McCarter 2000). Eulachon in Juan de Fuca Strait were observed during fall/winter, which coincides with eulachon migrating into the Strait of Georgia.

3.3 SUPPLY OF HABITAT MEETING DEMANDS

As discussed in the above 'Habitat Extent' section all habitats that eulachon use at each life history stage either are unknown or very poorly known. The habitat services eulachon need or that their habitats provide are unknown. The population size that eulachon could reach in the different habitat types they utilize at different life history stages (habitat 'demand') is unknown. Similarly, the sum of the amount of habitats of each type that are known to exist multiplied by the densities that eulachon could reach in those habitats, if they were to saturate it, also are unknown (habitat 'supply').

3.3.1 Freshwater

It is not known if sufficient freshwater habitat exists for eulachon in BC. Further, this element should be examined on a river by river basis or a DU by DU basis, both beyond the scope of this background document. Further, habitat degradation in some rivers may be more of a concern than others (e.g. point sources of pollution or impacts) and any future changes in habitat could further limit the current supply of habitat that could impede recovery rates in the long term. Also, degraded habitat could impact the resilience of eulachon. Thus, habitat needs to be sufficient in both quality and quantity to support increased returns.

3.3.2 Marine

The habitat eulachon require in the marine environment is not known. However, since eulachon spend approximately 95% of their life in this environment, this appears to be a major knowledge gap.

3.4 HABITAT RESTORATION ADVICE

Since it is unknown if habitat supply is meeting demands for eulachon no advice can be provided on restoration activities for either the freshwater or marine environments.

3.5 HABITAT ALLOCATION ADVICE

In cases where habitat supply is expected to exceed demand when recovery targets are reached, options will be available for designating (or “allocating”) various subsets of the supply as critical habitat (DFO 2007c). Based on information available for eulachon in BC, this is unknown.

3.6 RESIDENCE

Section 2(1) of the SARA defines residence as “a dwelling place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, staging, wintering, feeding or hibernating”. The definition of residence was recently reviewed and an agreement was reached that spawning shoals are not residences based on Environment Canada guidelines on defining residence (EC 2004, DFO 2010a). Residence has been interpreted by DFO as being something constructed by the organism (e.g. a spawning redd) in several recent species RPA’s including: Atlantic salmon (DFO 2009b), spotted gar (Bouvier and Mandrak 2010), lake sturgeon (Cleator et al. 2010) and pugnose shiner (Bouvier et al. 2010).

Eulachon do not have any known dwelling place similar to a den or nest during any part of their life cycle. They are not known to change their physical environment or invest in any structures. Eulachon lay their eggs on the substrate where they attached and are fertilized externally and thus eulachon do not directly interact with their physical environment to construct any habitat features. Since they die after spawning there is no investment of energy into defending the spawning location or young. Therefore, no habitat features meet the SARA definition of residence as interpreted by DFO.

4. OPTIONS FOR POPULATION AND DISTRIBUTION GOALS AND TARGETS

Options for population and distribution targets for recovery are presented in the following section based on DFO guidelines for developing science advice on recovery targets (DFO 2005b, 2010a, 2011). If eulachon are listed as Threatened, Endangered or Extirpated by COSEWIC and subsequently SARA, the selection of specific recovery targets will be done as part of the recovery strategy (DFO 2007a, 2011). Population and distribution targets should be developed for each Designatable Unit (DU) identified by COSEWIC (DFO 2011). However, if there is credible information that suggests the DU may consist of demographically discrete populations, distinct targets can be developed for each one (DFO 2011). In the interim, the following science advice should support the development of specific recovery targets and may be applied to individual DUs after their determination at the upcoming COSEWIC assessment (COSEWIC 2010a).

4.1 POPULATION GOALS AND TARGETS

Quantitative data like the relative abundance of spawning eulachon or qualitative data such as presence/absence of spawning eulachon within rivers is the most useful metric to set recovery targets to evaluate population status and its progress towards a recovery goal. In river estimates are not confounded like mixed stock estimates could be. For example, offshore indices for Queen Charlotte Sound (QCSD) and west coast of Vancouver Island (WCVI) can be used to monitor relative trends in offshore abundance, but can not be used to evaluate in river returns. The offshore indices are not an estimate of total eulachon abundance offshore, as the proportion of the population these surveys capture is unknown. Also, the index to assess the status of the north coast river populations is new and thus the time-series is short and only available post-collapse. Further genetic baseline samples would be needed to refine the spatial distribution and relative proportion of offshore eulachon that return to each river. There is an apparent inconsistency in the magnitude of biomass estimates derived offshore with those derived in-river, something that should be resolved. This is especially noticeable for the Fraser River (Figure 4, Figure 7). Finally, the offshore indices are not temporally correlated with in-river returns. For these reasons it is recommended that offshore abundance indices should not be used to asses individual river population trends at this time.

It is probable that groups of spawning rivers will be delineated as a single DU. It has been suggested that mixing of multiple rivers occurs in some BC estuaries (McCarter and Hay 1999) and these units could be viewed as discrete populations. Further, it is within the purview of COSEWIC to identify DUs that could consist of multiple estuary units (e.g., grouping several Central Coast systems). It is important to recognize that if a river is extirpated within a DU it is a loss to at least part of the distribution of the species and may be accompanied by loss of genetic variability within the species. To evaluate the status of a DU, individual rivers will ultimately still need to be assessed and targets should be set to ensure retention of as much potential population structure and genetic variability as possible.

An **immediate recovery goal** for all eulachon populations could be no significant change to the likelihood of extinction or extirpation. A corresponding target would be to observe in-river returns to rivers that are depleted. This should result in an arrest to the decline or a stable population trajectory.

A **short term recovery goal** would likely be an improvement in population size that would result in a down-listing to either 1) Threatened from Endangered or 2) Special Concern from Threatened. A **long term recovery goal** would result in an improvement in population size to “not at risk”.

4.1.1 Options For Abundance Criteria To Set Population Targets:

Population targets should consider COSEWIC’s criteria for assigning risk to a species. Short term recovery targets that correspond to the short term goals above could include: population attains an abundance greater than or equal to: 1) 50% or 2) 70% of the estimated initial (pre-decline) abundance. These are the biological reference points below which COSEWIC considers the population to be Endangered and Threatened, based on the assumption that eulachon will be assessed under indicator A2 (COSEWIC 2010b): “An observed, estimated, inferred, or suspected reduction in total number of mature individuals over the last 10 years or 3 generations, whichever is longer, where the reduction or its causes may not have ceased or many not be understood or may not be reversible…”

DFO is committed to using the Precautionary Approach in the management of fisheries and it is being considered for use in recovery descriptions and planning (DFO 2005b; 2006). This framework has three stock status zones: Healthy, Cautious, and Critical and two reference points: the Upper Stock Reference (USR) and the Limit Reference Point (LRP) (Figure 9). These reference points could be used as specific short and long term recovery targets to assess where the population currently is and where it would be considered “recovered”. The Removal Reference (RR) is the maximum acceptable removal rate (ratio of all human induced removal to the total exploitable stock size). DFO has circulated a draft “Fisheries Stewardship and Sustainability Checklist” version 1, with suggested proxies for the PA harvest strategy reference points:

“In absence of precautionary reference points and harvest rules, the following reference points should be used as provisional elements to assess the stock in relation to sustainability. These include 80% of the biomass which gives maximum sustainable yield (0.8 B_{MSY}) for the USR and 40% of B_{MSY} as the LRP (0.4 B_{MSY}), and the fishing mortality that gives maximum sustainable yield (F_{MSY}) as the maximum RR. The checklist advocates using a linear increase in the RR from 0 to F_{MSY} when the stock status is between the LRP and the USR”.

A draft of Version 2 of the Checklist is still in the approval process within DFO. In addition, this multi-zoned schematic is very similar to the one employed in the Wild Salmon Policy, although specific thresholds (reference points) likely vary.

Most rivers do not have a consistent abundance monitoring program to evaluate population status. Monitoring programs within rivers are needed to allow current population levels to be evaluated and compared with past trends in order to assess the population’s progress to a recovery goal. Improving abundance monitoring ultimately will identify when recovery has been achieved. Annual larval assessment for a range of rivers was one of the top three research recommendations from the 2007 eulachon workshop (Pickard and Marmorek 2007). This type of survey currently provides an index of spawning stock biomass (SSB) for the Fraser River but the technique would have to be validated before large scale application in other BC eulachon rivers due to significant inter-river differences. Hay and McCarter (1999) suggested in river egg and larval surveys are a good way to estimate spawning stock biomass as there is less variation in vulnerability and catchability of larvae than adults. Further, potential population level impacts of collecting this life history stage is less than pre-spawned adults.

Where enumeration of population abundance is not feasible a qualitative indicator could be used (e.g. run status comments from local fishers, predator abundance, visual observation of run status). For most individual rivers there is not a single abundance measure available to compare the current magnitude of stock size with that before the decline, or it is unknown what pre-decline abundances were. An index would allow for the combination of multiple abundance measures into a single indicator. Moody (2008) developed a scale to describe run status in the Bella Coola system based on run size comments from DFO and using traditional ecological knowledge. Abundance metrics that are available and could be used to evaluate individual river populations and set targets are listed under the ‘information on status’ column in Table 1. Historical catch data could be used as estimates of minimum spawning stock biomass pre-decline for some rivers. These catches are considered minimum because fishers would not have captured all eulachon that spawned in any one year but it remains unknown what proportion of the total spawning stock biomass was fished for each river. It is possible that historical catches for some rivers may be reconstructed through grease production estimates similar to methods employed for the Bella Coola (Moody 2008) but considerable uncertainty would remain in any eulachon population estimation.

4.2 DISTRIBUTION TARGETS

Some rivers have virtually no returning spawning runs including, but not limited to, the Kitimat and Bella Coola Rivers. A long term distribution recovery goal is for all spawning rivers in BC to have self sustaining populations. A corresponding long term distribution recovery target is an increase in all river populations in abundance to meet corresponding population recovery targets.

There is no indication of a change in the marine distribution of eulachon. A reasonable goal would be to maintain the current distribution.

4.3 POPULATION PROJECTIONS

Due to knowledge and data gaps in eulachon life history parameters there are no stock assessment models to project eulachon population trajectories. The carrying capacity and population growth rates of eulachon are not known and suitable proxies have not been identified. Further, due to knowledge gaps, key life history parameters that influence the likelihood and time to recovery are unknown. Insufficient data exists to model the relative effects of various mortality and productivity parameters and the time and likelihood of attaining hypothetical recovery targets.

Specific timescales to achieve abundance and distribution recovery targets can not be provided at this time, as no projections are available on the time required for eulachon populations to grow to higher than current levels. All indicators of eulachon abundance show annual variation that can span an order of magnitude. Eulachon population status should thus only change if it has remained in a different status level for a certain amount of time to determine if the trajectory is stable. Given the relatively short life history of eulachon and their estimated age of maturity at three years, five consecutive years of abundance at a new level or change in trajectory would be appropriate before a population status change should be considered. This would coincide with SARA's timeline of reporting on progress towards meeting recovery strategy objectives every five years.

Populations in the U.S. on the southern border (Washington, Oregon, California) are depleted, which resulted in the southern Distinct Population Segment (DPS), being listed as Threatened under the US Endangered Species Act by the National Marine Fisheries Service (NMFS) in March 2009 (effective May 2009). Details are available at: [http://www.nwr.noaa.gov/Other-Marine- Species/Eulachon.cfm](http://www.nwr.noaa.gov/Other-Marine-Species/Eulachon.cfm). Genetic data indicates mixing of both the Columbia and Fraser River populations off the west coast of Vancouver Island; however, there is still genetic differentiation between these two rivers and even greater differences between these rivers and northern BC populations (Beacham et al. 2005). Therefore, there is little scope for rescue effect from U.S. eulachon populations to the south in consideration of their effect on any management scenarios in Canada or setting recovery goals and targets. There is no information on the linkages of different river populations utilizing habitat and mixing across the Alaska-BC border. It is difficult to determine the potential for rescue from this direction, but Alaska also has reported low returns in some river systems and thus it is appears unlikely a significant rescue effect would be realized.

5. THREATS

The factors that caused the coastwide decline of most BC eulachon populations is unclear as are factors preventing their recovery. All known and potential sources of mortality that have been identified during eulachon meetings and by researchers (Hay and McCarter 2000, ERC 2000, Eulachon Conservation Society 2002, Pickard and Marmorek 2007, Moody 2008, and NMFS 2010) are described. The term 'threat' is used in the context of SARA as defined in the Environment Canada 2007 *Draft Guidelines on Identifying and Mitigating Threats to Species at Risk* (DFO 2010a):

> "as any activity or process (both natural and anthropogenic) that has caused, is causing, or may cause harm, death, or behavioural changes to a species at risk or the destruction, degradation, and/or impairment of its habitat to the extent that population-level effects occur."

It is likely that many threats are impacting eulachon populations, either independently or synergistically. Threats to survival may have changed over time, and threats that are impacting recovery now may not have been responsible for the initial decline. The impact of each of the following threats has not been quantified. For all potential sources of eulachon mortality, the extent of the impact at the population-level is not known as there are limited studies in the literature on threat-specific cause and effect relationships for eulachon. The absolute eulachon population abundance offshore is unknown and quantitative estimates of marine mortality on each population from each potential source of mortality can not be provided. Therefore the term 'threat' may not correctly define each mortality source. The following known and potential sources of mortality are separated by threats to the eulachon and their habitat but are not listed in any particular order.

5.1 THREATS TO INDIVIDUALS

5.1.1 <u>Predation</u>

Eulachon are prey for many predators including fish, marine mammals, and birds. The following list of known predators includes reports from the U.S. on predators that also are present in BC. Predator aggregations occur during the beginning of eulachon runs, and the number of predators is often reported as an indicator of run strength and timing (Collison 1916, Marston et al. 2002). This may be a period of particularly high predation during the eulachon's life history.

In river predators include: White sturgeon (*Acipenser transmontanus*) (Semakula and Larkin 1968), eagles (Marston et al. 2002), Stellar sea lions (*Eumetopias jubatus*) and harbour seals (*Phoca vitulina*) (Jeffries 1984, Olesiuk 1993). Other animals observed in the spawning areas that probably also feed on eulachon include bears (*Ursus* spp.), wolves (*Canis lupus*), mink (*Mustela vison*), river otters (*Lontra canadensis*) and loons (*Gavia* spp) (Marston et al. 2002). Also, salmon (coho salmon *Oncorhynchus kisutch* and Dolly Varden trout *Salvelinus malma*) have been reported to feed on eulachon eggs or larvae within rivers (M. Wipfli pers. comm. as cited in Marston et al. 2002).

In the marine environment fish predators include: dogfish (Jones and Geen 1977), Pacific cod (Westrheim and Harling 1983), Pacific hake (Outram and Haegele 1972, Livingston and Bailey 1985), salmon, lingcod (Barraclough 1964), green sturgeon (*Acipenser medirostris*) (Fry 1979), walleye pollock (*Theragra chalcogramma*) Pacific halibut (*Hippoglossus stenolepis*), sablefish

(*Anoplopoma fimbria*), rougheye rockfish *Sebastes aleutianus*) (Yang and Nelson 2000), and arrowtooth flounder (*Atheresthes stomias*) (Kabata and Forrester 1974, Yang and Nelson 2000). Larval and juvenile eulachon have been reported to be occasional prey of Pacific herring (*Clupea palasii*), surf smelt (*Hypomesus pretiosus*), Pacific sandlance (*Ammodytes hexapterus*), kelp greenling (*Hexagrammos decagrammus*), threespine stickleback (*Gasterosteus aculeatus*), steelhead trout (*Oncorhynchus mykiss*), and chinook (*O. tshawytscha*), sockeye (*O. nerka*), coho (*O. kisutch*), chum (*O. keta*), and pink (*O. gorbuscha*) salmon in the Strait of Georgia (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968). In addition to fish, marine mammal predators include both year round residents: Stellar sea lions (*Eumetopias jubatus*) (Marston et al. 2002), harbour seals, killer whales (*Orcinus orca*), Dall's porpoise (*Phocoenoides dalli*), Harbour porpoise (*Phocoena phocoena*) (Jeffries 1984), Pacific white sided dolphins (*Lagenorhyncus obliquidens*) (Morton 2000) as well as part time visitors: northern fur seal (*Callorhinus ursinus*) (Antonelis and Perez 1984) and humpback whales (*Megaptera novaeangliae*) (Marston et al. 2002). Lastly, predation by birds (also would apply to rivers) can not be ignored with predators including: bald eagles (*Haliaeetus leucocephalus*), gulls, terns (Laridae), ducks (Anatidae), shorebirds (Scolopacidae), Kingfisher (Alcedinidae), raptors (Falconidae) and passerines (Corvidae, Motacillidae, Emberizidae), grebes (*Podiceps* spp), scoters (*Melanitta* spp.), mergansers (*Mergus* spp.) and marbled murrelets (*Brachyrhamphus marmoratus*) (Marston et al. 2002).

There are two main stocks of Pacific hake (*Merluccius productus*) on the BC coast, one in the Strait of Georgia and an offshore migratory stock that is found primarily off the west coast of Vancouver Island (Beamish and McFarlane 1985). In the spring, offshore hake migrate north to feeding areas from northern California to northern BC and return south in the fall to spawn off southern California between December and March (McFarlane and Beamish 1985). Recent spring surveys of the distribution and abundance of hake larvae have detected increasing numbers of larvae off the Oregon and Washington coats since 2003, supporting the hypothesis that hake spawning is occurring much further north than occurred historically (Phillips et al. 2007). In the early 1990s, the biomass of hake in Canadian waters increased from approximately 210,000 tonnes to over 400,000 tonnes as a migratory population from lower latitudes expanded its summer migration route further north (Benson et al. 2002). It appears this range expansion was due to a warm phase of the Pacific Decadal Oscillation (PDO) that resulted in an expanding finger of warm water up the coast of North America (Benson et al. 2002). A diet study off the west coast of Vancouver Island in 1989 found that smelt (both eulachon and whitebait smelt) accounted for approximately 10% by weight of hake diet for all sizes sampled (Buckley and Livingston 1997). However, eulachon is not commonly observed in the stomach contents of hake examined during echo integration-trawl surveys in the 2000s off the coast of BC (John Holmes, DFO, pers. comm.).

Humboldt squid (*Dosidicus gigas*) are important predators throughout their northeastern Pacific range (Rosa and Siebel 2008). Various characteristics of Humboldt squid allow them to have large impacts on marine food webs such as rapid growth, short life spans, ability to travel great distances, extreme adaptability, and generalist feeding habits (Field et al. 2007). Field et al. (2007) found that they consumed mostly forage fish (Pacific hake, northern lampfish (*Stenobrachius leucopsarus*), northern anchovy (*Engraulis mordax*), blue lanternfish (*Tarletonbeania crenularis*), and Pacific sardine (*Sardinops sagax*) as well as some groundfish species (rockfishes, flatfishes), and euphausiids, crustaceans, shrimp and other squid. In 2009 Humboldt squid were more abundant in BC waters than in previous years and were found from July to October to depths of a few hundred meters just seaward of the continental shelf (Crawford and Irvine 2010). Eulachon also have been observed in these locations (Figure 2). It is unknown whether Humboldt squid eat eulachon, but considering that they are opportunistic predators and overlap in time and space with eulachon it is highly probable that they would consume them when intercepted.

Increases in harbour seals in the last 20 years may be having an impact on eulachon abundance. Harbour seals were hunted for pelts between 1913 and 1964, after being protected in 1970 in Canada their populations began to increase. BC populations have been estimated between 9000 and 10,500 individuals in 1970 and 108,000 in 1998 based on aerial counts (Olesiuk 1990, 1999). Most predation from harbour seals would occur when eulachon migrate to inshore waters before spawning.

5.1.2 Environmental Shifts

In 1976/77, there was a well documented shift in the Pacific Decadal Oscillation (PDO) from a cool phase to a warm phase that lasted until the late 1990s (Mantua and Hare 2002, Peterson and Schwing 2003, Litzow 2006). Associated with this atmospheric change were many changes in marine community structure for plankton, fish and marine mammals (Venrick et al. 1987; Francis et al. 1998; McFarlane and Beamish 1992; Clark et al. 1999). Furthermore, Anderson and Piatt (1999) determined there was a change in the Gulf of Alaska from a forage species (shrimp, capelin, etc.) dominated to a higher trophic level (groundfish) dominated system. Specific changes in ocean conditions from this shift include sea surface temperature, freshwater runoff, salinity, pH and sea levels. There is no evidence that any of these factors would affect eulachon populations.

The 1976/1977 regime shift also was correlated with changes in zooplankton abundance and community composition (Tanasichuk 1998; 1999; Mackas et al. 2001; DFO 2010b). Euphausiids had drastic (up to five-fold) decreases in the early 1990s and were slow to recover (Tanasichuk 1999; Tanasichuk 1998). Eulachon are known to prey on euphausiids, and may even have a preference for *Thysanoessa spinifera* (Hay and McCarter 2000). After the extreme El Nino (ENSO) events in 1992 and 1993, *T. spinifera* started a drastic and persistent decline in adult biomass until at least 1996 (Tanasichuk 1998). At the end of the time series, Tanasichuk (1998) found that the adult biomass was approximately 13% of the same population before the ENSO events. Hake, which also are known to depend on euphausiids (Livingston and Bailey 1985), did not seem to be greatly affected by this change, as neither the importance of euphausiids in their diet, nor the size of euphausiids eaten changed during this period (Tanasichuk 1999). Tanasichuk (1999) suggested that hake may have been largely unaffected due to either a change in distribution, or a change in biomass. Because eulachon are known to be poor swimmers (Marston et al. 2002; B. McCarter, DFO, pers. comm.), it is likely that they would not be able to follow prey as closely as hake, and therefore may be more acutely affected by a decrease in prey abundance. This was identified as an important link, but of uncertain magnitude at the 2007 workshop (Pickard and Marmorek 2007).

During the 1990s there was a distinct shift in zooplankton species in the California Current from an assemblage common from 40°N to the Bering Sea to an assemblage dominated by southern species (Mackas et al. 2001). It is thought that southern species are less oil rich than boreal species of zooplankton, and therefore represent a less significant source of nutrition (Pickard and Marmorek 2007). As coldwater zooplankton species became dominant once again from 1999 to 2002 (Pickard and Marmorek 2007), eulachon numbers were seen to spike in various indicators, including the Fraser River larval survey (DFO 2010a), the offshore index (Pickard and Marmorek 2007). This is a relationship that should continue to be investigated in the future to get a better understanding of the interactions between eulachon and zooplankton.

In addition to the regime shifts noted above, climate change and/or climate variability could be impacting eulachon in both freshwater and marine environments by increasing mortality. For example, marine productivity could be changing in the marine environment creating a potential mis-match when juvenile eulachon start to feed. Similarly, changes to river hydrology could be affecting a number of factors including temperature, sedimentation, water flow, etc. Once the DU structure is known for eulachon climate change related effects can be explored in greater detail.

5.1.3 Directed Catch

5.1.3.1 Commercial Fisheries

Recently, directed eulachon commercial fishing has only occurred on the Fraser River. The fishery commenced in 1877 (McHugh 1941) and operated until 1997, with two limited openings in 2002 and 2004 (Figure 6). It has remained closed since 2005 due to conservation concerns (DFO 2010b).

The Nass River once supported a large commercial fishery and some commercial catch statistics have been reported for the Skeena River and Knight and Kingcome Inlets (Common Resource Consulting Ltd. 1998, Moody 2008). Currently, no commercial eulachon fisheries exist in other rivers thus the threat is zero.

5.1.3.2 First Nation Food, Social and Ceremonial (FSC) Fisheries

First Nations fisheries for eulachon once occurred on many rivers (Table 1). Most fisheries for grease have ceased due to declines in runs but it is unclear how much harvest for social or ceremonial purposes continues. It is known that there is limited Food, Social and Ceremonial (FSC) harvest on the Nass and Fraser Rivers, although FSC catches on the Fraser have declined in recent years (Figure 10). Catch data (First Nations, commercial and recreational fisheries) for eulachon over their entire range were collated by Moody (2008) and summarized in the '1.3 Abundance' section in this assessment for each river. However, data on catches and effort is lacking for most First Nations fisheries.

5.1.3.3 Recreational Fisheries

Sport fishing in freshwater systems with nets is prohibited. Specifically for eulachon this includes: dip nets, gillnets, minnow nets and cast nets in freshwater (DFO 2009a). Tidal water recreational harvesting is open for Pacific Fisheries Management Areas (PFMAs) 1 to 5 (North Coast) and 11 to 27 (inshore waters of Vancouver Island) and due to conservation concerns is prohibited in areas 6 to 10 (Central Coast) and 28 and 29 (Fraser River, southern Strait of Georgia and Howe Sound) (DFO 2010d). There is no catch reporting program and thus the data are patchy. Limited records from fisheries officer reports are available for the Fraser River (Figure 10).

5.1.3.4 Research Surveys

Eulachon are observed in the multispecies small mesh bottom trawl surveys (often referred to as "shrimp" surveys) conducted by DFO in both inshore and offshore areas of the coast. Surveys in the inshore waters (Strait of Georgia, Johnstone Strait and Chatham Sound (Figure 2)) are conducted with the Canadian Coast Guard Ship (CCGS) Neocaligus and use an excluder device as part of the sampling gear and therefore only species small enough to pass through the grate are quantified. Surveys in Queen Charlotte Sound (QCSnd) and off the west coast of Vancouver Island (WCVI) (Figure 2) are conducted with the CCGS WE Ricker and do not use an excluder device.

All of the catch is identified to the species level and quantified, additional biological information is collected from a subset of species. For eulachon length/weight and DNA samples are collected. Eulachon biomass indices are calculated annually based on this survey data, for QCSD and WCVI (Figure 4). The relative amount of eulachon removed in these surveys compared to the estimated eulachon biomass is small (Figure 4, Figure 5). The surveys also are limited in time and space, occurring for approximately one week a year for each survey location (refer to survey bulletins: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/surveys.htm).

Eulachon have been caught in many different groundfish fishery independent multispecies research surveys (Table 5). There are four fishery-independent synoptic surveys that together cover the continental shelf and upper slope of most of BC. The first Queen Charlotte Sound survey began in 2003, followed by the West Coast Vancouver Island survey in 2004, the Hecate Strait survey in 2005 and the West Coast of Haida Gwaii survey in 2006 (Olsen et al. 2009). Surveys are conducted on a rotating biennial schedule with the Queen Charlotte Sound and Hecate Strait surveys conducted in odd-numbered years and the West Coast Vancouver Island and Haida Gwaii surveys conducted in even-numbered years (Olsen et al. 2009). All four of these synoptic surveys caught eulachon, however, only an individual tow on the West Coast Haida Gwaii survey in 2006 caught eulachon, and not in measurable numbers. Other surveys that eulachon catches were recorded in measurable numbers (i.e. more than a trace, or enough eulachon was caught to weigh) included: the Hecate Strait Multispecies Assemblage Survey which finished in 2003 and became the new Hecate Strait survey in 2005, Hecate Strait Pacific Cod Monitoring Survey, Hecate Strait Juvenile Flatfish Survey, Goose Island Gully POP Trawl Survey, West Coast Vancouver Island Hake Survey, Hake Stock Delineation, and the Strait Of Georgia Hake Survey. It should be noted that not all historical research surveys have been entered into the electronic system (DFO 2010f) and therefore summaries on historical data are not as complete, particularly pre-1980 (K. Rutherford, DFO, Nanaimo, pers. comm.).

As noted previously, pelagic multispecies surveys caught 9.5 t from 1963-1999.

5.1.4 Indirect Catch

5.1.4.1 Commercial Shrimp Trawl Fishery

The commercial shrimp trawl fishery employs two main gear types: otter and beam trawls. Eulachon are incidentally caught by both these gear types and this is a source of mortality (Hay et al. 1999a, Hay et al. 1999b, Olsen et al. 2000). A bycatch monitoring program was started in 1997 to provide annual estimates of eulachon bycatch and sampling effort but observed coverage ranged from 0.4 to 1.0% for beam trawls and 2.0 to 3.9% for otter trawls making it difficult to quantify eulachon mortality (Hay et al. 1999, Olsen et al. 2000). Further, gear configurations and effort have changed since the publication of these reports rendering initial mortality estimates less useful for the current fishery. Currently, there is no way to accurately determine impacts. Coastwide observer coverage remains a small proportion of total fishing effort (Table 4). Estimates of eulachon bycatch are calculated annually for the west coast of Vancouver Island (WCVI) shrimp management areas (SMAs): 124OFF, 125OFF, 126OFF, 121OFF, 21IN and 23IN (refer to Figure 11, by fisheries managers based on extrapolation of at sea-observer data for these areas (DFO 2010c)). The observer coverage is primarily used by managers to monitor eulachon bycatch in relation to the eulachon action level for the WCVI. This eulachon action level is a maximum eulachon bycatch limit at which point additional management measures may take effect (DFO 2010c). The spatial and temporal coverage of the bycatch sampling program is insufficient to estimate eulachon (and likely total) annual bycatch in the shrimp trawl fishery. Without reliable estimates of eulachon bycatch, the impact of this fishery on eulachon cannot be quantified.

5.1.4.2 Commercial Groundfish Trawl Fishery

Eulachon are incidentally caught in commercial groundfish mid-water and bottom trawl fisheries that now have 100% observer coverage (Figure 12).

5.1.4.3 Escapement Mortality

Mortality could be attributed to eulachon after they have escaped both fishing nets and bycatch reduction devices in the fisheries where they are intercepted, from a variety of factors as described in Broadhurst et al. (2006). The magnitude of this “sieving” impact is unknown.

5.2 THREATS TO HABITAT

In river threats occur at a local scale and vary among spawning rivers. In addition to direct and indirect mortality attributed to fisheries, threats from land and water management identified and discussed at the 2007 workshop included: pollution, dredging, shoreline development and forestry activities.

5.2.1 Pollution

No studies were found that investigated the effects of deleterious contaminants on eulachon.

5.2.1.1 Industrial Pollution

Pollution from industry occurs in the Fraser (Rogers et al. 1990), Kitimat (Mikkelson et al. 1996) and Columbia (Smith and Saalfeld 1955) Rivers. Eulachon may be more susceptible to lipophilic pollutants due to their high concentration of lipid tissue (Rogers et al. 1990) and their return to spawning rivers at times of low water flow, when river effluent concentrations are highest (Beak Consultants Limited 1995). Deleterious substances are discharged into the Fraser River from industrial and municipal effluent, stormwater and spills (Garrett, 1980; Rogers et al. 1986; Birtwell et al. 1988 as cited in Rogers et al. 1990).

Within the Fraser River, Rogers et al. (1990) found the following chemicals in both water and eulachon tissues in the late 1980’s: chlorophenols from wood preservation, chloroguaiacols from pulp processing, DDT compounds from pesticides, and polychlorinated biphenyls (PCBs). PCB concentrations ranged from 130 to 1800ng/g in gonads and the author’s suggested that there may be an impact on spawning success as similar studies conducted for Baltic flounder and herring found PCB concentrations above 120ng/g negatively affected egg hatchability (Von Westernhagen et al. 1981; 1987).

The Fraser River Action Plan was initiated in 1990 to protect the watershed and monitor water and habitat quality (Fraser Basin Council 2004b). As part of that plan, Brewer et al. (1998)

investigated a range of riverbed sediment pollutants and found that the concentration of dioxins, furans, chlorophenolics, PCBs, and certain pesticides had improved since pre-1990 levels. Due to the establishment of management guidelines for these substances, future increases were determined to be unlikely. Some other substances however, namely trace metals, nonylphenol, pesticides in general, and polycyclic aromatic hydrocarbons (PAHs) were seen to persist at similar levels or even increase in some cases. The annual DFO State of the Pacific Ocean publication (Crawford and Irvine 2010) reports on contaminant trends in the Strait of Georgia and indicates that the concentration of flame retardant polybrominated diphenyl ethers (PBDEs) are increasing rapidly in sediment. While the production and import of PBDEs recently has been banned in Canada, they continue to be present in products we import and have been detected in biota.

After the Kitimat pulp mill became operational, local First Nations noticed the fish were tainted and monitoring began. The effluent from the Eurocan Pulp and Paper mill, completed in 1969, was determined to affect the taste of eulachon in 1973 by the Fisheries and Marine Service and in 1975 by the Environmental Protection Service (Beak Consultants Limited 1995). In 1991 Eurocan began conducting tainting evaluations as well as other studies (Beak Consultants Limited 1995). In 1994 one study tested the effect of effluent on egg survival and the results indicated no detrimental effect (Beak Consultants Limited 1995).

Mikkelson et al. (1996) found eulachon tissues from the Kitimat and the Kemano Rivers to contain PCBs, dioxins (PCDDs), and polyaromatic hydrocarbons (PAHs) but there were no differences in these chemicals between fish exposed and not exposed to pulp mill effluent. Exposed fish contained higher levels of sulphur aromatic dibenzothiophene and derivatives, which also occur in oil-based defoamers used in pulp mills. Chloroanisoles (PCA) were present but the source was unknown.

Eulachon have been exposed to pollution within the Fraser and Kitimat Rivers for considerable time before their sharp decline occurred in the mid-1990s. Other rivers with minimal pollution, such as the Kemano, Bella Coola, and Wannock Rivers also have suffered declines. Thus, it may be a contributing factor within rivers but the magnitude is uncertain (Pickard and Marmorek 2007). Also, an incremental generational impact could arise whereby a small reduction in survival may add up over time resulting in either a decline or loss of resilience. This would apply to other sources of mortality due to environmental stressors and needs further investigation.

5.2.1.2 Agricultural Pollutants

Fertilizer and manure runoff, the two main sources of agricultural nutrients, may not be extreme from any one farm, but the combined effect of these nutrients leaching through the groundwater to the river could be problematic (Brisbin 1995). Within the Sumas River watershed, Fraser Valley, between 1986 and 1996 significant increases in agriculture occurred. Both farms and number of animals were linked to increased levels of nitrate, high ammonia and coliform levels, and low dissolved oxygen, particularly during the winter wet season (Berka et al. 2001).

Metals and supplements, such as zinc, cooper and nickel, from livestock feed can leach into the watershed (Schreier et al. 1999). Nickel and zinc were both seen to have increased significantly in streambed sediments since 1974, and both zinc and copper levels were at “heavily polluted” levels as defined by the US EPA (Schreier et al. 1999).

It is uncertain if high concentrations of either nutrients or base metals have a detrimental effect on eulachon. However, the eggs are in direct contact with sediments on the river bottom and could be in contact with some of these substances thus resulting in increased mortality.

5.2.2 Dredging

Dredging removes sediment from a river bed for the purposes of increasing and/or maintaining the depth of water in a navigation channel, for flood and erosion control or for the sale of sediment (FREMP 2005). The Fraser River has been dredged since the 1800s, when the first navigation channel was made (Brós 2007). Tuttey and Morrison (1976) estimated that 17,417 eulachon were entrained in dredging equipment between March 15 and June 4, 1976. It was suggested that the larger impact was entrainment of eggs and larvae when dredging was occurring during the spawning season.

In addition to the direct effects of dredging, indirect effects could include potential changes to river sediment and hydrology. For example, dredging activities could result in changes in flow characteristics and sediment deposition patterns that negatively impact spawning substrates needed by eulachon. Also, changes in flow could alter residence time of the eggs/larvae such that conditions become less suitable for eulachon survival. Additional research would be needed to better understand impacts on eulachon.

5.2.3 Forestry

5.2.3.1 Removal of trees

The Fraser River watershed has been subject to logging, and it was estimated in 2001 that approximately 11.4% of the forested area of the watershed had been heavily disturbed by logging; 2.6% had been lightly disturbed; 2.5% had been cleared, and a further 2.1% was planned to be logged (Rhemtulla et al. 2001). Removal of trees can increase the amount of organic debris (Swanson et al. 1984), as well as the amount of fine sediment (Hall 2008) being washed down the river. The Fraser River naturally has a high sediment load dominated by sand sized grains (Milliman 1980). This benefits eulachon, as they prefer clean coarse sand to small gravel sized sediment grains to attach their eggs (Samis 1977). However, an increase in fine sediments and organic matter, could reduce spawning habitat, and/or increase mortality of eggs as Langer et al. (1977) found in the Nass River where areas with fine silt and organic matter were used much less and had higher egg mortality rates than those of gravel or sand.

5.2.3.2 Log booming/handling

Log booming can impact the river by depositing large amounts of organic debris underneath log handling sites, which could lead to anoxia (Conlan and Ellis 1979). It restricts upstream migration of eulachon, deposits silt and organic matter into the river and it can harm fish when blasting is used to clear river blockages (Langer et al. 1977). The Skeena and Fraser Rivers still have log booms and these could be a concern in these rivers (Pickard and Marmorek 2007). The extent of eulachon spawning underneath log booms or their impact on eulachon in general is unknown (Hay and McCarter 2000). Also, some forestry operations in BC use heli-logging to extract timber and the drop zones for some companies could be in areas of eulachon spawning. However, it is unknown what the impact from this activity would be.

5.2.4 Shoreline Construction

Shoreline construction, including dykes and roads, may decrease accessibility to, and the amount and quality of eulachon spawning habitat. Dykes are structures built either along the side of a riverbank, or in the shallows at the sides of a river to prevent high water levels from spilling out of the river channel and flooding surrounding land. Due to concerns over flooding, dyking in the Fraser River Valley has been extensive (Figure 13). Since the Fraser River Flood Control Program was started in the early 1970s there were 600km of dykes built by 2004 (Fraser Basin Council 2004a), and it is possible many of these areas had eulachon spawning habitat. Eulachon preferentially spawn in moderately flowing water (as discussed in the 'Habitat Requirements' section). Dykes narrow the path of flow which consequently generates strong fast flows through the center of the river (Sandheinrich and Atchinson 1986), thus because eulachon are weak swimmers this could limit their upstream migration and could prematurely wash their eggs/larvae into the ocean (Pickard and Marmorek 2007).

Historical knowledge indicates Highway 16, which runs alongside of the Skeena River, covers prime eulachon spawning habitat (ERC 2000). In other areas the road has isolated back channels removing this spawning habitat from the system (ERC 2000).

Although shoreline construction can significantly alter river hydrology, it is likely other factors can do this as well, including changes related to climate. Although eulachon spend a relatively small percentage of their total life cycle in freshwater (approximately 5%), it is the critical egg/larval stage. Thus, further investigation is required to better understand how dams, dykes, roads and shoreline construction affect the hydrology of the river and how human-mediated changes could be exacerbated by climate related changes (e.g., shift in timing of freshets).

5.2.5 Industrial Development

New industrial developments could contribute to habitat degradation that may affect eulachon in both freshwater and marine habitats. Run-of-the-river (ROR) hydroelectric facilities by Independent Power Producers (IPPs) (http://www.ippbc.com/EN/about_ippbc/; http://www.ippwatch.info/w/) are part of BC's energy policy and may impact flow conditions by diverting water from the mainstem of a river and re-routing it back further downstream. New developments in the Kitimat region include: a LNG liquefaction and export terminal and the Proposed Enbridge Northern Gateway terminal and oil pipeline project that would increased vessel traffic in the region. The risk of potential leaks and spills would increase and the effects have been shown to be detrimental for other species and can persist for a long time.

5.2.6 Euphausiid Fishery

A fishery for krill (several species of euphausiids) has operated in the Strait of Georgia (SOG), mostly around Malaspina Strait and Jervis Inlet since 1983 with a Total Allowable Catch (TAC) of 500 tonnes (DFO 2007d). There are 23 species that have been reported in BC (Jamieson and Francis 1986), which the dominant five species are: *Euphausia pacifica, Thysanoessa spinifera, T. inspinata, T. longipes* and *T. rashii*. *E. pacifica* and accounts for 70 to 100% of the biomass in the SOG where the commercial fishery occurs (Jamieson et al. 1990 as cited in DFO 2007d). The fishery operates from January 5 until the quota is reached or March 31 (which ever is reached first). A mid season fishery can open on request from Aug 16th to Oct 31st and the late season fishery will open Nov 1st and will continue until December 31st or until the quota is achieved (DFO 2007d). These fishery openings do not overlap in space and time with eulachon larvae and thus any potential incidental catch is unlikely.

DFO (2007d, p 3 of their Appendix A) states "The 500 tonne allowable harvest has been estimated to be less than 3% of the annual consumption of euphausiids by all predator species in the Strait of Georgia (Jamieson et al. 1990). The total allowable harvest is less than 0.02% of the estimated biomass in some years. Consequently, the commercial allowable harvest is considered to be conservative and sustainable. It is not clear what proportion of eulachon may stay in the Strait of Georgia from the Fraser and other rivers nearby and if they would prey on the krill species and size class captured in the fishery. There are no estimates on the amount of euphausiids, or composition and size class that eulachon eat. The impact expected on any eulachon that remain in the Strait of Georgia and potentially feed on the euphausiids of the size class caught in the fishery is expected to be minor.

6. MITIGATION AND ALTERNATIVES TO ACTIVITIES

Current and potential sources of eulachon mortality were identified in the above "Threats" section. Existing mitigation measures and potential alternatives to these sources of mortality are listed below. Potential mitigation measures that would decrease the impact of some threats have been inventoried with input from DFO Fisheries Management and Science Branch but the impact of each threat was not quantified nor have current or potential mitigation measures been evaluated for their effectiveness. Once the DU structure for eulachon is known, it will be possible to derive DU-specific mitigation measures to each threat identified for that DU.

6.1 MITIGATION AND ALTERNATIVES TO THREATS TO INDIVIDUALS

6.1.1 <u>Directed Catch</u>

6.1.1.1 <u>Current Mitigation</u>

Fraser River Commercial Fishery

The Eulachon Integrated Fisheries Management Plan (IFMP) provides a planning framework for the conservation and sustainable use of eulachon within the Fraser River, which is the only river where commercial eulachon fishing occurs currently. The following directed fishery provisions, openings and closures for Fraser River eulachon have been listed there annually since 1996. The Fraser River commercial fishery currently is closed for 2011 and has been closed in recent years due to conservation concerns (DFO 2010b; e). A multi-indicator framework was developed by Hay et al. (2003) and revised by Therriault and McCarter (2005) to provide science advice to managers on the stock status of Fraser River eulachon in order to identify potential harvest opportunities. Three pre-season indicators were assessed and include: 1) spawning stock biomass (SSB) from the previous two years, which is the best estimate on stock status (Therriault and McCarter 2005); 2) offshore biomass index from the previous year, and 3) same year catches from the Columbia River. SSB is the main determinant in providing stock status advice and the other two are indicators are provided for consistency. Another in-season indicator, the New Westminster Test Fishery, was used until 2005 when it stopped operating. Hay et al. (2003) and Therriault and McCarter (2005) provide guidelines for management to interpret these indicators of stock status, which are referred to as 'response points'. A year with a SSB lower than 150 tonnes is a cause for concern and removals should be restricted. A low SSB for two or more consecutive years is a conservation concern and all removals should be halted. The last commercial fishing event was in 2004; since then this indicator has been well below the 150 tonne response point.

First Nations Fisheries

First Nations access to eulachon for food, social and ceremonial (FSC) purposes is managed through a communal Aboriginal fishing licence (DFO 2010b). Recently there has been limited access to eulachon on many BC rivers due to conservation concerns and low returns (DFO 2010b). First Nations employ traditional practices that may afford some conservation but the details and efficacy of these methods has not been documented. For DU-specific assessments, additional details will be required.

Recreational Fisheries

Sport fishing in freshwater systems with nets is prohibited. Specifically for eulachon this includes: dip nets, gillnets, minnow nets and cast nets in fresh water (DFO 2009a).

A British Columbia Tidal Waters Sport Fishing Licence is required for the recreational fishing of all species of fish, including eulachon, in marine waters (DFO 2010d). Recreational harvesting is open for Pacific Fisheries Management Areas (PFMAs) 1 to 5 (North Coast) and 11 to 27 (inshore waters of Vancouver Island) and due to conservation concerns is prohibited in areas 6 to 10 (Central Coast) and 28 and 29 (Fraser River, southern Strait of Georgia and Howe Sound) (DFO 2010d). There is a daily limit of 20kg and possession limit of 40kg. Gear requirements include gillnets that do not exceed 7.5m in length and have a mesh size greater than 25mm and less than 50mm (DFO 2010d).

Research Surveys

There are currently no mitigation measures as eulachon catches in research surveys are directed.

6.1.1.2 <u>Potential Mitigation</u>

Fraser River Commercial Fishery

If the precautionary approach (PA) and draft Fisheries Stewardship and Sustainability Checklist (FSSC) provisional guidelines are applied to the spawning stock biomass (SSB), as discussed earlier in the 'Options for Population and Distribution Targets' section, the current response point of 150 tonnes would fall into the critical zone. This indicates that the population is at high risk of serious or irreversible harm to stock productivity and exploitation rates should be as low as possible, with no directed fisheries and practical bycatch reduction measures in place (DFO 2005a, 2006). Other similar frameworks such as the one outlined in the Wild Salmon Policy also should be explored and potential reference points among different models compared to determine if the current response points for the Fraser River stock are valid. The adoption of a science-based conservation framework is needed to ensure that if the stock does rebound in the future that it is not immediately reopened to fishing.

First Nations Fisheries

Restrictions, closures and/or traditional methods for conservation (e.g., fishing on spawned out individuals, using traditional fishing gears and methods) could be explored with First Nations as options for conserving spawning eulachon.

Recreational Fisheries

Recreational catches are not required to be reported to DFO and thus the amount of eulachon caught recreationally is unknown. Closing the currently open areas (PFMAs 1 to 5 and 11 to 27) could be considered.

6.1.2 Indirect Catch

6.1.2.1 Current Mitigation

Shrimp Trawl Fishery

The following steps have been taken by the shrimp trawl fishery and DFO Fisheries Management to mitigate the impacts of incidental eulachon catches. Detailed descriptions are reported annually in both the Eulachon and Shrimp Integrated Fishery Management Plans (IFMPs) and are summarized below (DFO 2010b; c).

1) Implementation of Eulachon Action Levels (EAL) by DFO management for the shrimp trawl fishery off the west coast of Vancouver Island (WCVI) shrimp management areas (SMAs): 124OFF, 125OFF, 126OFF, 121OFF, 21IN and 23IN (refer to Figure 11).
    a. The EAL is set for the present year at 1% of the eulachon biomass index estimated during the multispecies small mesh bottom trawl survey for the WCVI from the previous year to a maximum of 20 tonnes combined for SMAs 124OFF and 125OFF and 20 tonnes combined for 23OFF, 21OFF and 23IN. The EAL may be adjusted in season based on 1% of the eulachon biomass index from the present year small mesh multispecies survey (DFO 2010c).
    b. A bycatch monitoring program was initiated in 1997. Estimates of eulachon bycatch are calculated annually for the WCVI shrimp management areas: 124OFF, 125OFF, 126OFF, 121OFF, 21IN and 23IN, by fisheries managers based on extrapolation of at sea-observer data for these areas (DFO 2010c). The observer coverage is primarily used by managers to monitor eulachon bycatch in relation to the EAL for the WCVI. The amount of observer coverage coastwide has been variable and very low since the program began in 1997 (Table 4) and varies regionally depending on shrimp trawl effort and management goals.
    c. If the by-catch estimate reaches the EAL further management actions may be implemented which could include: closure of the shrimp trawl fishery, closure of certain areas to trawling, increased monitoring by at-sea observers, or restricting trawling to beam trawlers only (DFO 2010c).

The major difficulty interpreting the validity of the EAL is the scientific basis for it and how it might relate to actual trends in offshore eulachon abundance. So far, the EAL has been reached only once, in 2000, and at this time gear restrictions were implemented with closure of the otter trawl fishery while beam boats were allowed to continue fishing (D. Clark, DFO, pers. comm.).

2) Area and seasonal closures:
    a. The Queen Charlotte Sound (QCSD) shrimp management area was closed in 1999 due to conservation concerns of eulachon spawning populations within Central Coast rivers. The shrimp IFMP states that “considerations to re-open QCSD will be dependent on the criteria established by DFO in discussion with the shrimp trawl industry and First Nations. These criteria include seeing returns of eulachon to Central Coast rivers, increased index of offshore eulachon abundance, identifying an available shrimp quota, and adopting a precautionary approach to eulachon by-catch.”
    b. The Nass River Pacific Fisheries Management subareas 3-12 and 3-18 are closed from February 1, 2010 to March 31, 2010 to “avoid interaction with schooling eulachon returning to spawn” (DFO 2010c). “This closure will be

reviewed annually with industry and First Nations, considering expected eulachon returns" (DFO 2010c).

6.1.2.2 Potential Mitigation

Research Surveys (where eulachon are intercepted)

Potential options to reduce overall survey impacts may include:

1. Reduced individual tow times
2. Reduced number or tows
3. Reduced periodicity of survey or fisheries
4. Terminate survey or fisheries

The implications of adopting any of these potential mitigation measures need to be evaluated very carefully. These measures may limit the ability to monitor eulachon both in rivers and offshore in addition to a number of SARA and commercial fishery species. Any potential mitigation measures would likely have to be directed at reducing overall survey catches for all species, not just eulachon.

Commercial Fisheries.

By-catch Reduction Devices (BRD's).

1. There are two types of BRD's that have been implemented by this fishery: 1) a grate, either hard or soft, at the entrance of the codend that deflects large fish up through an opening in the top of the net; 2) a 42sq ft. panel of 2" rigid square mesh fastened to the upper belly of the trawl net.
2. In 2000, the shrimp trawl industry recommended 100% of the fleet voluntarily adopt the use of grates for both beam and otter trawl nets. In the early 2000s the use of grates in beam trawl nets and the combined use of grates and rigid square mesh in the otter trawl nets became a requirement.

The effectiveness of BRDs has not been quantified. According to Olsen et al. (2000) the grate BRD was not found to reduce eulachon bycatch but it should be noted that there was limited data in this study. A report compiled by the shrimp trawl industry claims the snow fencing BRD reduced eulachon bycatch by 53.5% (Clayton 2001, 2002) but these reports have not been peer-reviewed making interpreting the validity of findings difficult.

While not a mitigation measure, DFO currently is working to improve their bycatch monitoring in all other fisheries. These efforts may help identify other fisheries where eulachon are incidentally caught and better quantify the amount of eulachon bycatch in all fisheries where intercepted.

6.2 MITIGATION AND ALTERNATIVES TO THREATS TO HABITAT

Mitigation measures to threats to habitat have not yet been explored. Until the DU structure is known for eulachon in BC, it is not possible to know which threats (and hence mitigation) would apply. Currently, under the *Fisheries Act* (Section 35) there are overarching mitigation measures in place to protect fish habitat, some of which would apply to eulachon.

6.2.1 **Dredging**

6.2.1.1 Current Mitigation – Fraser River

Dredging (clamshell and suction) of material volumes greater than $4,000m^3$ has been suspended annually in the lower Fraser from March 1 to June 15 in order to protect eulachon and juvenile salmonids (Fraser River Estuary Management Plan 2005). This allows for completion of the full eulachon spawning cycle (spawner migration, egg deposition and incubation and evection of larvae out of the river) to occur without interception with these dredging operations.

6.2.1.2 Potential Mitigation – Fraser River

Attention should be paid to any changes in eulachon run timing within the Fraser River outside of the current seasonal closures, so the dredging activities can be adjusted if necessary. In addition, a better understanding of potential changes in sediment regimes and hydrology due to dredging activities could help refine the window when dredging would have the least impact on eulachon spawning success.

6.3 ACTIVITIES TO INCREASE PRODUCTIVITY

No studies were found that documented increased eulachon productivity in relation to human intervention.

6.4 ALLOWABLE HARM CONSIDERATIONS

Until the DU structure is determined quantitative recommendations on allowable harm can not be made. Allowable harm within rivers would likely have to be considered on a river specific basis while allowable harm offshore would have to consider each DU potentially affected.

7. RECOVERY POTENTIAL CONSIDERATIONS

A specific recommendation on recovery potential of eulachon spawning rivers can not be made at this time and will be explored during subsequent DU specific analyses.

At present, most in river populations are low compared to historic levels. Given the short life history (generation time of approximately 3 years) and the consistently low returns observed in most rivers for over a decade, this suggests a long term reduction in survival and a poor outlook for productivity of future generations. This poses concern for loss of genetic variability and reduced resilience of populations to stochastic events.

8. SOURCES OF UNCERTAINTY

There are substantial gaps in our knowledge of eulachon biology and ecology including: life history parameters, population size, population structure and genetics, habitat use and requirements.

8.1 LIFE HISTORY PARAMETERS

Age (currently no age validation technique)

- Growth rates
- Natural Mortality [M] between life history stages (i.e. from eggs to larvae, larvae to juveniles, juveniles to spawning adults)
- Total Mortality [Z]
- Recruitment Compensation

8.2 POPULATION SIZE

- Unfished biomass of individual rivers as well as offshore populations. There are gaps in historical catch records and no independent measures. Some gaps in historical catches could be filled by back calculating eulachon biomass from grease production as was developed and done by Moody (2008) for the Bella Coola River.

8.3 POPULATION STRUCTURE

- Genetic differences between river populations and river origin of offshore eulachon. More DNA samples are needed from rivers where currently no samples have been taken as well as increasing sample sizes from baseline rivers. Ideally at least 400 samples (adults and/or eggs and larvae) should be taken for each river for genetic analyses (J. Candy, DFO, pers. comm.). Additional genetic analysis will refine geographic genetic differences and temporal stability within and between river populations. Offshore, mixed stock samples could be re-analyzed as more baseline rivers are completed to further refine the origin of offshore eulachon.

8.4 HABITAT

- The marine and spawning habitats used by eulachon during all life history stages need to be better quantified to understand habitat requirements and to determine if there are seasonal differences in marine habitat use.
- Retrospective analysis of habitat impacts for eulachon rivers where data are available could help disentangle what threats may be impacting specific rivers.
- To determine the full extent of river habitat usage, confirmation would be required of eulachon presence within the rivers identified as probable based on the presence of larvae in the surrounding nearshore waters (McCarter and Hay 1999) (Table 1).
- Additional stomach sampling would be required to confirm adult and juvenile prey requirements.

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TABLES

Table 1: List and classification of confirmed and probable eulachon spawning rivers. Probable rivers/areas are based on anecdotal information and/or the density and lengths of larvae found in adjacent inlets/estuaries during ichthyoplankton surveys in coastal mainland inlets (McCarter and Hay 1999) and are indicated by a (P) under the column 'Confirmed (C) or Probable (P)'. The number of eulachon larvae (NEULA) observed by survey year is given as an indication of the certainty of eulachon spawning in the adjacent river. Confirmed (C) rivers are where adult, egg and/or larval eulachon have been observed within the river. The 'Estuary/Marine area' column indicates the closest marine area. The 'Fisheries' column indicates whether First Nations (FN) and/or Commercial (Co) fisheries existed. 'Information on Status' includes a list of data sources available on the status of the eulachon populations within that river. 'References' includes where the information for each river came from. 'DNA' indicates whether a DNA sample has been taken. 'Relative fecundity is the number of eggs per gram of spawning eulachon. Rivers are ordered geographically, from northern to southern BC.

#	Spawning river or adjacent area to a potential unknown river	Estuary/Marine area	C/P	Fisheries: First Nations (FN) and/or Commercial (Co)	Information on Status	DNA	Relative Fecundity (eggs/g of spawning fish)	References
1	Bear River	Portland Canal	C		None			(Blair Stewart pers. comm.) Note: Stewart River as reported in DFO (1999) is an error.
2	Nass River	Portland Inlet	C	FN, Co	CPUE data from First Nations fishery (1997-present), historical catch statistics, anecdotal reports, 1 year SSB (1983)	Y		Hay and McCarter (2000), Moody (2008)
	Tributaries:							
	Bear				None			Moody (2008)
	Rainy				None			Moody (2008)
3	Skeena River	Chatham Sound	C	FN, Co	Larval surveys (1992-1993, 1997), SSB (1997), Run size and interview and local expert comments	Y		Hay and McCarter (2000), Moody (2008)
	Tributaries:							
	Ecstall River							(Don Roberts pers.

	and tributaries: Mud and Sparkling Creek							comm. as cited in Stoffels 2001), Moody (2008), (Dave Rolston, Kitsumkalum Fisheries, pers. comm.)
	Khyex River							(Don Roberts pers. comm. as cited in Stoffels 2001), Moody (2008)
	Scotia Creek							(Don Roberts pers. comm. as cited in Stoffels 2001)
	Khtada Creek							(Don Roberts pers. comm. as cited in Stoffels 2001)
	Kasiks River							(Don Roberts pers. comm. as cited in Stoffels 2001)
	Gitnadoix River							(Don Roberts pers. comm. as cited in Stoffels 2001)
	Exchamsiks							(Dave Rolston, Kitsumkalum Fisheries, pers. comm. 2011)
4	Kitimat	Douglas Channel – Kitimat Arm	C	FN	Catch statistics, CPUE data (1994-1996 and 1998-2009), SSB 22.6t (1993) (Pederson et al. 1995). Researcher comments		252	Hay and McCarter (2000), Moody (2008)
5	Kildala River	Douglas Channel – Kitimat Arm	C	FN	Run size comments			Hay and McCarter (2000), Moody (2008)

6	Gilttoyees Inlet	Douglas Channel	P		NEULA (1996 : 28)			Hay and McCarter (2000), McCarter and Hay (1999)
7	Foch Lagoon	Douglas Channel	P		NEULA (1996: 15)			Hay and McCarter (2000), McCarter and Hay (1999)
8	Kemano/Wahoo Rivers	Gardner Channel	C	FN	Catch statistics (1969-73, 1988-2009), CPUE data (1988-2009)	Y		Hay and McCarter (2000)
9	Kowesas River	Gardner Channel	C	FN	Run size comments; Some potential biomass data available but not reported (Hay and McCarter 2000).			Hay and McCarter (2000)
10	Kitilope River	Gardner Channel	C	FN				Hay and McCarter (2000)
11	Khutze River	Princess Royal Channel	P		NEULA (1997: 31)			Hay and McCarter (2000), McCarter and Hay (1999)
12	Aaltanhash River	Princess Royal Channel	P		NEULA (1997: 11)			Hay and McCarter (2000), McCarter and Hay (1999)
13	Mussel River	Mussel Inlet, North of Mathieson Channel	C	FN	NEULA (1997: 1)			Hay and McCarter (1999), Megan Moody, Nuxalk Fisheries, pers. comm. 2011.
14	Kainet or Lard Creek	Kynoch Inlet, Mathieson Channel	P		NEULA (1997: 5)			Hay and McCarter (2000), McCarter and Hay (1999)
15	Kimsquit River	Dean Channel	C	FN	Run size comments			Hay and McCarter (2000), Moody (2008)
16	Dean River	Dean Channel	C	FN	Run size comments			Hay and McCarter

								(2000), Moody (2008)
17	Skowquiltz River	Dean Channel – west side	P		NEULA (1997:1)			McCarter and Hay (1999), Hay and McCarter (2000)
18	Cascade Inlet	Dean Channel	P		NEULA (1997:4)			McCarter and Hay (1999), Hay and McCarter (2000)
19	Bella Coola River	Dean Channel - North Bentick Arm	C	FN	Catch statistics (1945-1946, 1948-1989, 1995 and 1998)	Y	285 (Moody 2009)	Hay and McCarter (2000), Moody (2008)
20	Necleetsconay River	Dean Channel. North - Bentick Arm	C					Moody (2008)
21	Paisla Creek	Dean Channel - North Bentick Arm	C	FN				Moody (2008)
22	Noeick River	Dean Channel - South Bentick Arm	C	FN				Hay and McCarter (2000), Moody (2008)
23	Taleomy River	Dean Channel - South Bentick Arm	C	FN				Hay and McCarter (2000), Moody (2008)
24	Asseek River	Dean Channel - South Bentick Arm	C	FN				Moody (2008)
25	Kwatna River	Burke Channel - Kwatna Inlet	C	FN				Hay and McCarter (2000), Moody (2008)
26	Quatlena River	Burke Channel -Kwatna Inlet	C					Moody (2008)
27	Clyak River, Moses Inlet	Rivers Inlet - Moses Inlet	C		TEK NEULA (1994: >100, 1997: 49)			Hay and McCarter (2000), Winbourne (2002) as cited in Moody (2008)

28	Wannock River	Rivers Inlet – Queen Charlotte Strait	C	FN		Y		Hay and McCarter (2000), Moody (2008)
29	Chuckwalla/Kilb ella Rivers	Rivers Inlet – Queen Charlotte Strait	C	FN				Hay and McCarter (2000), Moody (2008)
30	Hardy Inlet (uncertain source)	Rivers Inlet	P		NEULA (1994: 5, 1997: 1)			McCarter and Hay (1999), Hay and McCarter (2000)
31	Nekite River	Queen Charlotte Strait - Smith Inlet	P		NEULA (1997 >100)			McCarter and Hay (1999), Hay and McCarter (2000), Winbourne and Dow (2002) as cited in Moody (2008)
32	Kingcome River	Kingcome Inlet	C	FN		Y		Hay and McCarter (2000), Moody (2008)
33	Kakweiken River	Johnstone Strait - Thompson Sound	P		NEULA (1997 >100)			Hay and McCarter (2000) McCarter and Hay (1999)
34	Klinaklini River	Knight Inlet	C	FN		Y		Hay and McCarter (2000), Moody (2008)
35	Franklin River	Knight Inlet	C	FN				Hay and McCarter (2000), Moody (2008)
36	Port Neville	Johnstone Strait	P		NEULA (1994: 6)			Hay and McCarter (2000). Potential from larval survey, although not directly

								mentioned in McCarter and Hay (1999) but deduced from this data
37	Stafford and/or Apple Rivers	Johnstone Strait - Loughborough Inlet	P		NEULA (1997 >500)			Hay and McCarter (2000), McCarter and Hay (1999), Moody (2008)
38	Homathko River	Johnstone Strait - Bute Inlet	P		NEULA (1994, 1997 >100)			McCarter and Hay (1999), Hay and McCarter (2000)
39	Squamish River	Strait of Georgia - Howe Sound	Suspected		Anecdotal reports (Hay and McCarter 2000); Single eulachon caught in the Squamish estuary, August 1978 (Levy and Levings 1978)			Hay and McCarter (2000), Moody (2008)
40	Fraser River	Strait of Georgia	C	FN, Co	SSB (1995-present, historical catches (1877-2004), test fishery data (1995-2005)	Y	350-400 (McCarter and Hay 2003)	Hay and McCarter (2000), Moody (2008)

Table 2: Run timing of British Columbia eulachon spawning rivers.

Spawning River	**Run Timing**
Nass	Middle of March, peaks in fourth week and extends into April, which indicates a second wave. There may also be a late run in June (Langer et al. 1977).
Skeena	Peak occurs the second week of March and there may have been a second wave of eulachon spawning in June (Lewis 1997). Historically the run returned during the first week of March; however, in the past decade, it has occasionally returned earlier, during mid to late February (Don Roberts, pers. comm. 2006 as cited in Moody 2008).
Kitimat	Usually peaks mid to late March but they have been captured in late April and May (Kelson 1996 as cited in Moody 2008). 1993: spawning occurred between the 20th and 30th of March (Pedersen et al. 1995). 1997: peak from the 7th to 19th of March (Kelson 1997 as cited in NFMS (2010).
Kemano	Late March and early April (Lewis et al. 2002 as cited in Moody 2008).
Bella Coola	February to April (Moody 2009)
Kingcome	March to May, however initial samples taken in March had eggs and larvae present, therefore spawning began before this date. Eggs were also present in the last samples taken in June so there appears to be late spawning run. There were four “waves” of spawning with peaks on April 2, 15 (largest), 21 and May 2 (Berry and Jacob 1998). Peak abundance returns in the middle of April (Common Resources Consulting Ltd. 1998).
Klinaklini	April, peak abundance returns in the middle of the month (Common Resources Consulting Ltd. 1998).
Fraser	April-May (Ricker et al. 1954)

Table 3: Life history parameters of eulachon.

Life History Parameter	
Age of maturity	~3 years (based on size of returning fish, biomodal distribution of length frequency data offshore (Hay and McCarter 2000) and elemental analysis of otoliths (Clarke et al. 2007))
Sex Ratio	~1:1 Fraser River (Hay et al. 2002)
Relative fecundity	Refer to Table 1
Total Mortality [Z]	Unknown
Natural Mortality [m]	Unknown
Unfished Biomass	Unknown
Recruitment Compensation	Unknown

Table 4: Shrimp trawl fishing effort for the BC coast and the amount of effort observed in the bycatch monitoring program by shrimp fishing year (April 1 to March 31 the subsequent year).

Year	Shrimp trawl effort (hours)	Observed trawl effort (hours)	Proportion of effort observed (%)
1997	54798	966.5	1.8
1998	84614	822.15	1.0
1999	55935	546.7	1.0
2000	49190	378.1	0.8
2001	39150	336.2	0.9
2002	38010	278.3	0.7
2003	31208	266.9	0.9
2004	27567	348.5	1.3
2005	23502	287.2	1.2
2006	24563	213.5	0.9
2007	22652	207.0	0.9
2008	18696	363.9	1.9
2009	18363	167.6	0.9
2010	8209	Incomplete	

Table 5: Eulachon catches (kg) in all BC groundfish trawl surveys by year (GFBio database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC) on August 31, 2010. Eulachon catches are summarized by survey and year. The "Other" survey category is a consolidation of all surveys in the database with no description or name.

Year	Goose Island Gully Pop Trawl Survey	Hake Stock Delineation	Hecate Strait Juvenile Flatfish Survey	Hecate Strait Multispecies Trawl Survey	Hecate Strait Pcod Monitoring Trawl Survey	Hecate Strait Synoptic Trawl Survey	Queen Charlotte Sound Synoptic Trawl Survey	Strait Of Georgia Hake Survey	West Coast Vancouver Island Hake Survey	West Coast Vancouver Island Synoptic Trawl Survey	Other	Grand Total
1965											39.46	39.46
1966	29.48											29.48
1967	0.91										29.48	30.39
1968											303	303
1969	2.02										24.49	26.51
1970											166.47	166.47
1971	320.29										9.06	329.35
1972											30.39	30.39
1973	89.32										159.23	248.55
1974											181.45	181.45
1975											29.25	29.25
1976	146.87										2.78	149.65
1977	665.44										197.08	862.52
1978											158.9	158.9
1979											2.72	2.72
1980											2.95	2.95
1981			4								9	13
1982												
1983			40								74	114
1984	20			6							24	50
1985											4.2	4.2
1986											114	114
1987				170							10	180
1988											51	51
1989				33							27	60
1990											5	5
1991				10					10		4.1	24.1

1992									24		9	33
1993				3					1			4
1994									1			1
1995	8			21					9			38
1996				58					13			71
1997									42			42
1998				89							4.3	93.3
1999											0.2	0.2
2000				46							1	47
2001				4.09				40.94	453.03			498.06
2002				60.8	15.36			7.08			8.58	91.82
2003				151.64	13.58		50.1				130.98	346.3
2004					28.53		190.6			599.8	0.05	818.98
2005						107.17	36.54				0.9	144.61
2006										50.16		50.16
2007		216.28				23.92	20.32				0.78	261.3
2008		52.41								58.59		111
2009						145.56	122.54				65.17	333.27
2010*										48.48		48.48
Grand Total	1282.33	268.69	44	652.53	57.47	276.65	420.1	48.02	553.03	757.03	1879.97	6239.82

* Survey results were extracted on August 31, 2010, therefore survey results from 2010 will be incomplete until the year is finished and all the data has been entered.

FIGURES

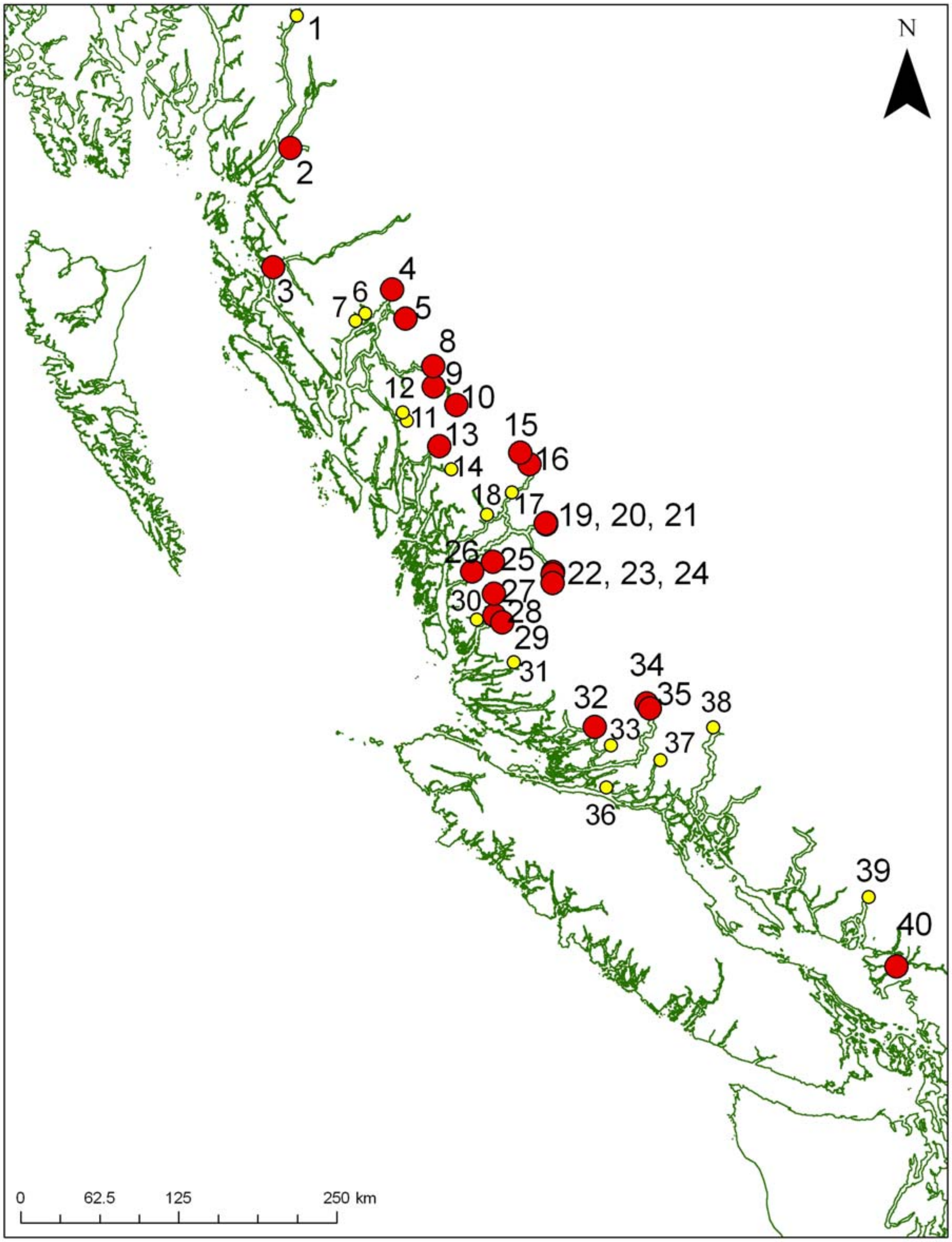


Figure 1: Eulachon spawning rivers in British Columbia. Red circles are confirmed rivers by the presence of adult eulachon and/or eggs or larvae (Hay and McCarter 2000, Moody 2008). Smaller yellow circles are probable rivers deduced from larval distribution and length frequency in the adjacent waters (McCarter and Hay 1999). Numbers correspond to the list of rivers in Table 1.

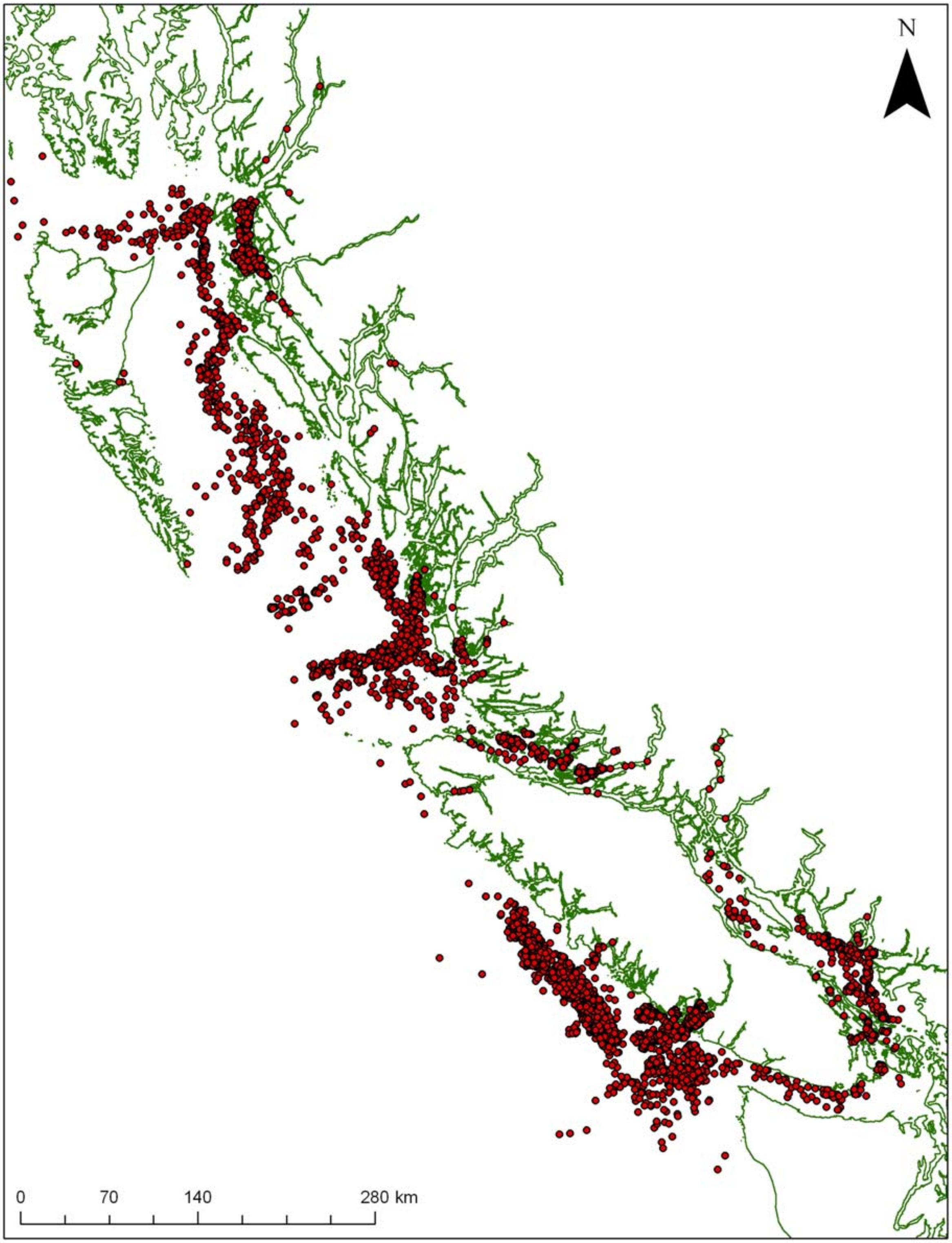


Figure 2: Catch locations of eulachon in bottom and mid-water research trawl surveys directed at groundfish, herring and shrimp in British Columbia.

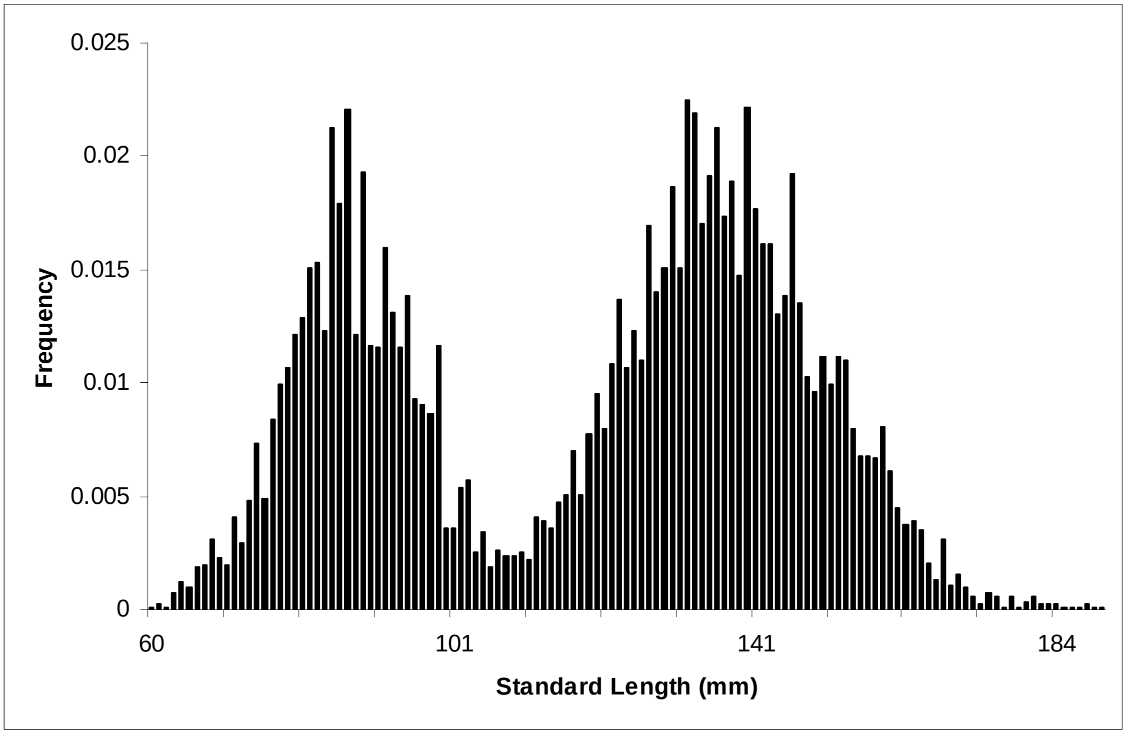


Figure 3: Eulachon length frequency size modes as an indication of age. Eulachon were observed off the west coast of Vancouver Island in 2004 during a multispecies small mesh bottom trawl survey. The two peaks presumably correspond to ages 1 and 2.

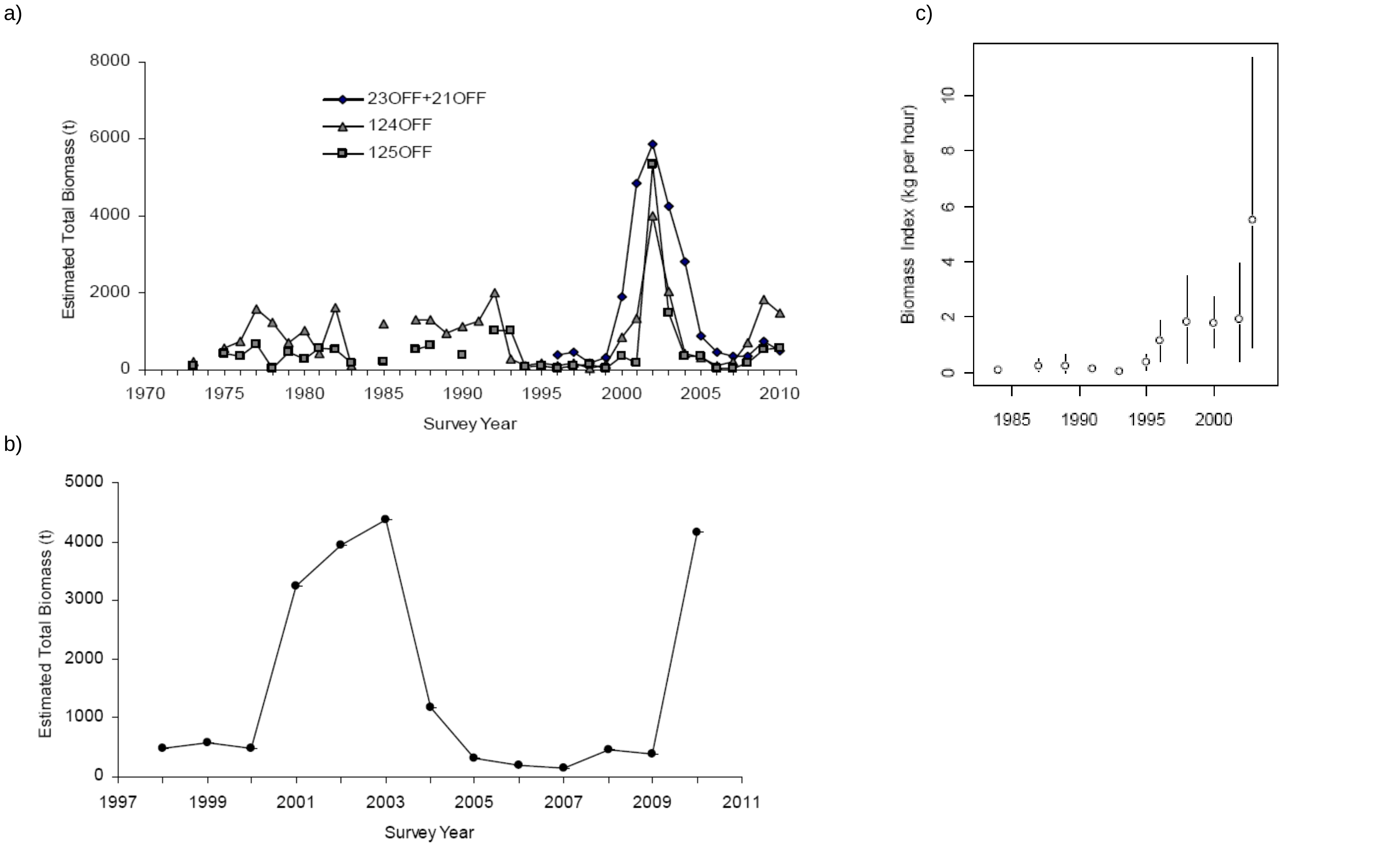
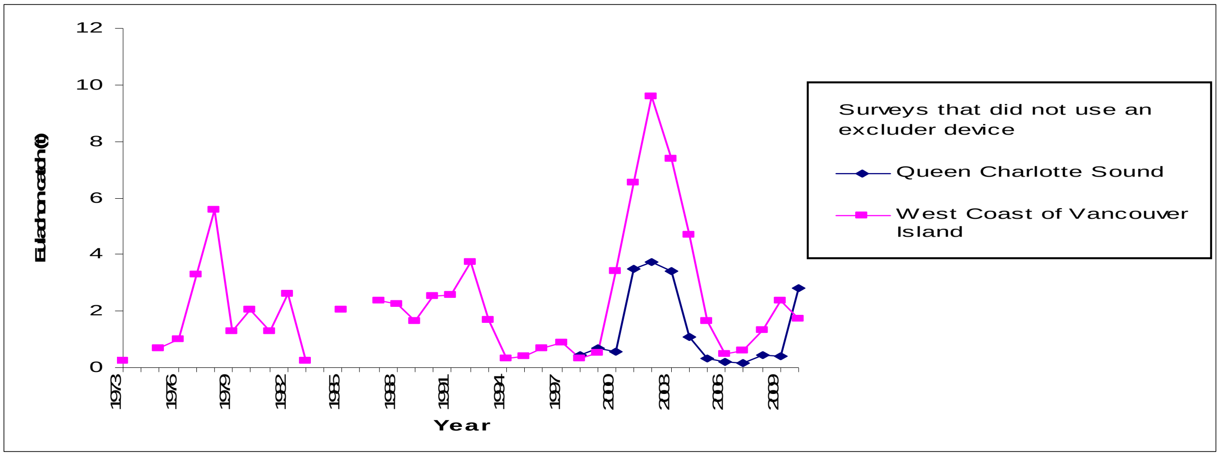


Figure 4. Eulachon biomass indices estimated from multispecies small mesh bottom trawl surveys for (a) the west coast of Vancouver Island shrimp management areas (SMAs) 124OFF and 125OFF from 1973 to 2010 and 23OFF+21OFF from 1996 to 2010; (b) Queen Charlotte Sound (QCSD) SMA from 1998 to 2010 (refer to survey bulletins: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/surveys.htm); (c) Biomass index calculated for Hecate Strait from 1984 to 2003 (Sinclair et al. 2007).

a)



b)

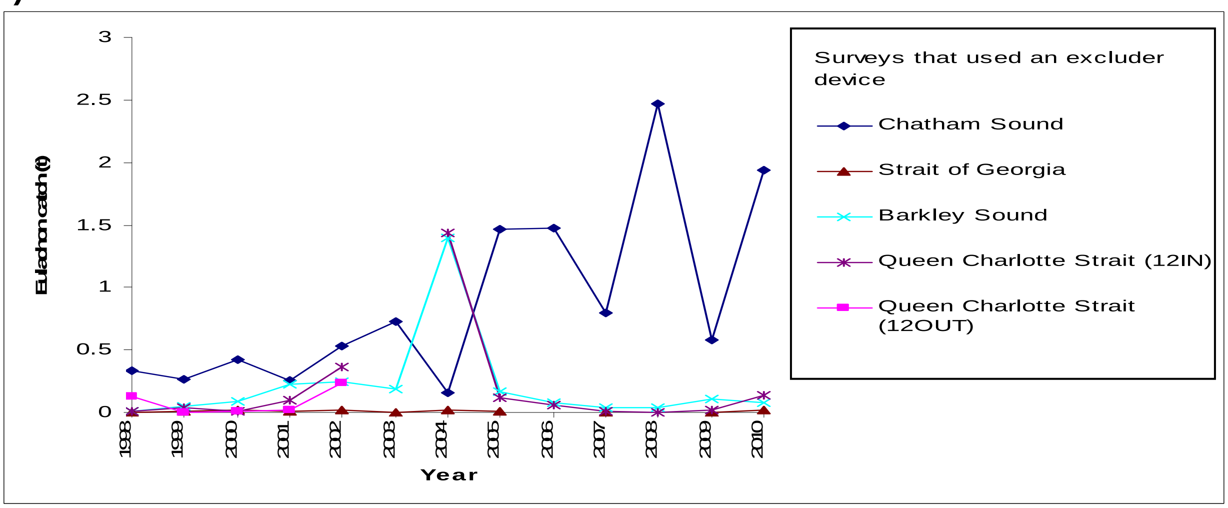


Figure 5. Eulachon catch (tonnes) in multispecies small mesh bottom trawl surveys off the coast of BC. Eulachon catch is summarized by regions of aggregated shrimp management areas (SMAs) and gear type. a) Surveys using the WE Ricker with no excluder device: Queen Charlotte Sound (QCSD and 9IN) and West coast of Vancouver Island (124OFF, 125OFF, 21OFF+23OFF) and b) Surveys using the Neocaligus and an excluder device: Prince Rupert (PRD); Queen Charlotte Strait (12OUT) Queen Charlotte Strait (12IN); Strait of Georgia (GSTE, FR, 14, 16, 18, 19) and Barkley Sound (23IN).

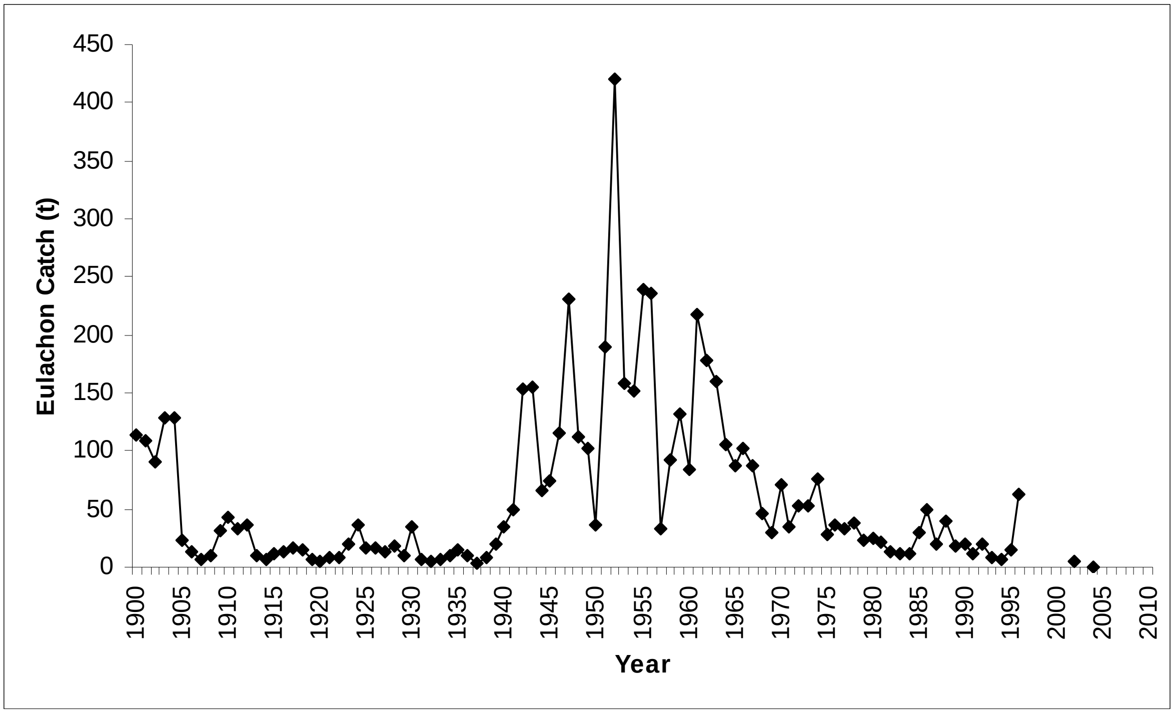


Figure 6: Commercial catches for the Fraser River from 1900 to 2004 (Parliament of Canada (1900-1916), Canadian Bureau of Statistics (1917-1976), Hay and McCarter 2000, DFO 2002; 2004). Data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lbs = 1 cwt. The fishery was closed from 1997 to 2001, 2003, and 2005 to present (2011).

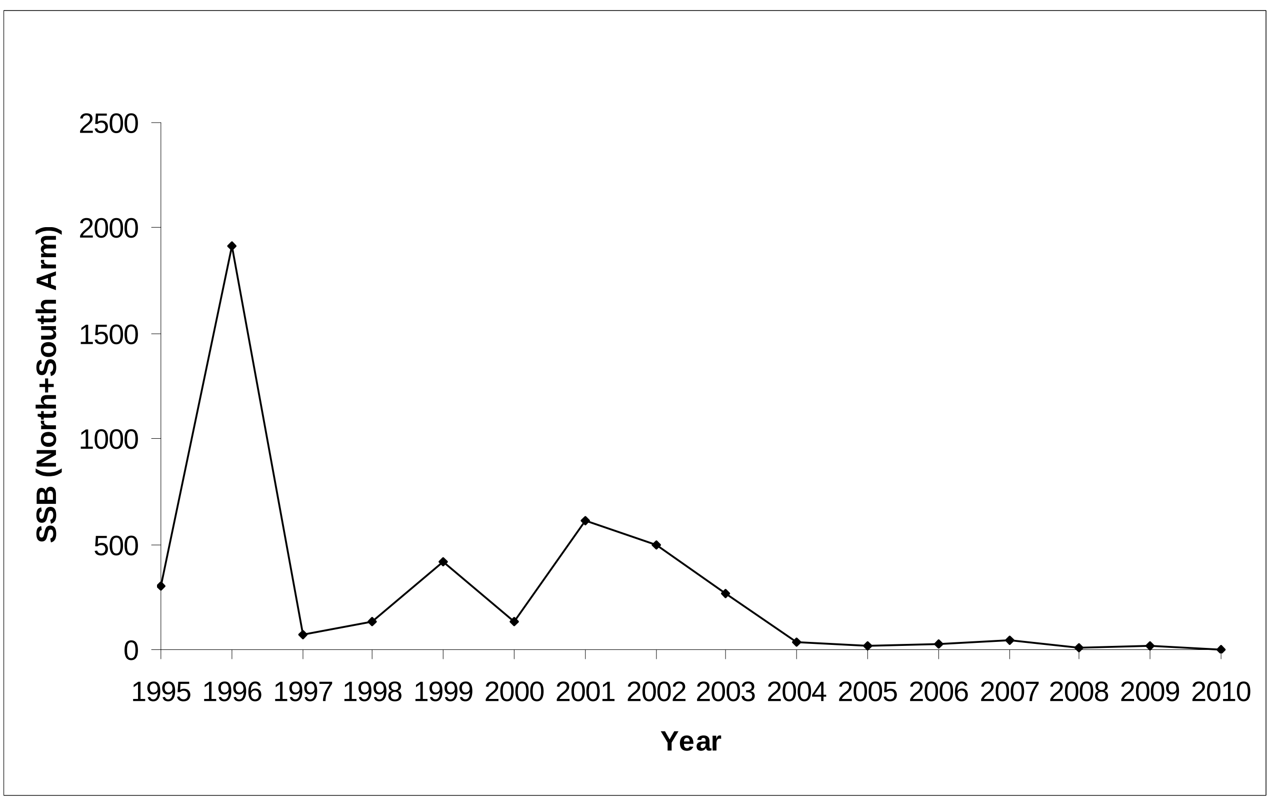


Figure 7: Spawning stock biomass (SSB) estimates for Fraser River eulachon. Methods and assumptions for assessments are explained in Hay et al. (2002).

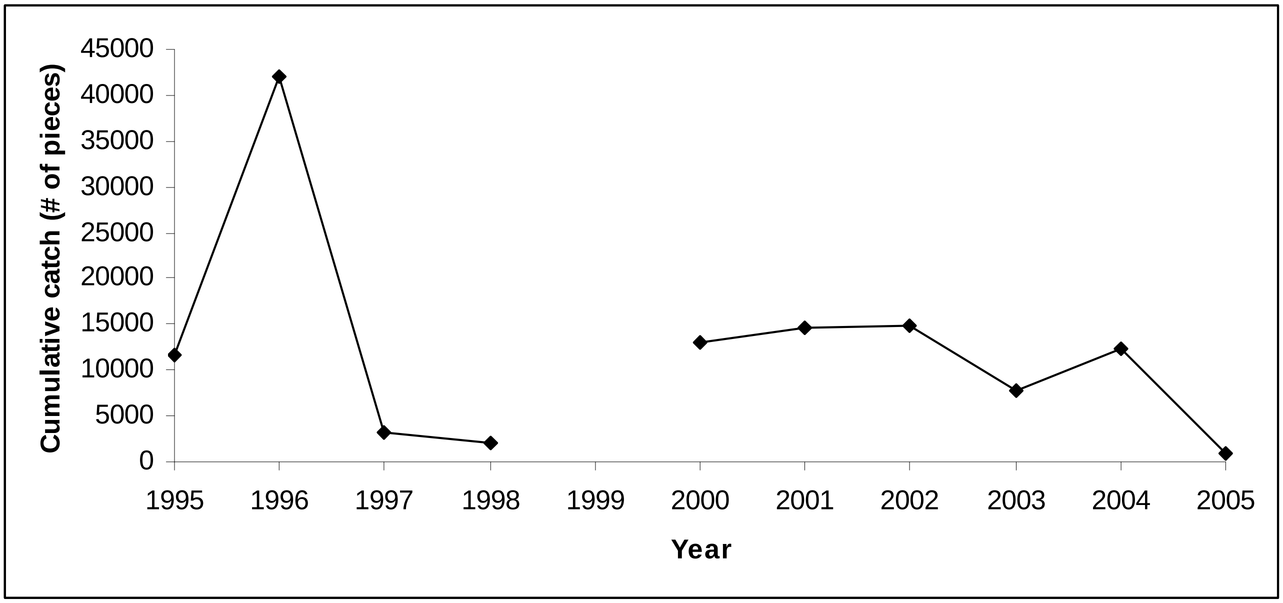


Figure 8: Fraser River eulachon test fishery cumulative catch (number of eulachon pieces) from 1995-2005. No test fishery occurred in 1999 or after 2005.

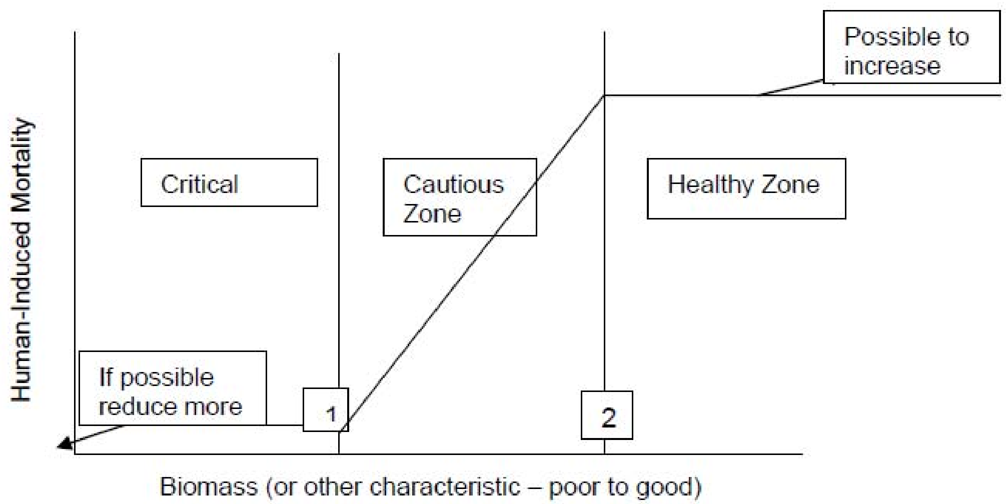
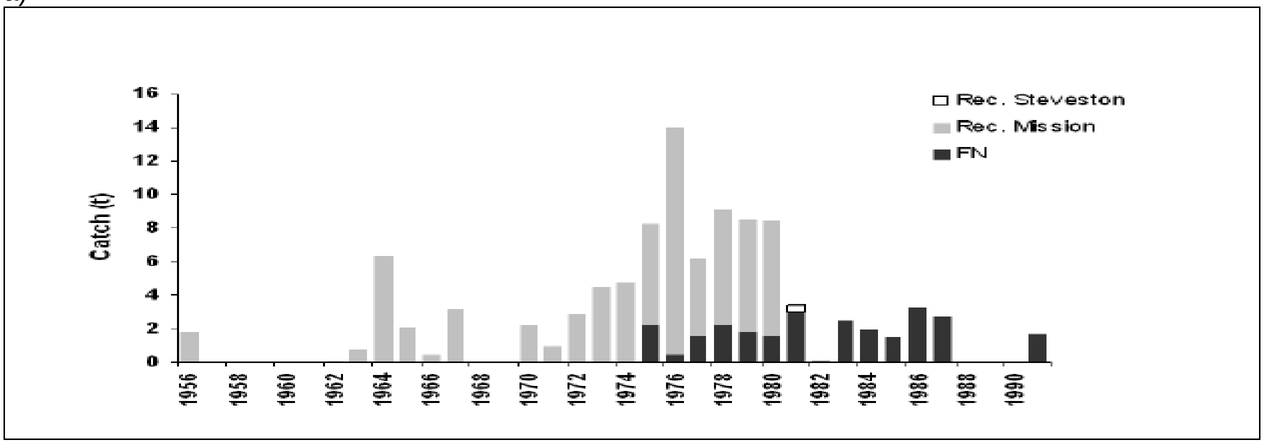


Figure 9: The fisheries management framework (harvest strategy compliant with the precautionary approach (DFO 2006)) being considered for use in recovery descriptions and planning. Positions 1 and 2 correspond to the limit reference point (LRP) (critical-cautious boundary) and the upper stock reference (USR) (cautious-healthy boundary) (DFO 2005b).

a)



b)

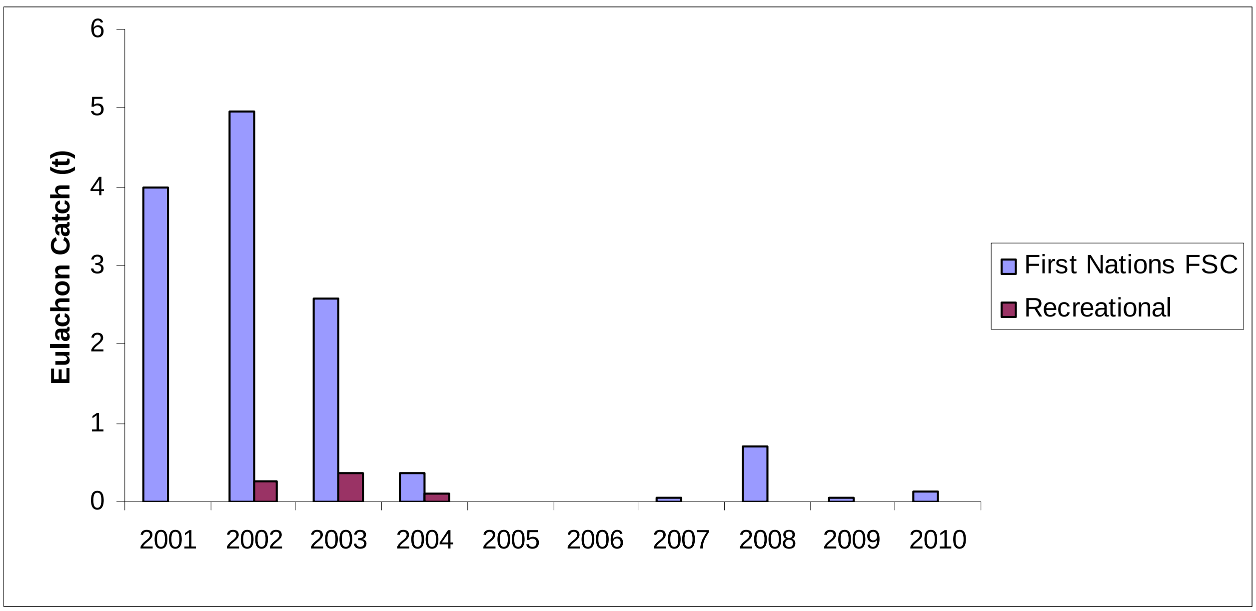


Figure 10: First Nations (FN) and recreational (Rec.) eulachon catches from the Fraser River from a) 1956 and 1990 at Steveston and Mission (graph obtained from Moody 2008) and b) 2001 to 2010 (DFO 2002-2010.

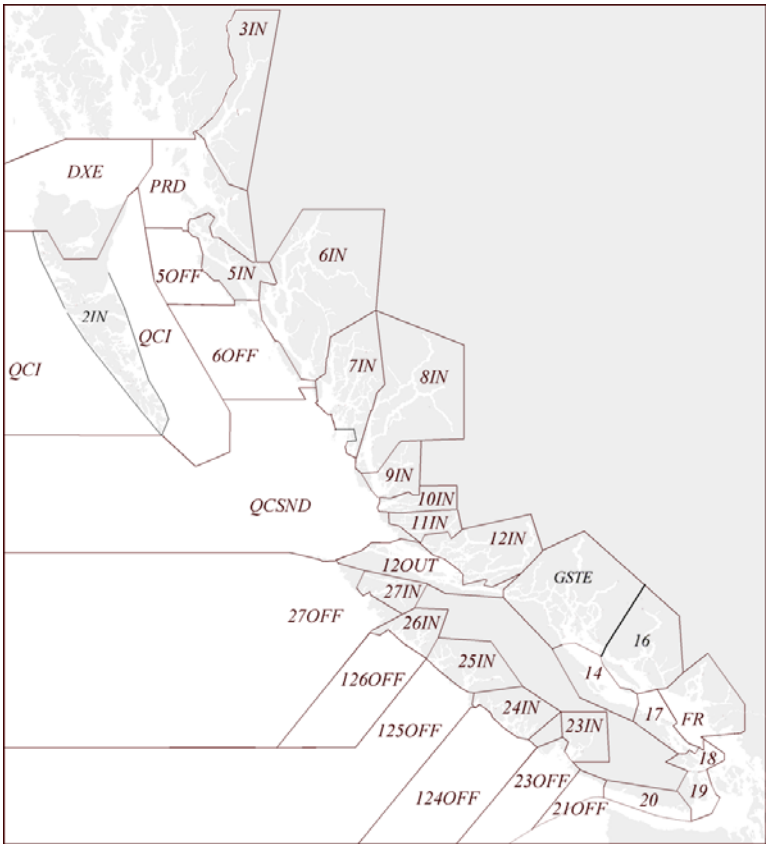


Figure 11. Map of Shrimp Management Areas (SMAs) (DFO 2010c).

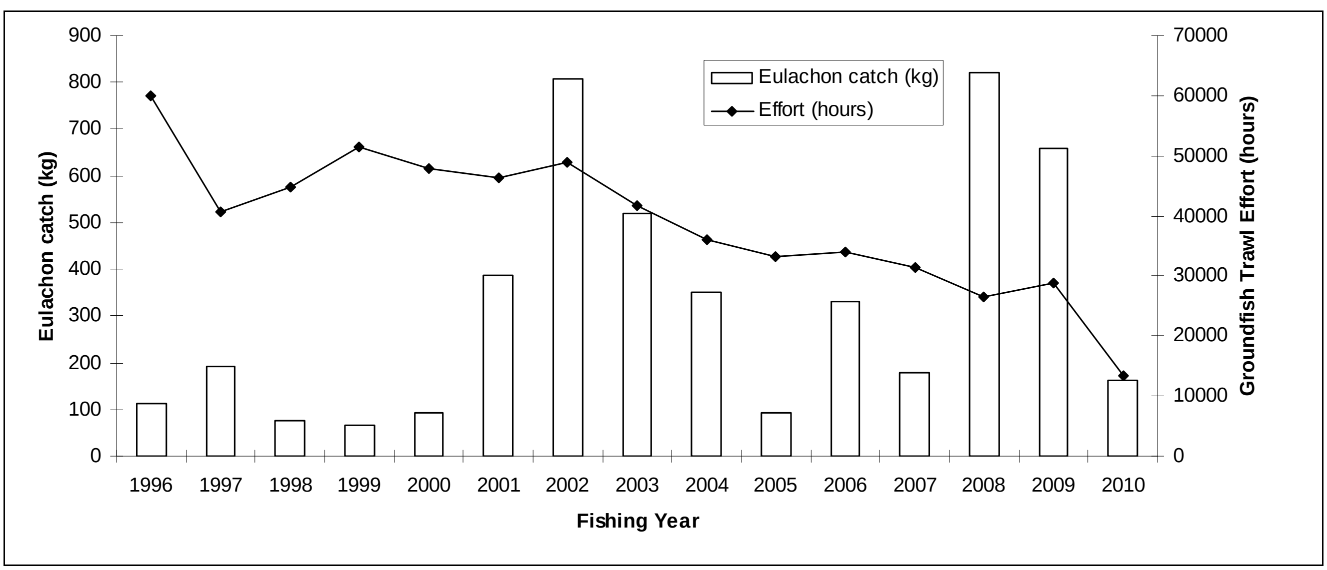


Figure 12: Eulachon bycatch (kg) in the Groundfish Trawl (bottom and mid water) fishery and fishing effort from 1996 when 100% observer coverage was implemented. Eulachon bycatch records were extracted from groundfish commercial trawl fishery observer PacHarvTrawl database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC) and FOS on September 1, 2010, therefore data from 2010 is incomplete.

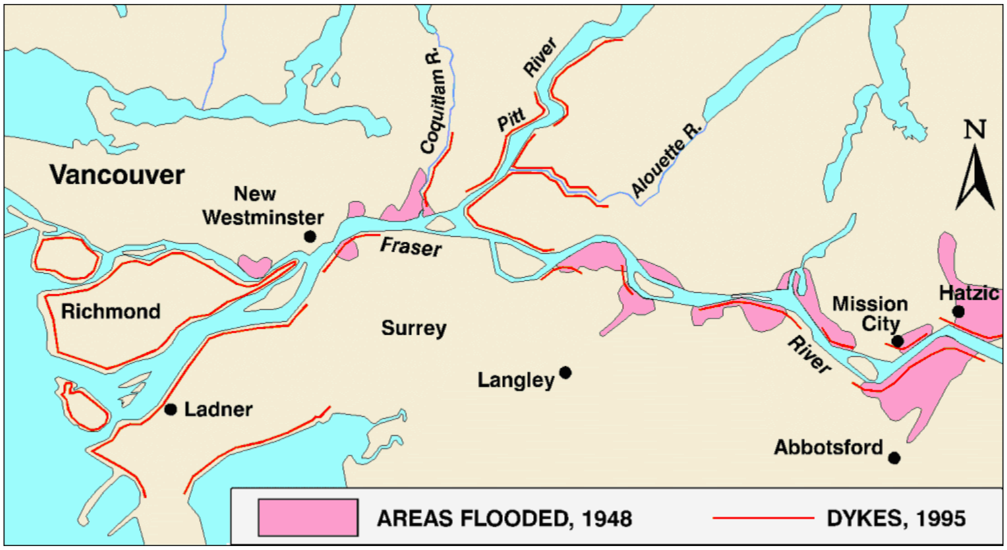


Figure 13: Extent of dyke projects in the Lower Fraser River up to 1995 (Natural Resources Canada 2008).