Bangarang Backgrounder[1]

February 2014

Forage Fish
(of coastal British Columbia)

Eric Keen

Abstract

Forage fish, being extremely abundant and nutritious, are highly influential players in marine food webs. They eat a lot and they are eaten a lot. The major forage fishes expected in the Kitimat Fjord System, BC, include clupeids (herring and sardine), osmerids (smelts; longfin smelt, surf smelt, eulachon and capelin), and sand lance. To the extent that seabirds and marine mammals rely on fish for their nutrition in this area, these species are probably their targets. Other episodic and less abundant species may include walleye pollock, pacific hake, anchovy, and several other smelts. This Backgrounder introduces these species and summarize their life history, seasonal geography, ecology, history of harvest, status, and possible role in the Bangarang study area during the summer foraging season.

Contents

For each featured species:
- Images
- Taxonomy
- Identification
- Life History
- Seasonal Geography
- Ecology
- The BC Fishery
- Status
- (Other)

[1] Bangarang Backgrounders are imperfect but rigorous reviews – written in haste, not peer-reviewed – in an effort to organize and

Introduction

On the BC coast, forage fishes (of the vertebrate class Osteichthyes, or bony fishes[2]) constitute an ecological cornerstone[3] for a complex food web that spans and unites offshore, inshore, intertidal, and terrestrial habitats. Larger fishes, seabirds, and marine mammals rely on forage fish to various extents, sometimes solely, and forage fish distribution may influence or even govern that of their predators. Some of these forage fish, clupeids and anchovies in particular, are the targets of some of the world's largest commercial fisheries. Other species, like the smelts who do not school, comprise only a small percentage of commercial fisheries catches[4] but the majority of forage fish bycatch[5].

The fish taxa represented in BC's coastal forage fish community include – but are not limited to -- the Clupeiformes (including the Clupeidae, herrings and sardines, and the Engraulidae, the anchovies), the Salmoniformes with their trademark adipose fins (the osmerids[6], smelts like capelin and eulachon), and the Perciformes (Ammodytidae, sand lance). Most of these forage fishes either move in large schools around coastal banks or aggregate in coastal and even intertidal areas. All of these species exhibit seasonal movements of some kind, some north-south and others inshore-offshore. Some are anadromous (return to ancestral freshwater sources to spawn) and even semelparous (spawn once and die). Many of the stocks for which population data are collected are currently in a state of decline.

Because small nekton like forage fish are difficult to sample rigorously from small-craft, they represent the largest question mark in the Bangarang's efforts to monitor the pelagic ecology of the Kitimat Fjord System. This is especially aggravating because these fish are likely playing a major, major role in the distribution and behavior of the predators we are studying. Knowing as much as we possibly can – then tailoring our sampling methods to get the best chances of success – is the best shot we have. If we can develop the intuition to identify small fish species readily from opportunistic field observations and to interpret echogram data accodingly, we can speak to this critical node in the Great Bear food web.


[7]

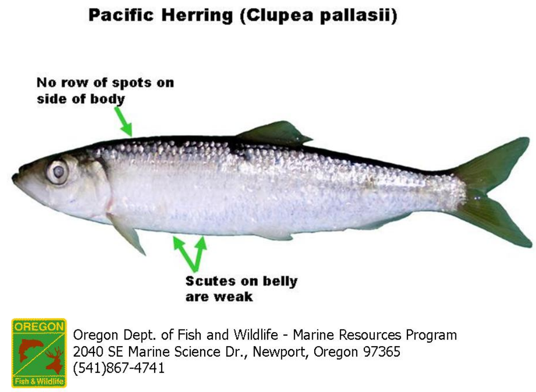
Young-of-the-year Pacific cod and juvenile Pacific sand lance captured in a purse seine during nearshore surveys conducted by AFSC scientists in 2011. Photo by Olav Ormseth.[8]

[2] Robards and Piatt. 1999; Phylum: Chordata, Subphylum: Vertebrata (Craniata), Superclass: Gnathostomata, Grade: Pisces, Class: Osteichthyes
[3] Willson et al.1999, many others
[4] McClory and Gothardt 2005.
[5] Nelson 2003
[6] Hart and McHugh 1944.
[7] http://www.afsc.noaa.gov/Quarterly/ond2011/divrptsREFM10.htm
[8] http://www.afsc.noaa.gov/Quarterly/ond2011/divrptsREFM10.htm

Pacific Herring

Clupea harengus


[9]

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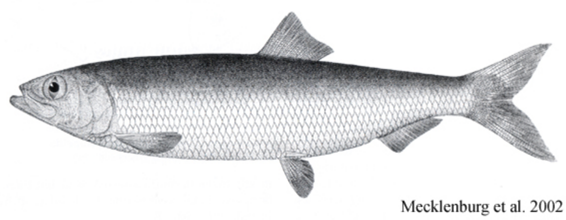

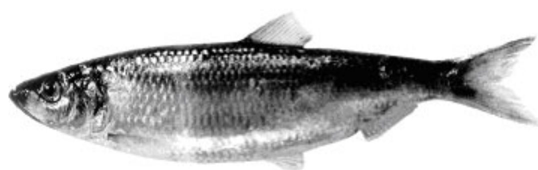
[11]

Taxonomy

- Order Clupeiformes. Family Clupeidae[12]. The most abundant and commercially important species of the genus *Clupea*, [13]
- Three species of *Clupea* are recognized (Araucanian, Atlantic, and Pacific).[14]
- The North Pacific herring is named for Peter Simon Pallas, a German naturalist and explorer[15].

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[9] DFO 2012b. Photo by K. Daniel.
[10] http://www.fao.org/fishery/species/2078/en
[11] https://www.dfg.ca.gov/marine/herring/

[12] http://en.wikipedia.org/wiki/Herring
[13] http://en.wikipedia.org/wiki/Herring
[14] http://en.wikipedia.org/wiki/Herring
[15] http://en.wikipedia.org/wiki/Pacific_herring

Identification

- A silvery fish with no spots or discrete marks. A bluish-olive back, silver-white sides and bellies.
- Bodies are highly compressed laterally.
- Back is much straighter, much less curved than belly. Their pot-belly distinguishes it from a sardine.
- Large scales that are easy to extract, but no scales on head, gills or tail.
- Large abdominal scutes bear a serrated look.[16]
- No striations on gill cover.[17]
- The caudal fin is deeply forked. Only one dorsal fin, located mid-body; no adipose fin.
- Typical length: can reach 18 inches[18]; maximum 45cm and 550 grams[19].
- No teeth on jawline, but some are present on the vomer[20].
- A well-enervated gas bladder affords very rapid vertical motions and changes in depth[21].
- Pelvic fins are located underneat dorsal fins.[22]

Life History

Within BC, Pacific herring typically mature and recruit to the spawning stock at age three (range is 2 to 5), but age-at-recruitment tends to increase with latitude up the coast.[23] Herring do not die after spawning; they can breed for successive years.[24] Fat concentration of the fish is highest during the winter months[25], just before spawning. Pacific herring spawn in intertidal and subtidal environments[26] (often on eelgrass and marine algae like kelp), usually early in the year.[27] Eggs take approximately 10 days to hatch, depending on temperature.[28] By the fall, hatchlings reach 3 to 4 inches and begin to leave the shallow areas.[29] In California, they live to 11 years and in Alaska they have been aged at 19 years.[30]

Seasonal Geography

The Pacific herring occur in relatively shallow waters of the east and west coasts of the northern Pacific basin[31],[32]. In the northeast Pacific, herring occur from Baja California to Alaska; on the west coast, they are found as far south as Japan.

Herring annually migrate between feeding and spawning areas.[33] In the winter, herring migrate inland from their offshore summer feeding areas. Their winters are spent in inlets and bays as they prepare for the annual winter spawn[34]. Although juvenile herring are found everywhere, the adults only spawn in select locations (Douglas Hay, pers. comm.). Herring spawn earlier in the south and later in the north.[35] Spawning occurs at night in shallow, sometimes intertidal, waters.[36] Hatchlings linger in shallow waters until the fall.

Herring in BC's Hecate Strait to the west of the study area represent a combination of migratory stocks from the Haida Gwaii, Prince Rupert, and Central Coast management zones (see Fishery section).[37]

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16 http://en.wikipedia.org/wiki/Pacific_herring
17 Love 1991
18 Love 1991
19 http://en.wikipedia.org/wiki/Pacific_herring
20 http://en.wikipedia.org/wiki/Pacific_herring
21 http://en.wikipedia.org/wiki/Pacific_herring
22 Love 1991.
23 DFO 2014
24 http://en.wikipedia.org/wiki/Pacific_herring
25 Watson et al. 2010
26 Haegele and Schweigert 1985
27 http://en.wikipedia.org/wiki/Pacific_herring
28 Love 1991.
29 Love 1991.
30 Love 1991.
31 McClory and Gothardt 2005.
32 http://en.wikipedia.org/wiki/Herring
33 DFO 2014
34 Watson et al. 2010
35 Love 1991.
36 Love 1991.
37 Boldt et al. in Irvine and Crawford 2013

Ecology

Because of its productivity, abundance, and role as both predator and prey, the Pacific herring can be considered a keystone species[38].

As Predator

Pacific Herring are zooplanktivorous, consuming primarily euphausiids (krill) and some copepods[39]. Adult pacific herring feed exclusively on euphausiids[40]. Juvenile herring from Prince William Sound were found to prey upon *Cirrepedia* nauplii, fish eggs, small and large calanoids, euphausiids, and larvaceans[41]. In BC, they are known to prey upon "planktonic crustaceans, copepods, euphausiids, amphipods, marine worms, and small fishes. Important forage species include *Calanus* and *Pseudocalanus* copepods, *Thysanoessa inermis* and *T. raschii* (euphausiids) and amphipods *Themisto* spp."[42].

As Prey

Predators of spawn: An entire appendix of predators can be found in Hay et al. (2011).

Fish predators: Pacific Hake[43], lingcod[44] (up to 88% of lingcod diet[45]), Spiny Dogfish[46], Pacific Cod[47], sablefish[48], Arrowtooth Flounder[49], Pacific Halibut[50] (40 % of Pacific Cod and Pacific Halibut diets[51]).

Marine Mammal predators: Steller Sea Lions[52], Northern Fur Seals[53], Harbour Seals[54] (35% - 45% of pinniped diets[55]), California Sea Lions[56], and Humpback Whales[57].

Bird predators: No seabird predator reports found by this author.

Depending on the ability of predators to prey switch, the dramatic fluctuations in herring biomass on the BC coast may affect predator population status.[58] Many fish predators of herring have been declining in recent decades as some marine mammal predators have been increasing[59]; it is thought that the overall impact on the West Coast Vancouver Island herring stock, for example, has been a slight net dampening of top-down regulation.[60]

Competition

No information on competition was found.

Fishery

Commercial herring fishery began in 1877 on the BC coast.[61] There was a marked collapse between 1968 and 1971[62], but herring stocks fluctuate dramatically.

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[38] http://en.wikipedia.org/wiki/Pacific_herring
[39] Wailes 1936
[40] Tanasichuk 1998
[41] Foy & Norcross 1998
[42] Gjøsæter 1998
[43] Schweigert et al. 2010
[44] Schweigert et al. 2010
[45] Pearsall and Fargo 2007
[46] Schweigert et al. 2010
[47] Schweigert et al. 2010
[48] Schweigert et al. 2010
[49] Schweigert et al. 2010
[50] Schweigert et al. 2010
[51] Ware and McFarlane 1986
[52] Schweigert et al. 2010
[53] Schweigert et al. 2010
[54] Schweigert et al. 2010
[55] Olesiuk et al. 1990, Womble and Sigler 2006, Trites et al. 2007, Olesiuk 2008
[56] Schweigert et al. 2010
[57] Schweigert et al. 2010
[58] Boldt et al. in Irvine and Crawford 2013
[59] Olesiuk 2008, Olesiuk et al. 1990
[60] Schweigert et al. 2010
[61] Watson et al. 2010
[62] Watson et al. 2010

Commercial fishing for Pacific Herring in BC is managed as five major stock management areas: Haida Gwaii (HG), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SOG), and West Coast of Vancouver Island (WCVI) – along with two minor herring stock management areas: Haida Gwaii Area 2W, and WCVI Area 27.[63] Of these 5 stocks, the biggest are HG, CC, and WCVI.

The Kitimat Fjord System (the Bangarang study area), Fisheries Management Area 6, is not within a BC herring management area.[64] Only 7 licenses were issued for FMA 5 (in the Prince Rupert District) in 2009.[65] Between 1998 and 2008, the value of the commercial food and bait herring fisheries in FMA5 varied between $250,000 (1999) and 2,271,760 (2002).[66]

Herring are harvested as roe (spawn, or eggs) or as "bait" (migratory adults). Roe is considered a delicacy in Japan[67] The roe fishery opens between mid-March and mid-April in northern BC[68], when gravid herring congregate on coasts to spawn on marine algae[69]. Roe fishermen puts out suspended lines of kelp fronds that will get covered in herring eggs.[70], [71] Poor economic conditions in Japan have resulted in a recently reduction in price of herring roe[72].

Migratory adult herring in BC waters are fished between November and January.[73] Herring are harvested by sein[74],[75] and gill nets[76].

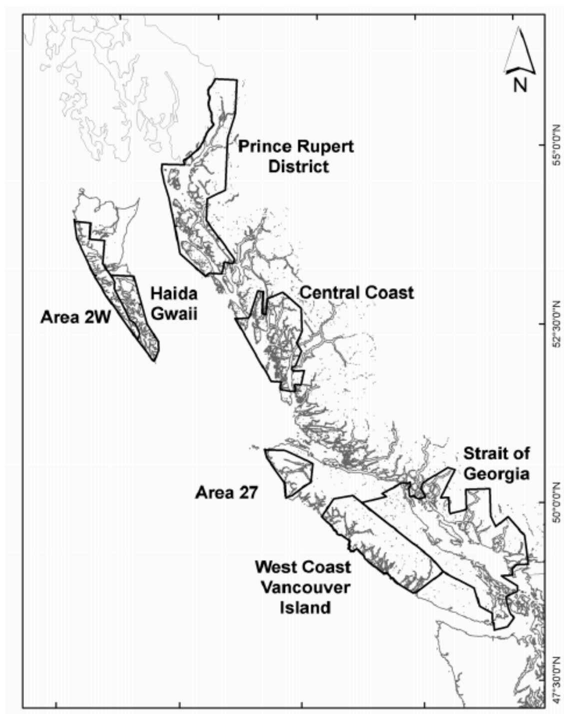

Figure 1. Map of B.C. herring stock areas. The five major stock are Haida Gwaii (HG or QCI 2E), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SOG), West Coast Vancouver Island (WCVI), and the minor stock areas are Area 2W and Area 27. 77

63 DFO 2014
64 Hay et al. 2011.
65 Watson et al. 2010
66 Watson et al. 2010
67 Watson et al. 2010
68 Watson et al. 2010
69 Watson et al. 2010
70 Watson et al. 2010
71 Watson et al. 2010
72 Watson et al. 2010
73 Watson et al. 2010
74 Watson et al. 2010
75 Watson et al. 2010
76 Watson et al. 2010
77 Hay et al. 2011.

Status

Each of BC's 5 major herring stocks[78] are assessed using a variety of measures. Catch data are the primary basis for assessments. Spawn deposition surveys (transects in which layers of eggs are counted by SCUBA divers) provide a fisheries-independent abundance index[79]. The density of eggs is a proxy for the density of herring that spawned there[80].

Following the herring harvest control rule, the maximum available harvest is based on a 20% harvest rate of the mature herring biomass[81].

Herring populations have been known since the mid-20th century for dramatic fluctuations[82]. Currently, three of the five stocks are in decline. The WCVI stock, in terms of both biomass and weight-at-age, has generally been in decline since the 1980s.[83] There has not been commercial fishing in WCVI for the majority of the past decade, but the stock remains very low, as low as it was in the 1960's following the reduction fishery (1951-1968).[84] Recruitment rates in 2012 and 2013 were very low too.[85] The Central Coast stock has been decreasing for the past 13 years[86]. The Haida Gwaii stock were also below fishery thresholds in 2012[87]. Stock rebuilding strategies have been recommended for these declining stocks[88], all of which have been below fishery thresholds in recent years[89].

The Strait of Georgia and Prince Rupert stocks have been relatively stable and as of 2013 were above the fishery threshold.[90],[91],[92]. In all management areas, the mean number of egg layers has decreased since the mid-1980's (which was when the first diver surveys occurred).[93] There has also been a declining trend in herring weight-at-age observed for all fishing stock areas.[94]

These patterns suggest that factors other than fishing – food supply or quality (perhaps brought about by oceanographic changes that are conducive for less nutritious prey[95]), predator abundance (e.g. increasing marine mammal populations), competition (perhaps from recent increases in sardine in BC waters, who both compete for herring prey and attract hering predators[96]), -- may be affecting populations.[97],[98] Tanasichuk (2012) relates WCVI herring recruitment to the biomass of euphausiids. Predation by large piscivorous hake may be reducing WCVI recruitment[99],[100]. However, the mortality rates cannot be fully attributable to increases in predation[101].

78 Boldt et al. in Irvine and Crawford 2013
79 Hay et al. 2011.
80 Hay et al. 2011.
81 Cleary and Schweigert 2010
82 McClory and Gothardt 2005.
83 Boldt et al. in Irvine and Crawford 2013
84 Boldt et al. in Irvine and Crawford 2013
85 Boldt et al. in Irvine and Crawford 2013
86 Boldt et al. in Irvine and Crawford 2013
87 Boldt et al. in Irvine and Crawford 2013
88 Boldt et al. in Irvine and Crawford 2013
89 Irvine and Crawford 2013
90 Boldt et al. in Irvine and Crawford 2013
91 Boldt et al. in Irvine and Crawford 2013
92 DFO 2012
93 Hay et al. 2011.
94 Irvine and Crawford 2013
95 Boldt et al. in Irvine and Crawford 2013
96 Schweigert et al. 2009
97 Irvine and Crawford 2013
98 Boldt et al. in Irvine and Crawford 2013
99 Tanasichuk, 2012
100 Boldt et al. in Irvine and Crawford 2013
101 Schweigert et al. 2010

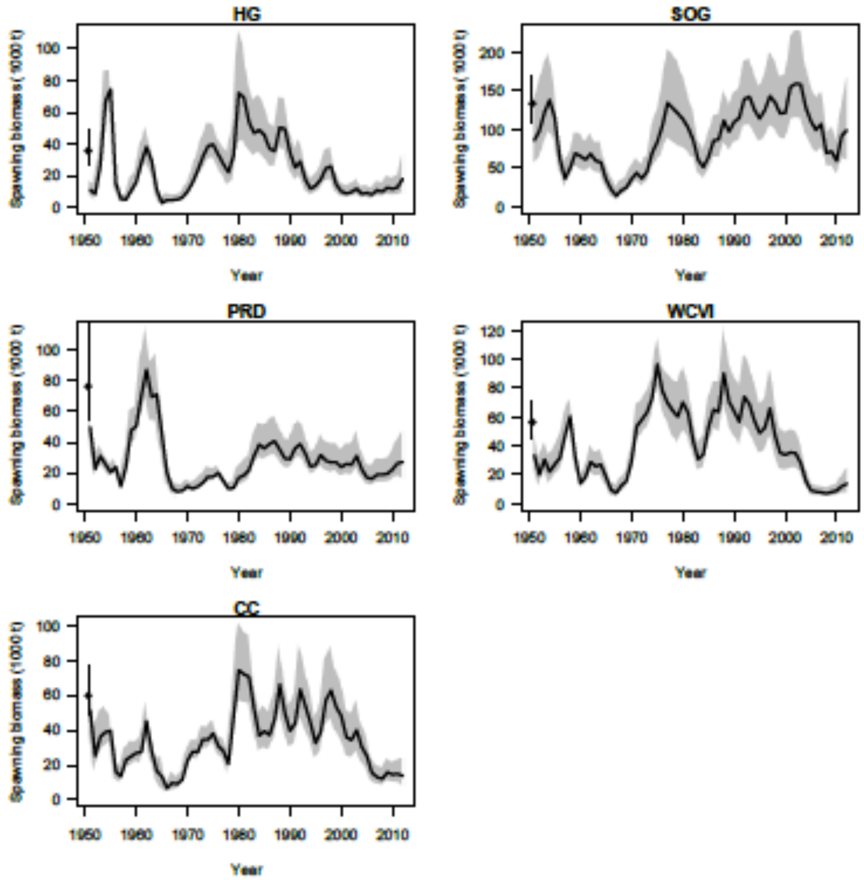

Figure 2. Median posterior density estimates of spawning stock biomass (Bt) for the five major stock areas, 1950-2012. Biomass is in thousands of metric tonnes (Bt) and scales differ between panels. The shaded envelope represents 90% of the distribution in estimates of Bt. Dark circle and extending vertical lines (at year 1950) represent the median estimates of unfished biomass, for the entire time series, and their distribution, for the major stocks only. [102]

[102] Boldt et al. in Irvine and Crawford 2013

Pacific Sardines (Pilchard)

Sardinops sagax caerulea (Jenyns, 1842)[103]


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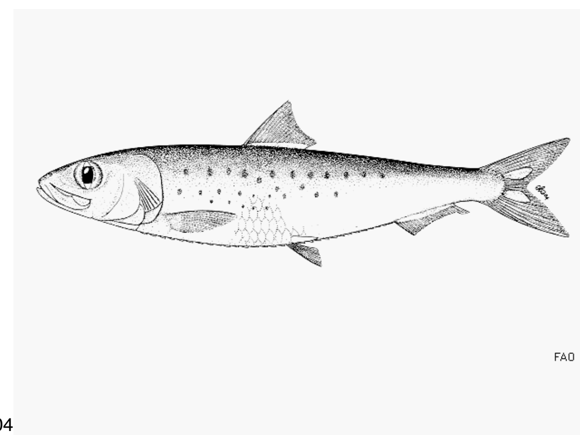


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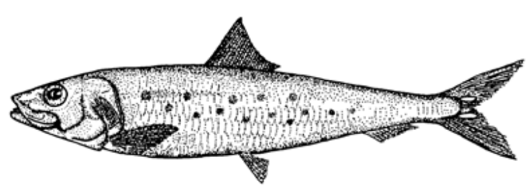
107

[103] Wikipedia: sardine
[104] http://www.fishwatch.gov/seafood_profiles/species/sardine/species_pages/pacific_sardine.htm
[105] http://tritonseafoods.com/Products
[106] http://www.fishbase.org/Photos/PicturesSummary.php?StartRow=3&ID=1477&what=species&TotRec=7
[107] DFO 2013.

Taxonomy

Worldwide, the terms "sardine" and "pilchard" are used interchangeably and inconsistently to refer to many species of small, oily pelagic clupeid fish. It is usually a term used for the Sardinops found in a local region[108]. This author has heard locals along the Inside Passage refer to "pilchards" (and, notably, humpbacks feeding upon them in Fitz Hugh Sound). The name "sardine" may come from the Mediterranean island of Sardinia, around which the fish was once abundant. [109]

The sardine species occurring throughout the Pacific Ocean[110], here called the Pacific herring or California Current herring, has also been called the South American pilchard[111].

Identification

- The north Pacific sardine grows 6 to 10 inches[112], depending on age; maximum 16 inches at 10 years[113]
- Black spots along their lateral line.
- A proportionally larger head than herring.
- They do have an adipose fin.
- A more sharply pointed and angular dorsal fin, accentuated by its pigmentation to look almost like a spine.
- Deeply forked caudal fin.
- A more convexly curved back than herring.
- Striations on gill cover.[114]

Life history

Most sardine biomass in the region is contributed by individual fish that are greater than 20cm fork length and 2 years old or more. [115] Sardines are relatively long-lived, the maximum reported age being 25 years.[116] Annual abundance, year class, and recruitment can vary greatly. At times, a single strong year class can comprise a major proportion of a stock for several years[117].

Seasonal Geography

The North Pacific sardine of the California Current ranges from San Diego California to Alaska. [118],[119] The population migrates annually en masse between southern California, where they spawn in winter and spring, to temperate waters (from Washington to Alaska) where they feed during summer and fall[120],[121],[122].. The older and larger fish tend to move even further north into BC waters[123],[124].

Their latitudinal range varies according to a variety of conditions, including their own abundance. See sections below. Low sardine production and contracted distribution has been associated with cold years, while increased biomass and latitudinal range has been associated with warmer years[125], El Nino events (such as the 97-98 El

[108] Wikipedia: sardine
[109] Wikipedia: sardine
[110] https://www.dfg.ca.gov/marine/cpshms/pacificsardine.asp
[111] Wikipedia: sardine
[112] http://www.fishwatch.gov/seafood_profiles/species/sardine/species_pages/pacific_sardine.htm
[113] Love 1991.
[114] Love 1991.
[115] DFO 2013.
[116] Whitehead 1985.
[117] DFO 2013.
[118] http://www.fishwatch.gov/seafood_profiles/species/sardine/species_pages/pacific_sardine.htm
[119] DFO 2013.

[121] DFO 2013.
[122] Hill et al 2010
[123] Clark and Janssen 1945, Flostrand et al. 2011
[124] DFO 2013 Sardines.
[125] Hill et al. 2011, Jacobson and MacCall 1995, Jacobson and MacCall 1995, McFarlane et al. 2001, Zwolinski et al. 2011, Zwolinski et al. 2012.

Nino) may induce rapid short-term northerly expansions of their range[126]. The timing of the northward migration seems to be influenced particularly by water temperature, particularly the 12ºC isotherm[127].

In some years sardines have remained in Canadian waters year-round.[128] In recent years, sardine have been rare offshore but abundant in the inlets and coastal waters of Western Vancouver Island[129]. It does not seem that they are well sampled for in northern BC waters (Hay, pers. comm.).

Ecology

As Predators
Sardine are active planktivorous filter feeders[130]. In BC, the most important prey items for the sardine in British Columbian waters are diatoms, euphausiids, euphausiid eggs, copepods, and oikopleurids (larvaceans).[131] In one study from 1997 fieldwork, euphausiids were found in over 55% of sardine stomachs and contributed nearly 60% of the overall stomach contents volume[132].

As Prey
Given that larger and older sardines migrate further north, sardines in the Kitimat Fjord System are not likely to be targeted by seabirds. If they are indeed preyed upon by humpbacks, it is unknown whether bubble-net tactics are effective on them. However, coordinated humpback group feeding – primarily shallow or surface lunges – may be used to feed upon sardines (James Pilkington, pers. comm.).

Of Fish: Coho and Chinook Salmon[133], Spiny Dogfish and other sharks, Albacore Tuna and other tuna, Pacific Hake, jack mackerel [134]

Of Marine Mammals: Humpback Whales, California Sea Lions and other pinnipeds[135] Seasonal migrations of sardines coincide with those of salmon and humpbacks, who love eating sardines.[136] Predators of sardine must be able to cope with the extreme fluctuations in their abundance and distribution[137].

Competition: No information on competition was found.

Fishery

Pacific sardine began being targeted intensively in World War I to fill the increased demand for canned, battlefield-ready meals[138]. From the mid-1920's to mid-1940's, the Pacific sardine fishery was the largest of any fishery in the world, averaging 40,000 tons annually[139]. But in 1947, the BC sardine fishery collapsed and the fish disappeared from BC waters[140]. The California fishery followed suit in the early 1950's[141]. This decline has been attributed to both environmental conditions and overfishing[142],[143].

[126] McFarlane et al. 2005
[127] Ware 2001
[128] McFarlane et al. 2005
[129] McFarlane et al. 2005
[130] https://www.dfg.ca.gov/marine/cpshms/pacificsardine.asp
[131] McFarlane et al. 2005
[132] McFarlane et al. 2005
[133] Chapman 1936
[134] DFO 2013.
[135] DFO 2013.
[136] DFO 2013.
[137] Flostrand et al. in Irvine and Crawford 2013
[138] https://www.dfg.ca.gov/marine/cpshms/pacificsardine.asp
[139] McFarlane et al. 2005
[140] McFarlane et al. 2005
[141] Flostrand et al. in Irvine and Crawford 2013
[142] Clark and Marr 1955, Jacobson and MacCall 1995
[143] Flostrand et al. in Irvine and Crawford 2013

After a 45-year absence, sardine were found again in BC waters during hake trawls[144] off southern Vancouver Island in 1992.[145] In the years following, the sardine's distributed expanded north. By 1998, it was found throughout the West Coast waters of Vancouver Island (WCVI), Hecate Strait and Dixon Entrance.[146]

The resurgence of B.C. sardine fishing began in 1995 as experimental fishery[147]. Gillnet and trap fisheries were opened in 2001 and 2002 with a commercial designation, but they were soon replaced with sein practices[148]. At first, due to competing fisheries and market prices, catch totals were initially small relative to the total allowable catches[149].

Since those experimental fisheries, sardines have been caught predominantly with purse sein nets[150]. From 2004 onward, sardines were rare offshore and on the northern BC coast; however, large catches persisted in inlets and coastal waters of WCVI (mainly Pacific Fishery Management Areas (PFMA) 25 and 26) and Queen Charlotte Sound[151],[152],[153].

From 2008-2012, commercial B.C. Sardine landings have increased (10,435-22,538 tonnes).[154] Population and seasonal abundance estimates increased in 2011 as well. Given these developments, the Total Allowable Catch (TAC) for the 2012 fishing season was 27,279 tonnes, which was the highest level since the fishery re-opened.[155] Approximately 70% of the 2012 Total Allowable Catch was landed.[156]

Today fished sardines are used primarily for human consumption, pet food, and tuna feed (in international aquaculture operations)[157]. The stock is managed according to the Coastal Pelagic Species Fishery Management Plan[158]. Most B.C. waters have been open to commercial sardine fishing, except for areas of high bycatch concern and protected areas with permanent fishery closures[159].

Status

Population trends are inferred from an annual surface trawl survey by DFO off WCVI (which began in 1997[160], switched to night-time sampling in 2006, and provides percent migration rates from US to BC waters[161]), a US population stock assessment, and commercial landings (scaled by effort).[162] These data streams, particularly the trawl surveys, are used to forecast annual abundances and set TAC limits for the upcoming fishing season[163]. Because of the limited coverage of these surveys, the results are considered minimum estimates of BC sardine populations[164]

Historical sardine abundance has been extremely variable along the US and Canadian west coast, cycling over approximately 60-year periods.[165] The range of the Pacific sardine stock expands and constricts according to these changing abundances[166], age and size composition[167], environmental conditions – all of which interact in complex ways that are not fully understood[168].

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144 Hargreaves et al. 1994
145 Flostrand et al. in Irvine and Crawford 2013
146 Flostrand et al. in Irvine and Crawford 2013
147 Flostrand et al. in Irvine and Crawford 2013
148 McFarlane et al. 2005
149 Flostrand et al. in Irvine and Crawford 2013
150 http://www.fishwatch.gov/seafood_profiles/species/sardine/species_pages/pacific_sardine.htm
151 McFarlane et al. 2005
152 McFarlane et al. 2005
153 Flostrand et al. in Irvine and Crawford 2013
154 Flostrand et al. in Irvine and Crawford 2013
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157 https://www.dfg.ca.gov/marine/cpshms/pacificsardine.asp
158 https://www.dfg.ca.gov/marine/cpshms/pacificsardine.asp
159 Flostrand et al. in Irvine and Crawford 2013
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162 Flostrand et al. in Irvine and Crawford 2013
163 Flostrand et al. in Irvine and Crawford 2013
164 Flostrand et al. 2011.
165 Flostrand et al. in Irvine and Crawford 2013. Cushing 1971, Hill et al. 2011
166 Hargreaves et al. 1994, McFarlane and Beamish 2001.
167 Lo et al. 2010, Hill et al. 2012
168 https://www.dfg.ca.gov/marine/cpshms/pacificsardine.asp

In the California Current, the sardine population increased dramatically throughout the 1980s and 1990s[169] (peaking at approximately 1,300,000 tonnes in 1999, and in 2006 and 2007[170]).

From 2008-2011, overall sardine stocks seemed to be increasing in BC waters[171] and migration rates were remaining fairly constant (between 10 and 12%, similar to 1950's rates)[172], but evidence of decline became apparent in WCVI catch data in 2006[173]. Then, extremely low densities were observed in WCVI waters in 2012[174],[175] (but they may have been a result of poor survey conditions and timing[176]). The last strong recruitment year was 2009[177]. A disjoint between migration rates and landings trends may be evidence of confounded changes in both population and migration patterns[178].

The most current population biomass estimate for age 1 year and older sardine is approximately 660,000 tonnes (as of July 2012).[179] The total BC catch that year was 20,621 tons (approx.. 95% of the TAC) [180]. In that year, all commercial landings occurred off the WCVI. [181]

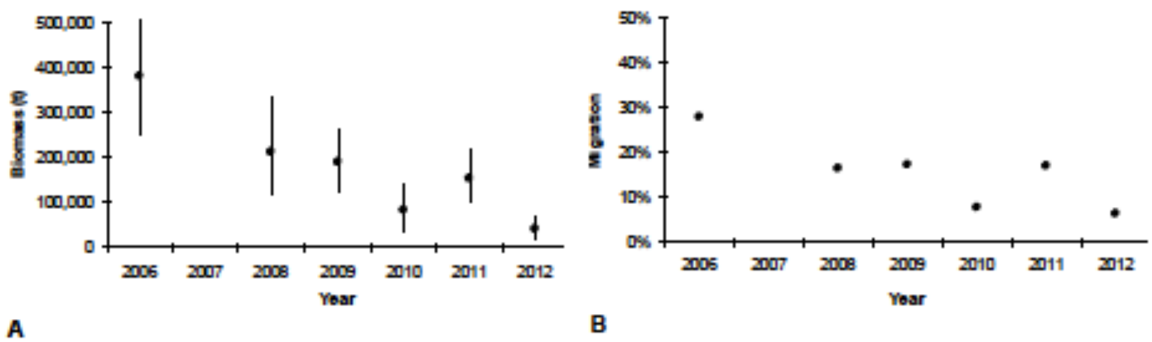


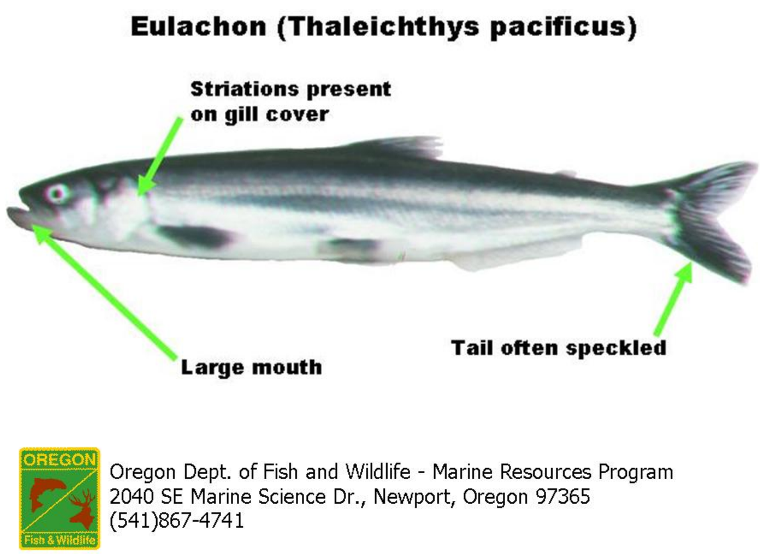
Figure 2. West coast of Vancouver Island (WCVI) summer trawl survey 2006, 2008-2012 (A) biomass estimates and 90% confidence intervals, and (B) migration rate estimates (calculated by year as WCVI biomass (panel A means) divided by age 1+ population biomass (Fig. 3 below from Hill et al., 2012). Migration rates are estimates of the proportions of the adult population that seasonally migrate into waters off the WCVI by mid summer when the DFO survey is conducted (late July/early August). [182]

[169] Irvine and Crawford 2013
[170] Flostrand et al. in Irvine and Crawford 2013
[171] Flostrand et al. in Irvine and Crawford 2013
[172] Flostrand et al. 2011.
[173] Flostrand et al. in Irvine and Crawford 2013
[174] Irvine and Crawford 2013
[175] Irvine and Crawford 2013
[176] Irvine and Crawford 2013
[177] DFO 2013.
[178] Flostrand et al. 2011.
[179] Flostrand et al. in Irvine and Crawford 2013
[180] Flostrand et al. in Irvine and Crawford 2013
[181] Flostrand et al. in Irvine and Crawford 2013
[182] Flostrand et al. in Irvine and Crawford 2013

Eulachon

Thaleichthys pacificus (Richardson, 1836)[183]

184



185

186

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183 http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=162051
184 http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=162051
185 http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=162051
186 http://www.cbc.ca/news/canada/british-columbia/camps-face-worker-shortage-as-eulachon-fishery-rebounds-1.1301486
187 http://www.adfg.alaska.gov/index.cfm?adfg=eulachon.photogallery&number=3

Taxonomy

- Order: Salmoniformes, Family: Osmeridae (the smelts).[188],[189]
- Pronounced “oolikan”.
- Also called oolichan, hooligan, ooligan, or candlefish (because it is so oily that, when caught and dried and lit on fire, the fish will slowly burn like a candle),

Identification

- Long anal fin (18-23 rays)[190]
- Elongate body shape (but not as lance-like as a sand lance).
- Hand-length. Age 1 eulachon average about 9-10 cm, and age 2 eulachon average about 14.5-15 cm.[191]
- Significant underbite.
- Caudal fin rounded and not as deeply indented as in herring and sardines.
- Tiny black dots on backs and sometimes on caudal fins.[192]
- They do have a sickle-shaped adipose fin.[193]
- Pectoral fins are longer in males than in females.[194]
- Circular striations on gill cover.[195]
- Teeth are often present, sometimes as large canines on the vomer bone.[196,,197]
- Adult coloration: brown to blue on back and top of head, silvery white on sides, white on ventral surface. Speckling, if any, is fine and restricted to the back.[198]
- Relatively large mouth.[199]
- Stick a wick in it ‘n’ light ‘er up![200], [201]

Life History

The eulachon is anadromous[202], meaning it returns to an ancestral river to spawn, and semelparous, meaning individuals die immediately after a single breeding event.

Most eulachon live to three years[203], at which age they return to ancestral streams, spawn and die. Some, however, may live two or four years. Eulachon are also known, rarely, to spawn twice in a lifetime.[204] Like other North Pacific fish species, there may be a latitudinal cline in the age at which eulachon spawn; more to the south live only two years, and more in Alaskan rivers are four years of age.[205]

Before spawning, eulachon are typically offshore and demersal[206]. The timing of their inshore migration to freshwater spawning grounds seems triggered by the arrival of warmer water temperatures (4-10 degrees C) and high tides[207], meaning spawning migrations are staggered up the coast, with early spawns generally in the south and later spawns generally in the north.[208]. In BC, these runs occur from late February to early April.[209]

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188 Schweigert et al. 2012.
189 Wilson et al. 2006.
190 http://en.wikipedia.org/wiki/Eulachon
191 http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/ocean1-eng.html
192 Love 1991.
193 http://en.wikipedia.org/wiki/Eulachon
194 http://en.wikipedia.org/wiki/Eulachon
195 Love 1991.
196 http://en.wikipedia.org/wiki/Eulachon
197 Wilson et al. 2006.
198 http://en.wikipedia.org/wiki/Eulachon
199 Wilson et al. 2006.
200 Love 1991.
201 http://en.wikipedia.org/wiki/Eulachon
202 http://en.wikipedia.org/wiki/Eulachon
203 Schweigert et al. 2012.
204 Wilson et al. 2006.
205 Gustafson et al. 2010
206 Schweigert et al. 2012.
207 Ricker et al. 1954; Bargman in Eulachon Research Council 2000; Prince Rupert Forest Region 1998.
208 Wilson et al. 2006.
209 Wilson et al. 2006.

Seasonal Geography

Eulachon can be found from northern California to Alaska.[210] Eulachon is perhaps the most abundant smelt near Haida Gwai'i[211]. In the Bering Sea, eulachon are reported to be concentrated between the area around Unimak Island and the end of the Alaska Peninsula and the Pribilof Islands (P. J. Anderson, unpubl. data, Kodiak Laboratory, National Marine Fisheries Service).[212]. Near the outer Kenai Peninsula and southwestern Prince William Sound, eulachon are found outside some bays in summer and at the head of other bays in winter[213]. In northern Southeast Alaska, eulachon are known to be common in the coastal fjords.[214]

Offshore Distribution

When not spawning, eulachon are found on the offshore shelf. There distribution there is not well understood, though it may be responsive to oceanic conditions[215]. While offshore, eulachon are demersal with shrimp, and so not expected to be too abundant in the study area (Hay, pers. comm.)

Adults and juveniles forage at moderate depths in shelf waters[216],[217]. Reported depth preferences include: 80m - 200m on the offshore shelf of Dixon Entrance and the Hecate Strait[218]; commonly 20-200 m, but may occur as deep as 500 m[219],[220]; as deep as 625m[221],[222], 30m to 180m in Prince William Sound (Gotthardt 2001, Ref. 170)[223].

Spawning Rivers

Spawning eulachon come to the lower reaches of *mainland* rivers in the early spring. Only a few island runs have been reported[224],[225]. Being anadromous, their site fidelity to ancestral streams has led to genetic structure in the northeast Pacific stock[226],[227]. Eulachon use only a select number of rivers along the North American west coast for spawning[228], at least forty of which occur in mainland B.C.[229],[230]. These include rivers in or near the Bangarang study area, in Douglas Channel, Gardner Canal, and Princess Royal Channel[231].

Young life stages

Young eulachon occur at a variety of depths, generally shallower than adults (e.g., 15m[232], but as deep as 182m[233]), and are often[234] but not necessarily demersal[235]. They are sometimes mixed in with schools of young herring and anchovy[236].

Larvae and fry become widely distributed[237] as they are advected from their stream or river of birth. In southern BC, for example, larve reach West Coast Vancouver Island by mid-summer[238].

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210 http://en.wikipedia.org/wiki/Eulachon
211 Gillespie and Westrheim 1997 in Wilson et al. 2006.
212 Wilson et al. 2006.
213 Brown et al. 2002
214 Carlson et al. [no date], in Wilson et al. 2006.
215 Gotthardt 2001
216 Hay and McCarter 2000
217 Wilson et al. 2006.
218 Watson et al. 2010
219 Hay and McCarter 2000; Anonymous in Eulachon Research Council 2000
220 Wilson et al. 2006.
221 Allen and Smith 1988 [Ref. 13] in Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001.
222 Wilson et al. 2006.
223 Wilson et al. 2006.
224 Wilson et al. 2006.
225 Blackburn et al. 1981
226 Beacham et al. 2005
227 Schweigert et al. 2012.
228 Schweigert et al. 2012.
229 Levesque and Therriault 2011
230 Schweigert et al. 2012.
231 Hay and McCarter 2000
232 Hay and McCarter 2000
233 Barraclough1964
234 Smith and Saalfeld 1955
235 Wilson et al. 2006.
236 Hay et al. 1992
237 Levings 1980
238 Hay et al. 1992

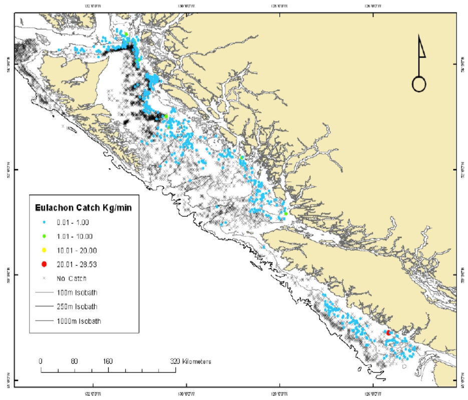

Figure 8 Eulachon catches from groundfish research surveys conducted in various areas of the BC coast from 2002-2010. 239

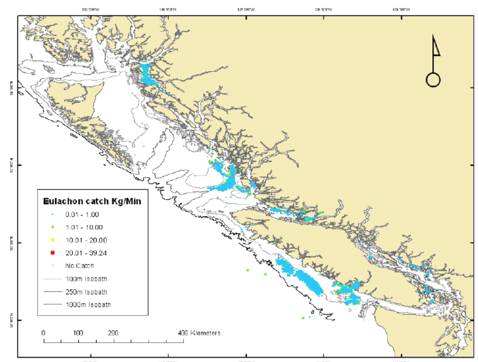

Figure 9 Eulachon catches from multispecies small mesh trawl research surveys conducted in various areas of the BC coast from 1967-2011. 240

FIGURES

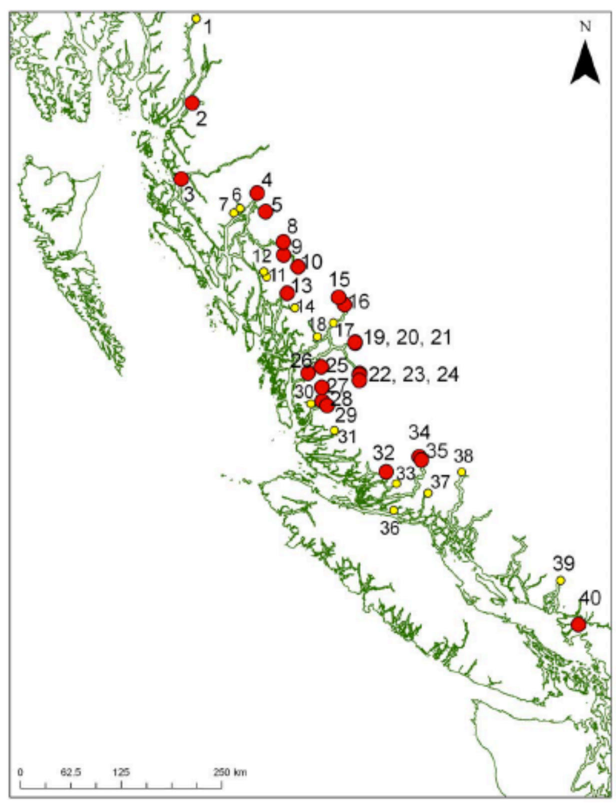

Figure 1: Eulachon spawning rivers in British Columbia. Red circles are confirmed rivers by the presence of adult eulachon and/or eggs or larvae (Hay and McCarter 2000, Moody 2008). Smaller yellow circles are probable rivers deduced from larval distribution and length frequency in the adjacent waters (McCarter and Hay 1999), from Levesque and Therriault 2011.

32

241

Ecology

As Predators

Eulachon feed primarily on euphausiids[242] (including Thysanoessa[243]), cumaceans[244], and copepods[245], but not during their spawning migrations[246]. Larvae and postlarvae eat phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, worm larvae, and eulachon larvae[247].

[239] Schweigert et al. 2012.
[240] Schweigert et al. 2012.
[241] Schweigert et al. 2012.
[242] Schweigert et al. 2012.

As Prey

The high lipid content (15% of body weight![248]) of eulachon render the species an important prey item for fish, mammals, and birds[249]. Individuals larger than 50mm are the most vulnerable to predation[250]. Eulachon abundance dynamics probably have cascading effects in the coastal food web. [251]

Of Fish

"…*Chinook and Coho Salmon, Spiny Dogfish, Pacific Hake, sturgeon, Pacific Halibut, Walleye Pollock, sablefish, rockfish, Arrowtooth Flounder..."*[252], [253].

"…sablefish, walleye pollock, and arrowtooth flounder..."[254]

"…white sturgeon, spiny dogfish, sablefish, salmon sharks, arrowtooth flounder, salmon, Dolly Varden, Pacific halibut, Pacific cod…"[255]

"Pacific hake is another species that has been identified as an important predator on eulachon in the west coast of Vancouver Island and Central coast regions"[256]

Of Marine Mammals

"…particularly sea lions in the estuaries, and porpoises,"[257]

"Marine mammals in British Columbia that are known to consume or have the potential to consume eulachon include part-time residents and migratory species, such as humpback whales (Megaptera novaeangliae), northern fur seals (Callorhinus ursinus), and California sea lions (Zalophus californianus), as well as resident species, such as harbour seals (Phoca vitulina) and Steller sea lions (Eumetopias jubatus)."[258]

"In general, eulachon has not been a significant component of the diet of any marine mammals, but determining their overall consumption is complex."[259]

"…baleen whales, orcas, dolphins, pinnipeds, belugas (Kajimura et al. 1980,Ref. 241; Huntington 2000, Ref. 223; Speckman and Piatt 2000, Ref. 402), and terrestrial mammals (brown bears, wolves)."[260]

"Harbor seals (Phoca vitulina) congregated at the early June spawning run in the Copper River (Imler and Sarber 1947, Ref. 224), apparently feeding exclusively on eulachon. Steve Moffitt (Alaska Department of Fish and Game; pers. comm.) reported that harbor seals outnumber Steller sea lions at eulachon runs in the Copper River area. In the Gulf of Alaska, eulachon was one of the top five prey of harbor seals (by volume, most samples from April to June) but was well behind pollock and octopus as a prey source for harbor seals (Pitcher 1980, Ref. 360)[261]

Marine birds[262]

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243 Barraclough 1964; Hay and McCarter 2000
244 Smith and Saalfeld 1955
245 Wilson, MF, RH Armstrong, MC Herman, K Koski. 2006. Eulachon:A review of biology and an annotated bibliography. AFSC PROCESSED REPORT 2006-12
246 http://en.wikipedia.org/wiki/Eulachon
247 Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001
248 http://en.wikipedia.org/wiki/Eulachon
249 Schweigert et al. 2012.
250 Schweigert et al. 2012.
251 Schweigert et al. in Irvine and Crawford 2013
252 Levesque and Therriault 2011
253 Schweigert et al. in Irvine and Crawford 2013
254 Schweigert et al. 2012.
255 Wilson et al. 2006.
256 Pickard and Marmorek 2007,Gustafson et al. 2010, Levesque and Therriault 2011.
257 Schweigert et al. in Irvine and Crawford 2013.
258 Schweigert et al. 2012.
259 Schweigert et al. 2012.
260 Wilson et al. 2006.
261 Wilson et al. 2006.
262 Schweigert et al. 2012.

Birds aggregate in intertidal zones and the mouths of rivers during eulachon spawning runs[263].

"…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, Ormseth et al. 2008)."[264]

In a Prince William Sound model, eulachon represented "*7% to 50%, by weight, of seabird diets: murres (7.4%), albatross and jaegers (8.3%), kittiwakes (10.1%), shearwaters (11.7%), puffins (14.2%), gulls (19.2%), cormorants (49.9%)*"[265].

"…*harlequin ducks, pigeon guillemots, common murres (Scott 1973, Ref. 387), mergansers, cormorants, gulls, eagles…*"[266]

"The response of gulls (Larus spp.) and bald eagles (Haliaetus leucocephalus) to eulachon runs can be dramatic (Drew and Lepp 1996, Ref. 127; Marston et al. 2002, Ref. 280). When the eulachon run began in Berners Bay, the number of gulls increased from a few thousand to more than 40,000 in just a few days, and the total number of eagles probably exceeded 1,000 as the run peaked and declined."[267]

As Competitors
It is possible that Pacific sardines compete with eulachon for prey, although the former is a surface species and the latter is demersal. The recent return of sardines to BC waters may be associated with eulachon decline[268,269]. Both feed extensively on euphausiids[270] (as do many recovering marine mammals in the region). "It should, however, be noted that sardine were abundant in the 1920s through the early 1950s, while eulachon were also apparently abundant in-river"[271].

The Fishery

First Nations
Eulachon are primarily harvested by First Nations on the BC Central Coast during their inland spawning migration[272]. This fishery is not well documented, so annual catch estimates are not available; best guess is an annual average of 150 tonnes[273]. Eulachon are a culturally important species to many Aboriginal groups[274]. Their oil, rich in Vitamin-D, has been used as a condiment by First Nations folks for centuries[275].

Commercial
Small commercial harvests occurred in Knight and Kingcome inlets in the 1940's[276],[277] and in the Fraser River[278]. Coast-wide, however, the spawning stock biomass has been below the action level (i.e., fisheries have been closed) since 2004[279]. When active, the fisheries occur in offshore regions, but occasionally in coastal areas in fjords or inlets (which acts as migratory corridors for eulachon) and at the mouths of spawning rivers[280].

Eulachon are also captured as bycatch in at-sea bottom trawl fisheries thare are targeting shrimp or groundfish

[263] Collison 1916, Marston et al. 2002
[264] Wilson et al. 2006.
[265] Ormseth etal. 2008
[266] Wilson et al. 2006.
[267] Wilson et al. 2006.
[268] Schweigert et al. 2012.
[269] Schweigert et al. 2012.
[270] Schweigert et al. 2012.
[271] Schweigert et al. 2012.
[272] Schweigert et al. 2012.
[273] Schweigert et al. 2012.
[274] Watson et al. 2010
[275] Love 1991.
[276] Moody 2008.
[277] Schweigert et al. 2012.
[278] Schweigert et al. 2012.
[279] Schweigert et al. in Irvine and Crawford 2013.
[280] Schweigert et al. 2012.

species, or in mid-water trawls for pelagics like hake[281]. In their spawning rivers, eulachon are captured with gillnets, seines or dipnets.[282]

Status

Eulachon stocks are assessed using 1) eulachon byatch in offshore fisheries, 2) commercial eulachon catches in the Fraser and Columbia rivers, and 3) annual egg and larval surveys in the Fraser River (the most active and current means of assessing the stock)[283].

In rivers throughout their distribution, eulachon have been in decline for the past decades[284],[285]. British Columbia indices remain at low levels[286]. In the early 2000's, there were virtually no catches in the Skeena or Kitimat Rivers near the study area[287].

These trends can have negative impacts for First Nations and commercial fishers[288]. No single threat has been identified, but possibilities include: log booming, dredging, discharge alteration of flow, runoff of pollution[289], and the increase in coastal aquaculture facilities[290]. Climate, predator community, and fishery pressure in the eulachon's oceanic stage seems to be more of a threat than changes in their riverine spawning stage[291].

In the US, the Columbia River Eulachon was listed as an endangered species, effective May 2010, and the regional fishery was closed. [292] BC fisheries have been predominantly closed in the 21st century. In Canada, COSEWIC manages eulachon as three populations, or designated units (DU): 1) Central Coast (endangered), 2) Fraser River (endangered), and 3) Nass/Skeena Rivers (under reassessment as of 2012). Recovery strategies for all three are being implemented. [293]

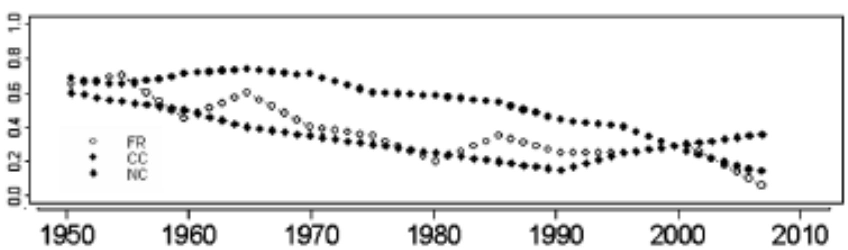
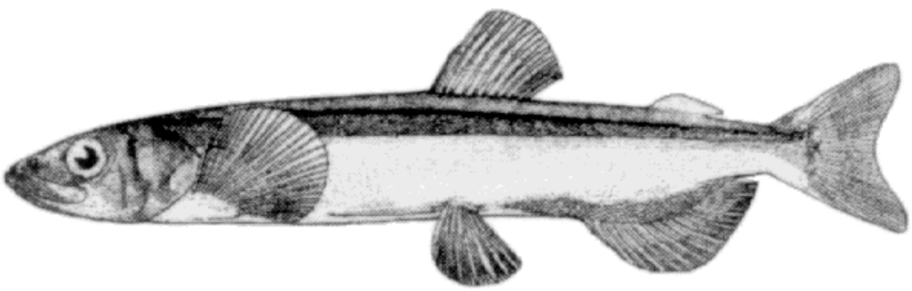


Figure 1. Estimated relative abundance trends for the three BC Eulachon designated units (DU); adapted from Schweigert et al. (2012). FR = Fraser DU, CC = central coast DU, NC = Nass/Skeena DU (symbols with post-1990 increasing trend). Y-axis is expressed in unit-less, relative values. [294]

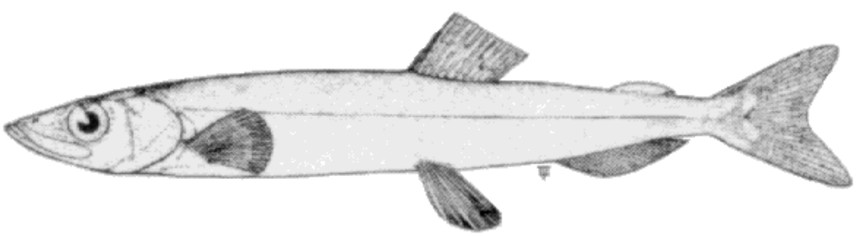
[281] Schweigert et al. 2012.
[282] Schweigert et al. 2012.
[283] Schweigert et al. in Irvine and Crawford 2013
[284] Irvine and Crawford 2013
[285] Schweigert et al. in Irvine and Crawford 2013
[286] Irvine and Crawford 2013
[287] Watson et al. 2010
[288] Schweigert et al. in Irvine and Crawford 2013
[289] Schweigert et al. 2012.
[290] Schweigert et al. 2012.
[291] Schweigert et al. in Irvine and Crawford 2013
[292] Schweigert et al. in Irvine and Crawford 2013
[293] Schweigert et al. in Irvine and Crawford 2013, COSEWIC 2011.
[294] Schweigert et al. in Irvine and Crawford 2013

Capelin

Mallotus villosus (Müller, 1776)



[295]



[296]

Taxonomy

- Order Salmoniformes, family Osmeridae
- Pronounced “cāpe-lin”

Identification

- Length: 15-19cm.[297]
- Maximum reported weight: 52 grams.[298]

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[295] Coad, BW. 1995. Encyclopedia of Canadian fishes. Canadian Museum of Nature and Canadian Sportfishing Productions Inc. Singapore.
[296] Coad, BW. 1995. Encyclopedia of Canadian fishes. Canadian Museum of Nature and Canadian Sportfishing Productions Inc. Singapore.

[297] http://www.fishbase.org/summary/252
[298] http://www.fishbase.org/summary/252

- Maximum reported age: 10 years. [299]
- Long adipose fin, with outer margin slightly curved. [300]
- Olive green on dorsal surface, silvery on sides and ventral. [301].
- As slender and long as a eulachon.
- Males have spawning ridge of raised scales along lateral line and base of the anal fin and long pectoral fins (second picture down) [302].

Life History

Capelin is an oceanic species[303], found in schools near the surface[304], that often enters brackish and fresh waters[305]. Capelin are semelparous[306], dying after they spawn, and they are anadromous – they migrate to inshore beaches of coarse sand or gravel to spawn. [307] They spawn at age 2 or 3, at 11-17cm[308],[309].

Seasonal Geography

Capelin are circumboreal and circumpolar in the Arctic; in the northeast Pacific, they can occur down to Juan de Fuca Strait[310],[311]. The Kitimat Fjord system lay at the southern terminus of the capelin's typical range, and therefore would be episodic and uncommon in the study area (Hay, pers. comm.)

Capelin spend most of their lives offshore, moving inshore only to spawn[312]. They are offshore in the winter, then the spawning population migrates inland for a mid-summer spawn. While offshore, capelin are found in surface and intermediate layers[313] as deep as 725m[314].

In the spring large spawning shoals migrate toward the coasts. Males usually arrive first.[315] In the northeast Pacific, spawning occurs from mid-May to late July[316]. During summer months, capelin perform vertical migrations that do not have a diurnal rhythm. [317]. Spawning generally occurs at depths less than 75 m[318].

Summer is also the feeding period for capelin, who share the juvenile walleye pollock's preference for foraging over the continental shelf[319]. In this season, adult distribution in relation to shore seems related to the local width of the continental shelf[320]. Over a broad shelf, like in the Bering Sea, capelin are found 100 or more kilometers offshore, moving inshore only to spawn[321]. Over a narrow shelf, like in southeast Alaska and near Kodiak[322], capelin are found near shore and in bays and fjords in the summer[323].

In polar latitudes, capelin move latitudinally with the sea ice, south as the ice advances and north as the ice retreats; this is in addition to their inshore spawning movements[324]. In the Gulf of Alaska, which remains ice-free year- round, capelin overwinter in bays[325].

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[299] http://www.fishbase.org/summary/252
[300] http://www.fishbase.org/summary/252
[301] Carscadden 1981, Mecklenburg et al. 2002, Nelson 2003
[302] McClory and Gothardt 2005.
[303] http://www.fishbase.org/summary/252
[304] http://www.fishbase.org/summary/252
[305] http://www.fishbase.org/summary/252
[306] http://www.fishbase.org/summary/252
[307] http://www.fishbase.org/summary/252
[308] Winters 1970, Hart 1973
[309] McClory and Gothardt 2005.
[310] http://www.fishbase.org/summary/252
[311] McClory and Gothardt 2005.
[312] McClory and Gothardt 2005.
[313] Gjøsæter 1998
[314] http://www.fishbase.org/summary/252
[315] http://www.fishbase.org/summary/252
[316] McClory and Gothardt 2005
[317] Gjøsæter 1998
[318] Pahlke 1985
[319] Logerwell et al. 2007.
[320] McClory and Gothardt 2005.
[321] McClory and Gothardt 2005.
[322] Brown 2002 and references therein
[323] McClory and Gothardt 2005.
[324] Gjøsæter 1998, Hjermann et al. 2004
[325] Nelson 2003

Ecology

As Predators

Capelin feed mostly during crepuscular periods. [326]
"Adults feed on planktonic crustaceans, copepods, euphausiids, amphipods, marine worms, and small fishes."[327]
"Capelin and juvenile pollock are both zooplanktivorous, foraging primarily on calanoid copepods and euphausiids[328]*;, but also on larvaceans, amphipods and other zooplankton prey."*[329]
"Only the largest capelin offshore (105–114 mm SL) consumed euphausiids (furciliae, juveniles and adults combined)." [330]

As Prey

Capelin is also an important forage fish, serving as prey for seabirds [331], groundfish [332] and marine mammals[333], [334].

"Capelin are a high energy food source and play a key role in marine food webs, transferring energy to higher level predators such as large fishes (e.g., cod, herring, and halibut), marine mammals (e.g., humpback whale, Steller sea lion), and birds (e.g., Common Murre, Black-legged Kittiwake)"[335].
"Predation can be high during and after spawning events (e.g., large predatory fish, such as halibut, gorge themselves on spawning capelin)."[336]
"In the Gulf of Alaska, their primary fish predators include arrowtooth flounder (Atheresthes stomias), Pacific cod (Gadus macrocephalus), Pacific halibut (Hippoglossus stenolepis), walleye pollock (Theragra chalcogramma)."[337]

As Competitors

Several studies have investigated the competitive interactions between capelin and juvenile (age 0) wall-eye pollock, another major forage fish in the region. Alternate fluctuations in the abundance of capelin and age-0 pollock have been associated with reorganizations of the GOA ecosystem.[338] The two species' diet overlap is very high[339]. This competition may have led to behavioral isolation: capelin feed mostly during crepuscular periods while Pollock mostly feed at night.[340] One study found evidence for the competitive exclusion of capelin from preferred habitat by age-0 pollock[341]. Wilson et al. (2006) hypothesized that, in response to limited prey availability (specifically euphausiids), capelin move to other foraging areas while age-0 pollock prey-switch[342].

The Fishery

There is no capelin fishery in the northeast Pacific, but they are taken incidentally as bycatch[343].

Status

Because there is no fishery in the northeast PAcific, this author has found no stock assessments or reported trends. Capelin were certainly abundant throughout 1970s small-mesh trawls in the Gulf of Alaska[344], and large spawning aggregations have recently been documented in Prince William Sound and the Gulf of Alaska[345].

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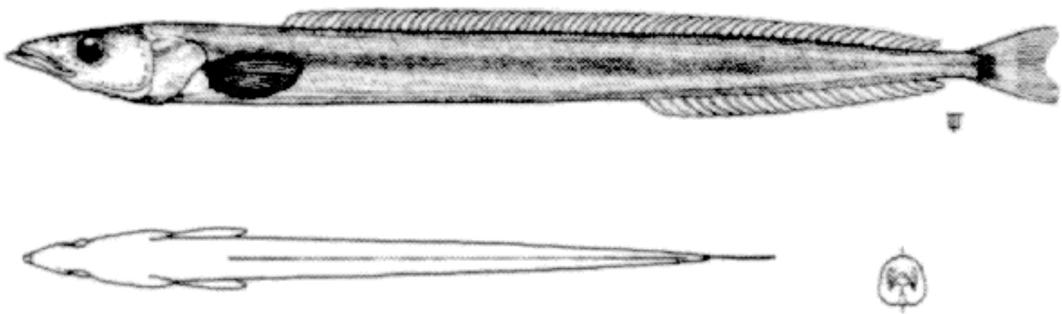
[326] Wilson et al. 2006.
[327] http://www.fishbase.org/summary/252
[328] Vesin et al., 1981; Naumenko, 1984; Brodeur and Wilson, 1996; Sturdevant, 1999, O'Driscoll et al., 2001; Orlova et al., 2002
[329] Gjøsæter, 1998; Wilson et al., 2005
[330] Logerwell et al. 2010
[331] Hatch and Sanger, 1992
[332] Jewett, 1978
[333] Sinclair and Zeppelin, 2002
[334] Logerwell et al. 2010
[335] Montevecchi and Piatt 1984, Erikstad 1990, Gjøsæter 1998, Payne et al. 1999
[336] McClory and Gothardt 2005.
[337] Yang et al. 2005
[338] Wilson et al. 2006.
[339] Wilson et al. 2006.
[340] Wilson et al. 2006.
[341] Logerwell et al. 2010
[342] Wilson et al. 2006.
[343] McClory and Gothardt 2005.
[344] Brown 2002
[345] Brown 2002

Pacific Sand Lance

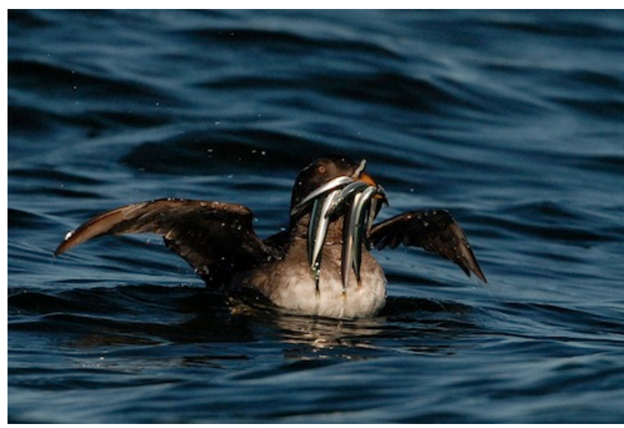
Ammodytes hexapterus (Pallas, 1814)[346]

[347]



[348]

[349]



[350]

Taxonomy

Subclass: Actinopterygii
Infraclass: Neopterygii
Division: Halecostomi
Subdivision: Teleostei
Infradivision: Euteleostei
Superorder: Acanthopterygii
Order: Perciformes
Suborder: Ammodytoidei
Family: Ammodytidae
Subfamily: Ammodytinae
Genus: *Ammodytes*

There are six recognized species within this genus in temperate and boreal regions.[351]

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[346] http://www.fishbase.org/summary/3822
[347] http://www.fishbase.org/summary/3822
[348] Coad, BW. 1995. Encyclopedia of Canadian Fishes. Canadian Museum of Nature and Canadian Sportfishing Production Inc. Singapore.
[349] http://pugetsound.org/science/what-we-do/citizen-science/WP_000586.jpg/view
[350] http://blog.oceanriver.com/celebrating-the-summer-solstice/
[351] Robards and Piatt. 1999.

Species: *personatus, hexapterus, americanus, dubius, marinus, tobianus*[352]

There is a single northeast Pacific species:[353] *A. hexapterus* Pallas 1814: Pacific sand lance. Also known as "sand eels". [354]

Etymology: *Ammodytes*: Greek, ammos = sand + Greek, *dytes* = anyone that likes immersions, diving.[355]

Identification

- Slender, elongate[356],[357], and sub-cylindrical[358] body
- 5-8 inches in length[359],[360].
- 100 grams[361].
- Needle-like nose[362],[363].
- Silvery sides, gray-green above.
- These fish do not have pelvic fins and do not develop swim bladders, staying true to their bottom-dwelling habit as adults. [364]
- Dorsal and anal fins have soft rays only – no spines[365].
- No teeth[366]
- No adipose fin.
- Scales almost invisible.
- Long dorsal fin.
- Lower jaw projects forward beyond the upper jaw (thought to be an adaptation for digging into substrates); [367]
- Caudal fin is forked.

Life history

Sand lances (reviewed thoroughly in Robards et al. 1999) are actively pelagic as they feed in the daytime, but they rest in the benthos – usually sand -- at night. These movements are crepuscular[368], although it is unclear if sand lance that enter the water column at dawn are active throughout daylight hours. In their daily pelagic phase, both adults and juveniles form well-formed schools[369]. They lack a swim[370].

Because they use shallow intertidal substrates, they can become exposed to air at extreme low tides. Sand lance can survive for at least 5.5 hours in damp exposed sand[371]. On hot days, a physiological threshold (perhaps heat-induced high metabolic rates conflicting with hypoxic environments) may induce schools of sand lance to surface spontaneously, leading to intense foraging events.[372],

Spawning occurs in late September and October on fine gravel and sandy beaches, soon after the summer when water temperatures begin to decline[373]. Spawning occurs in dense, writhing formations. Eggs are demersal and slightly adhesive. These eggs overwinter until prior to the spring plankton bloom. Larvae hatch at

[352] Robards and Piatt. 1999.
[353] Robards and Piatt. 1999.
[354] http://www.fishbase.org/summary/3822
[355] http://www.fishbase.org/summary/3822
[356] http://en.wikipedia.org/wiki/Sand_lance
[357] http://www.whatcom-mrc.whatcomcounty.org/Fact_Sheets/sandlance.htm
[358] Robards and Piatt. 1999.
[359] http://en.wikipedia.org/wiki/Sand_lance
[360] http://www.whatcom-mrc.whatcomcounty.org/Fact_Sheets/sandlance.htm
[361] http://www.fishbase.org/summary/3822
[362] http://en.wikipedia.org/wiki/Sand_lance
[363] http://www.whatcom-mrc.whatcomcounty.org/Fact_Sheets/sandlance.htm
[364] http://www.whatcom-mrc.whatcomcounty.org/Fact_Sheets/sandlance.htm
[365] Robards and Piatt. 1999.
[366] Hart 1973, Nelson 1994, Pietsch and Zabetian 1990
[367] Robards and Piatt. 1999.
[368] Hobson 1986, Inoue and others 1967
[369] Dick and Warner 1982, Inoue et al.1967, Macer 1966, Meyer et al.1979, Reay 1970
[370] Robards and Piatt. 1999.
[371] Robard and Piatt 1999.
[372] Dick and Warner 1982
[373] Robards and others 1999

a size of 4.5 to 5.5 millimeters[374] .

North Pacific sand lance live 7 to 11 years. [375]

Seasonal Geography

The North Pacific sand lance occurs from Baja California to the Beaufort Sea, as far west as the Japanese coast.[376] They are common in brackish waters and inlets[377].

Within their wide range, populations are patchily distributed among habitats of suitable shallow substrate . The sand lance can occur in large schools near the surface both inshore and offshore . While inshore, it is found in the intertidal and subtidal area, most commonly at depths less than 50 meters ; (often less than 6 meters , but as deep as 275m). Offshore, it is near the surface over deep water .

During early summer, adult sand lance (mostly second year) are the most abundant of early winter-spawning species. Later in the summer, juveniles become the most numerous age class as they migrate inshore and recruit to nearshore populations. Older fish seem to disappear early in summer, possibly because of reduced food requirements for growth or the need for earlier accumulation of fat [378]. They appear to be predominately dormant in the winter.

Ecology

As Predators

Larval sand lances target phytoplankton, from diatoms to dinoflagellates[379]. Adult sand lances feed primarily on copepods[380, 381, 382] (particularly *Calanus* – the major food source for adult lances[383].), but also chaetognaths, mysids, fish larvae and euphausiids[384]. In the winter, more of their food come from fellow epibenthic organisms.[385]

As Prey

*"*Ammodytes *are a quintessential forage fish, and as a group are possibly the single most important taxon of forage fish in the Northern Hemisphere"[386].*

"Sand lance constitute a major prey for at least some populations of over 100 species of consumer, including 40 species of birds, 12 species of marine mammals, 45 species of fishes, and some invertebrates."[387]

During their vertical migration, sand lances are preyed upon intensively by seabirds and marine mammals. Their easily swallowed cylindrical bodies[388] can be carried by the dozens in the beaks of small seabirds[389]. Sand lance availability has been correlated to reproductive success in at least 10 avian species: great skua, parasitic jaeger, shag, black-legged kittiwake, arctic tern, common tern, common murre, Atlantic puffin, tufted puffin, and rhinoceros auklet.[390]

[374] Field 1988
[375] http://www.fishbase.org/summary/3822
[376] Craig 1984, Hashimoto 1984, Kitaguchi 1979, Trumble 1973
[377] http://www.fishbase.org/summary/3822
[378] Winslade 1974c
[379] Trumble 1973
[380] Field 1988, O'Connell and Fives 1995, Scott 1973
[381] Robards and Piatt. 1999.
[382] http://en.wikipedia.org/wiki/Sand_lance
[383] e.g., Field 1988, O'Connell and Fives 1995, Scott 1973
[384] Craig 1987
[385] Rogers et al. 1979
[386] Springer and Speckman 1997
[387] Robards and Piatt. 1999.
[388] Wilson et al. 1999.
[389] e.g., Ainley et al.1996, Harris and Hislop 1978, Hislop et al.1991
[390] Robards and Piatt. 1999.

The sand lance's hearing may have been adapted to detect environmental cues and the pulsed signals of predatory humpback whales, a species which can scuff the seafloor with their jaws to flush sand lances from the substrate[391].

The relative importance of sand lace in the diets of seabirds in study area, based on studies from BC or AK-GOA (taken from Wilson et al. 1999):
Red-throated loon chicks, 10-50%,[392]
Sooty shearwater, >50%, Sealy 1973
Double-crested cormorant chicks, 10-50% [393]
Pelagic cormorant, chicks and adult, 10-50%,[394]
Mew gull, 10-50%,[395]
Glaucous-winged gull, chick and adult, 1-50%,[396]
Black-legged kittiwake, 10-50% chicks and adults,[397]
Arctic tern, <10% adult, 10-50% chicks,[398]
Common Murre, 10 – 50 %,[399]
Pigeon guillemot, <10% adults, >50% chicks[400]
Rhino auklet, >50% chicks,[401] (And many more citations)
Cassin's Auklet (>50% adults,[402]
Ancient Murrelet, none in winter, 10-50% in subadult, >50% in fledglings.[403]
Marbled Murrelet >50% chicks and adults[404]

Relative importance of sand lance to Marine mammals of study area based on BC and GOA studies (taken from Wilson et al. 1999):
Harbor seal: 10-50%,[405]
Stellar Sea Lion, none,[406]
Humpback whale – unknown
Fin whale – unknown

As Competitors
Sand lances have been observed schooling with herring, but it may be because the two species are both predator and prey for the other (herring eating sand lance[407]; and sand lance eating herring[408]).

The Fishery
There is no sand lance fishery in the northeast Pacific.

Status
This author has found no status data for Pacific sand lances (perhaps because there is no fishery).

Other
The sand lance's lack of a swim bladder results weak echo returns during hydroacoustic surveys.[409]

[391] Hain and others 1995
[392] Reimchen and Douglas 1984
[393] Robertson 1974
[394] Robertson 1974, Sanger 1986, 1987
[395] Sanger 1986
[396] Baird 1990, Baird and Gould1986.
[397] Baird 1990, Hatch et al 1978
[398] Baird 1986, Sanger 1986
[399] Vermeer 1992
[400] Hayes and Kuletz 1997, Krasnow and Sanger 1986
[401] Burger et al. 1993
[402] Burger and Powell 1990
[403] Gaston et al 1994
[404] Carter 1984, Carter and Sealy 1990, Mahon and others 1992, Vermeer 1992, Vermeer and Moira 1986, Hobson et al.1994
[405] Olesiuk et al 1990
[406] Fiscus and Baines 1966
[407] Hopkins et al.1989
[408] Rankine and Morrison 1988
[409] Robards and Piatt. 1999.

Others to Consider

Northern Anchovy

Engraulis mordax mordax

[410]

A schooling fish of the family Engraulidae in the Clupeiformes. Anchovies are translucent with a silver stripe and green back. They do not have an adipose fin[411]. Their caudal fin is forked, perhaps most notably, have a prominent snoot[412]. The upper jaw extends back well beyond eye, giving the mouth an underslung and dopey[413] look[414]. They grow to 10 inches. They are most abundant from Point Conception south to Baja and the Queen Charlotte Islands (west of the Bangarang study area) are the northern extent of their range[415]. Anchovies are filter feeders who use large eyes to seek out planktonic prey.[416]

Walleye Pollock

Theragra chalcogramma

[417]

[418]

juveniles

Pollock seems a very common fish in the Gulf of Alaska, but this author found little information about their presence on the BC coast. The Alaska Fish and Game website shows their range ending at the Alaska-Canada border, but that may be a management zone and not their true range[419]. In the Gulf of Alaska, age-0 walleye pollock are key forage fish[420], [421], [422]. It is a target species for one of the world's largest fisheries.[423]

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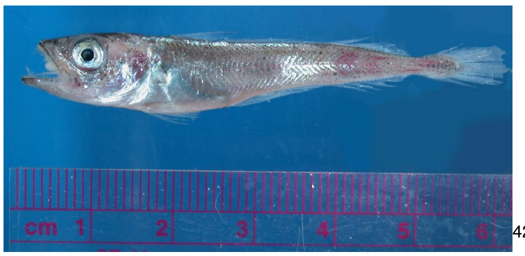
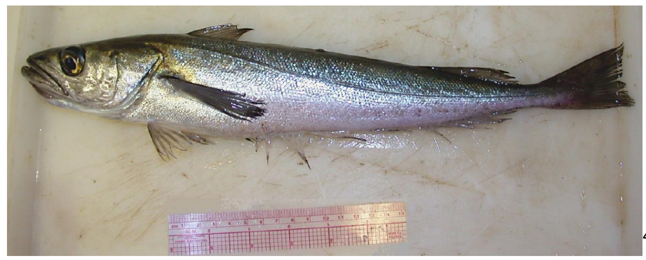
[410] Sakuma et al. 2013.
[411] Hastings, P. 2013. Biology of Fishes. Lecture Notes, Scripps Institution of Oceanography.
[412] Hastings, P. 2013. Biology of Fishes. Lecture Notes, Scripps Institution of Oceanography.
[413] Love 1991.
[414] Hastings, P. 2013. Biology of Fishes. Lecture Notes, Scripps Institution of Oceanography.
[415] Love 1991.
[416] Hastings, P. 2013. Biology of Fishes. Lecture Notes, Scripps Institution of Oceanography.
[417] http://www.adfg.alaska.gov/index.cfm?adfg=walleyepollock.main
[418] http://alaskafisheries.noaa.gov/mapping/ShoreZoneMvcServices/FishAtlas/FishDisplayPage?spCode=POLLOCK
[419] http://www.adfg.alaska.gov/index.cfm?adfg=walleyepollock.main
[420] Logerwell et al. 2010
[421] Wilson et al. 2006.
[422] Logerwell et al. 2010
[423] Logerwell et al. 2010

Young walleye pollock school in inshore waters.[424] As noted in the Capelin section, young pollock and capelin have high overlap in diet (small and large copepods, adult and juvenile euphausiids, thecosome pteropods, and larvaceans[425]) and likely compete with one another for food and habitat. Pollock seem more capable of prey switching than capelin[426]. Pollock mostly feed at night, whereas capelin are diurnal[427]. Alternate fluctuations in the abundance of capelin and age-0 pollock have been associated with reorganizations of the GOA ecosystem.[428]

Hake (Whiting)

Merluccius productus


[429]

[430]

Hake reach 3ft in length and up to 23 years in age.[431] Individuals form dense midwater schools[432] between 35-3000ft depth, but most commonly from 150 to 1800 ft.[433] They are rarely reported as common prey for seabirds and marine mammals, but they are major predators of euphausiids. They are primarily planktivores, but have also been known to consume eulachon and other smelts.

Hake constitutes one of the largest single species fish biomasses on the west coast of North America, though their abundance has been in decline since the 1980s[434]. There is a distinct coastal hake population, ranging from Baja to the Bering Sea, that makes extensive annual migrations.[435] Similar to sardines, hake spawn off California and migrate into British Columbia waters each summer to feed, and the extent of their movement is dependent on ocean conditions like temperature.[436]

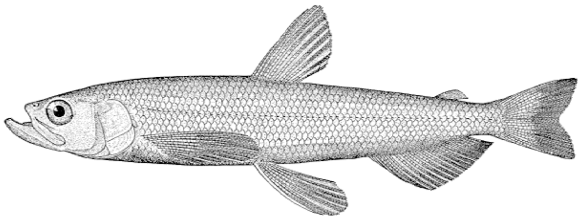
Other Osmerids

There is a considerably diverse assemblage of smelts to be found in BC waters, though for most of the ones listed below their typical range is further south and/or offshore of the Bangarang study area. The exceptions, however, are the longfin and surf smelts. They may be a very good candidate for the Kitimat Fjord System, though less is known about them.

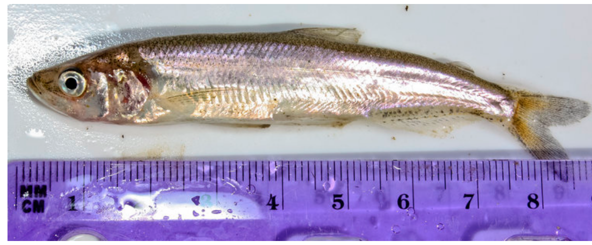
[424] Love 1991.
[425] Wilson et al. 2006.
[426] Wilson et al. 2006.
[427] Wilson et al. 2006.
[428] Wilson et al. 2006.
[429] Juvenile, Sakuma et al. 2013.
[430] Sakuma et al. 2013.
[431] Love 1991.
[432] Love 1991.
[433] Love 1991.
[434] Schweigert et al. 2012.
[435] Love 1991.
[436] Schweigert et al. 2012.

Longfin Smelt

Spirinchus thaleichthy



437



438

Other than their long fins, the long fin smelt is identified by a long upper jaw[439] and a jutting lower mandible. They are silvery to white and 9cm is a typical size[440]. Longfin smelt are anadromous[441]. Adults spawn at age 2 in streams not far from the sea[442]. A few adults survive spawing but most die soon after[443].

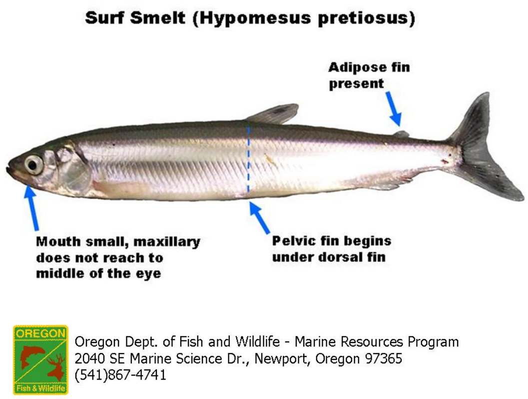
The species is found in marine, fresh, and brackish waters close to shore in bays and estuaries[444]. It occurs from Monterey Bay to Prince William Sound, and has been observed near Prince Rupert and in BC fjords like Indian Arm[445]. Large numbers are found in the Gulf of Alaska[446]. Populations within inlets are reportedly unable to swim between estuaries[447]. In estuaries, the species is usually found in the mid- to lower-water column[448] but spawning occurs on sand-gravel substrates, rocks, or aquatic plants[449]. In BC, spawning occurs October – December[450].

Adults and juveniles at sea feed on copepods, cumaceans and euphausiids[451]. The longfin smelt is an important prey items for seabirds and piscivorous fishes[452] (but not reported as such for marine mammals). They are harvested for subsistence in Alaska[453].

[437] calphotos.berkeley.edu
[438] Evermann, B.W. and E.L. Goldsborough. 1907. The fishes of Alaska, Bull. US Bur. Fish. 26:219-360.
[439] McClory et al. 2006
[440] McClory et al. 2006
[441] McClory et al. 2006
[442] McClory et al. 2006
[443] Scott and Crossman 1973, Morrow 1980
[444] McClory et al. 2006
[445] McClory et al. 2006
[446] USFWS 1994
[447] McClory et al. 2006
[448] McClory et al. 2006
[449] USFWS 1994
[450] Morrow 1980
[451] Morrow 1980
[452] McClory et al. 2006
[453] Shields 2005

Surf Smelt
Hypomesus pretiosus


[454]



[455]

Surf smelt have small mouths and a silvery band along their sides. They grow to 10 inches and live up to 5 years. [456] Surf smelt schools are often composed of only one sex. [457]

This species is found from Prince William Sound to Long Beach, CA[458], often near shore and in brackish water [459] where spawning occurs throughout most of the year[460] on fine gravel or coarse sand beaches in the upper intertidal[461]. Found near mouths of rivers (Hay, pers. comm.). They are not reported as prey for whales, only for porpoises, dolphins and birds[462].

Whitebait Smelt
Allosmerus elongatus


[463]

Typically found from Vancouver Island to Strait of Juan de Fuca to San Francisco Bay.[464] Common in offshore trawls (Hay, pers. comm.)

Nightsmelt
Spirinchus starksi

Occurs from southeast Alaska to central California. A regular occurrence in Canadian waters, but benthopelagic[465] and found predominately offshore (Hay, pers. comm.).

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[454] http://wdfw.wa.gov/publications/01219/wdfw01219.pdf
[455] http://www.dfw.state.or.us/mrp/fishid/FishIDOthers.asp
[456] Love 1991.
[457] Love 1991.
[458] Love 1991.
[459] Love 1991.
[460] Love 1991.
[461] Love 1991.
[462] Love 1991.
[463] Sakuma et al. 2013
[464] http://www.sdsc.edu/~sekar/dijlibdemo/sdsc_sp-whitebait-smelt.html
[465] http://www.fishbase.org/summary/Spirinchus-starksi.html

Comparison Key

Herring

Sardine

Anchovy

Eulachon

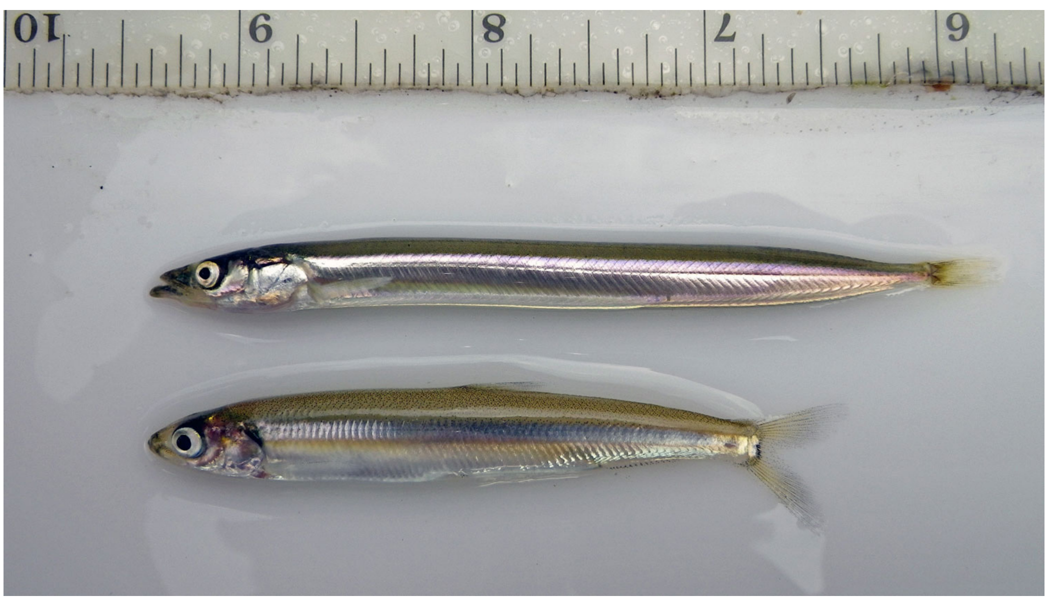
Capelin

Longfin

Surf

S Lance

THREE EXAMPLES OF FORAGE FISH COMMONLY FOUND IN PRINCE WILLIAM SOUND AND THE GULF OF ALASKA. FROM TOP TO BOTTOM: PACIFIC SANDLANCE (*AMMODYTES SPP.*) PACIFIC HERRING (*CLUPEA PALLASII*), AND CAPELIN (*MALLOTUS VILLOSUS*). PHOTO DAVID IRONS, USFWS. PHOTO BY MAYUMI ARIMITSU. [466]


[467]

Sand lance and juvenile surf smelt from Bainbridge Island, WA.

[466] http://www.gulfwatchalaska.org/monitoring/pelagic-ecosystem/forage-fish-2/
[467] http://soundwaves.usgs.gov/2013/04/

Kitimat Fjord System: Expectations

Expected species

The Kitimat Fjord system lay at the northern range extent of some species and the southern extent of others.

Herring is the clupeid expected to be most common in the Bangarang study area. Juvenile herring are highly abundant, seemingly ubiquitous (Hay, pers. comm.) and likely utilized by both seabirds and all marine mammals in the study area. Given current knowledge, adult herring should not be common inland of Caamano Sound during the summer, though they may be seen further inland during the fall. The study area is at the northern margin of sardine's and anchovy's range, which implies their presence is sporadic and, when present, would be represented by the older and larger individuals.

The potential osmerids include eulachon, capelin, surf smelt, surf smelt and longfin smelt (in increasing order of likely presence in the study area). Eulachon are typically offshore and demersal. In the summer they are most likely concentrated over the broad shelf of Hecate Strait and Queen Charlotte Sound, and their inland spawning run to specific river mouths occurs before April. It is possible that adult eulachon are completely absent from the study area in summer, though juveniles may be found alone or in mixed schools with juvenile herring. Capelin may be present in some years, during their mid-May to late July inland spawning migration. They do not spawn in rivers so they may be present in open channels. Though less is known about surf smelt and longfin smelt, they are the most persistently coastal and shallow species of the candidate osmerids. Longfin smelt seem particularly adapted to inlet habitats. Surf smelts spawn year-round and longfin spawn in the late autumn.

Hake and pollock are the larger important forage fish species in the northeast Pacific, but the Kitimat Fjord System at their northern and southern range terminus, respectively. Both would only be seasonally present, if at all. If they are important prey for baleen whales in the study area, it would be juveniles of these species. However, resident killer whales may include hake and pollock as a small percentage of their diet.

Sand lances have been observed numerous times in nearshore feeding events in the study area (this author; J Pilkington, pers. comm.). They are probably a major prey item in the area, definitely for seabirds but probably for humpback and fin whales too. Their distribution is likely patchy, concentrated near viable beach substrates in coves such as the shore of Ashdown Island, east Taylor Bight, Barnard Harbor and those lining Campania, Caamano and Estevan Sounds.

Expected timing

In the February to April before the field season, herring have moved inshore to spawn. Their eggs hatch within weeks, and larvae then juvenile herring are flooding the inland waterways. Sand lance larvae hatch in the spring as well. While the larvae disperse widely to forage phytoplankton, adult sand lance become the most common shallow-water, nearshore forage fish in the early summer. These adults practice the stereotyped crepuscular migrations to and from the benthos. In the warm days and spring tides of summer, shallow concentrations of sand lances may be vulnerable to hypoxic, high-temperature, and high-predator-density environments. If balls of lances are driven to the surface, seabirds, including bald eagles and marine mammals can descend upon them en force.

In the height of summer, a diverse assemblage of forage fish may be active in the study area. Adult herring move through the waterways in schools of varying density; they are likely the species targeted in humpback bubble-net feeding (Scott Baker, Doug Hay, James Pilkington, pers. comm.) Juvenile herring could be everywhere. Juvenile sand lance are roaming widely while diel-migrating adult sand lances in great numbers. Longfin and surf smelts are persitstently present. Sardine schools and capelin (maybe even pollock and hake) may make episodic appearances.

Later in the summer, juvenile herring are growing large enough to target macrocopepods and other more nutritious zooplankton, which they may move further inshore to find (Doug Hay, pers. comm.). This might be a contributing factor in the late summer landward drift of humpback whales.

As the autumn nears, non-spawning adult sand lances become less common; they linger longer in the benthos and may move offshore; juveniles become the most abundant life stage as they recruit to nearshore spawning populations. Spawning, which can involve writhing masses of sand lances at the surface, will begin occurring in the early fall.

Fish Morphology Aid

From lecture notes on Phil Hastings' course, Biology of Fishes
Scripps Institution of Oceanography, Fall 2013:

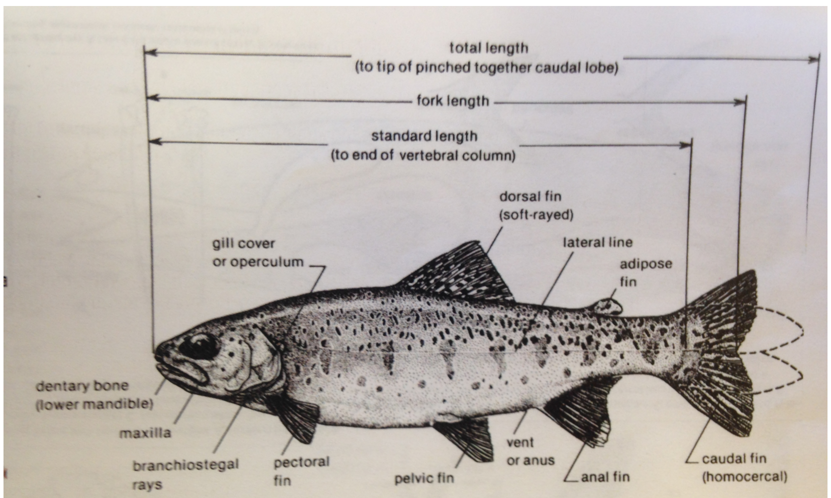


Figure 2-3. External features of a soft-rayed fish, the rainbow trout, showing different ways of measuring the length of a fish. Total length is preferred by anglers; the other two are used by biologists because they are less subject to argument.

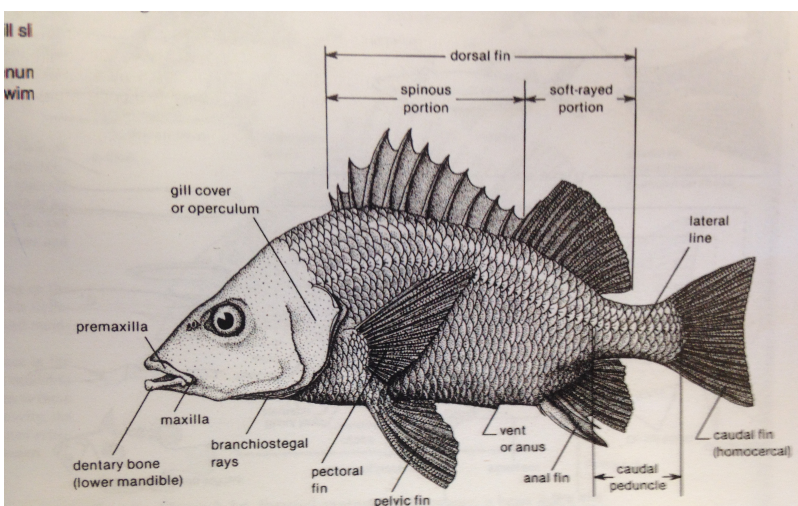


Figure 2-4. External features of a spiny-rayed fish, a snapper.

Literature Cited

(Image and website credits can be found in the footnotes)

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