

Occurrence of Pacific sardine, *Sardinops sagax*, off southeastern Alaska

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Pacific sardines, *Sardinops sagax* (Jenyns, 1842), are an important forage and commercial species off central and southern California. From the late 1920s through the early 1940s, sardines were a major resource of the oil and meal fisheries of British Columbia, Washington, and Oregon (Hart, 1973). In 1931, sardines were unusually abundant on southern and central British Columbia fishing grounds and more numerous than usual in northern British Columbia (Shultz et al., 1932). In the early 1940s, however, yield of these fisheries declined radically and the species range was restricted to waters off central and southern California. After the decline, Pacific sardines were rarely reported north of the California–Oregon border (Reid, 1960; Mearns, 1988). Since 1992, Pacific sardines have again been observed off southern and central British Columbia (Hargreaves et al., 1994; McFarlane and Beamish, 1999).

Although the occurrence and changes in abundance of Pacific sardines in British Columbia waters are well documented, the presence of this species off Alaska is poorly documented. Schultz et al. (1932) reported Pacific sardines from Alaska on the basis of 24 adult specimens collected 8 August 1931 from the Cape Ommaney herring fishery (Clark, 1936; 1947). No additional specimen was documented from Alaska until 1992, when larval Pacific sardines were collected southwest of the Shumagin Islands, southwestern Alaska (Busby et al.¹).

Specimen collection

Eight adult sardines were captured in a surface trawl at 57°31'N, 136°34'W, 28 km west of Khaz Point, northern southeastern Alaska, on 20 August 1998. The fish were captured during a National Marine Fisheries Service research cruise to compare rope trawl and gill-net sampling methods for juvenile sablefish, *Anoplopoma fimbria*, and juvenile salmon, *Oncorhynchus* spp., in coastal Alaska. We used a Nordic 264-rope trawl (24-m horizontal opening, 30-m vertical opening) equipped with 3-m foam-filled doors and extra trawl floats to hold it at the surface.

Two additional specimens from Garnet Point (54°43'N, 130°41'W), near Nakat Bay, southern southeastern Alaska, were taken in a commercial salmon gill net on 1 September 1998. Fishermen reported that sardines were common but not numerous in eastern Dixon Entrance near Nakat Bay through August and early September 1998.

Both collections were frozen before being transported to the Auke Bay Laboratory, where lengths and weights

of thawed fish were recorded. The fish were fixed in 4% formaldehyde, transferred to isopropyl alcohol, and then dissected to determine sex, maturity, and stomach contents. The fish were then deposited in the Auke Bay Laboratory reference collections.

Results

The 10 Pacific sardines averaged 233.3 ±11.30 mm standard length and 183 ±38.02 g wet weight (Table 1). On the basis of scale annuli, the collections were divided equally between 7- and 8-year-old fish. They were equally divided between males and females, and all gonads were in the resting stage. The fish had been feeding and had mesenteric fat deposits. Identifiable foods consisted of diatoms and euphausiids (*Euphausia pacifica* and *Thysanoessa* spp.) at Garnet Point and euphausiids (*E. pacifica* and *Thysanoessa* spp.) and small calanoid copepods (*Acartia* spp. and *Pseudocalanus* spp.) at Khaz Point.

Discussion

The occurrence of adult Pacific sardines in Alaska coastal waters is probably due to a northward extension of their summer feeding migration. Pacific sardines have a complex migration and spawning cycle, moving northward from California spawning areas during summer. The largest, oldest fish reach central Vancouver Island or farther north (Hart 1973). Historically, few Pacific sardines have overwintered in southern British Columbia (Schultz et al., 1932; Hart, 1943; Hargreaves et al., 1994), but during February–April 1998, juvenile sardines were observed off the western coast of Vancouver (McFarlane and Beamish, 1999). Sardines overwintering in British Columbia could migrate north into Alaska waters the following summer. In summer 1931, sardines were observed at many northern British Columbia locations near the Alaska border and were common in the fall and winter

¹ Busby, M. S., W. W. Watson, and W. Shaw. 2000. Identification of larval and juvenile Pacific herring (*Clupea pallasii*) and Pacific sardine (*Sardinops sagax*) and their distribution in waters off British Columbia and in the Gulf of Alaska. *In prep.* [Available from M. S. Busby, RACE, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Bin 15700, Seattle WA 98115-0070.]

Table 1
Biological data for Pacific sardines, *Sardinops sagax*, collected in Alaska, during summer 1998.

Standard length (mm)	Wet weight (g)	Age (yr)	Sex	Maturation stage	Food
Collection no. AB 98-39, Garnet Point, 54°43'N, 140°41'W, 1 Sep 1998, 2 specimens					
233	153	7	M	resting	diatoms
235	155	7	M	resting	diatoms and euphausiids
Collection no. AB 98-44, Khaz Point, 57°31'N, 136°34'W, 20 Aug 1998, 8 specimens					
225	155	7	M	resting	euphausiids and copepods
225	157	8	M	resting	trace of zooplankton
230	204	8	F	resting	trace of zooplankton
215	156	7	F	resting	trace of zooplankton
255	254	8	F	resting	euphausiids and copepods
240	207	8	F	resting	trace of zooplankton
230	157	7	F	resting	trace of zooplankton
245	232	8	M	resting	euphausiids and copepods

herring fisheries of southern British Columbia (Shultz et al., 1932).

Both years in which Pacific sardines were observed in southeastern Alaska were exceptionally warm and at the end of strong El Niño periods. The occurrence of sardines in Alaska reported in our study followed the exceptionally strong 1997–98 El Niño and is similar to the 1931 occurrence of Pacific sardines in Alaska, which followed the 1930–31 El Niño. Increased water temperature associated with El Niño events typically results in northward range extensions and anomalous distributions of fishes (Radovich, 1961; Schoener and Fluharty, 1985; Mearns, 1988). Although not specifically associated with sardines, several fishes were recorded north of their normal ranges during the 1930–31 (Walford, 1931; Mearns, 1988), 1982–83, and 1997–98 El Niños (Table 2). Included in 1997–98 records is an unconfirmed report of coho salmon, *Oncorhynchus kisutch*, feeding on northern anchovy, *Engraulis mordax*, near Yakutat, Alaska. Northern anchovy previously have not been reported north of the Queen Charlotte Islands, British Columbia. Interannual variations of El Niños and their effects on the distribution of marine organisms are difficult to assess because adequate time series data are lacking (Schoener and Fluharty, 1985), especially for Alaska coastal waters before 1960. In addition, not all unusual occurrences associated with El Niños are range extensions. More frequently, these occurrences are the result of anomalous strays beyond normal ranges or are the result of changes in abundance or shifts in habitats (Table 2).

Although water temperature is a factor determining sardine distribution (Radovich, 1961), other factors may determine abundance and whether a range extension persists. Most Pacific sardine spawning occurs off southern California at 15–18°C temperatures (at a lower threshold limit

Table 2

Inter-El Niño comparison of unusual northern occurrences of marine fishes in Alaska coastal waters. Occurrences were coded according to Schoener and Fluharty (1985). E = range extension, H = habitat anomaly, A = range anomaly, C = change in abundance (+ or -). Sources: 1930–31 (Shultz et al., 1932); 1957–58 (Radovich, 1961); 1982–83 (Karinén et al., 1985; Pearcy and Schoener, 1987); 1991–94 (Wing, unpublished files); 1997–98 (Wing, unpubl. files).

Species	1930–31	1957–58	1982–83	1991–94	1997–98
<i>Sardinops sagax</i>	E				E
<i>Alosa sapidissima</i>			A	A	
<i>Engraulis mordax</i>					E
<i>Cololabis saira</i>			A		A
<i>Sarda chiliensis</i>		E	A		
<i>Scomber japonicus</i>				C+	C+
<i>Thunnus alalunga</i>		C+	C+		C+
<i>Thunnus thynnus</i>		E			
<i>Seriola lalandi</i>					E
<i>Trachurus symmetricus</i>				C+	C+
<i>Merluccius productus</i>					C+
<i>Sphyræna argentea</i>		A	A		A
<i>Mola mola</i>			A	A	A
<i>Brama japonica</i>			A	C+	C+
<i>Atractoscion nobilis</i>		E			
<i>Balistes polylepis</i>			E		
<i>Prionace glauca</i>			A/C+		C+
<i>Carcharodon carcharias</i>			A		A

of 13°C) (Ahlstrom, 1954). Laboratory studies have shown high mortalities and abnormal development at temperatures below 14°C (Lasker, 1964). There is some spawning off northern Oregon (Clark, 1938; Ahlstrom, 1948; Bentley et al., 1996). No spawning has been documented off British Columbia, although mature females with loose eggs have been reported from British Columbia (Walford and Mosher, 1941; Hart, 1943, 1973). Water temperatures off the northern British Columbia and southeastern Alaska coasts are sufficiently high for successful spawning and development of eggs and larvae in July and August. The progeny may not survive, however, to maturity if subsequent foraging, predation, and overwintering conditions are severe. If spawning does occur off British Columbia, it may be only a temporary extension of the spawning range and may not create long-lasting populations. In Alaska, such a temporary range extension was observed in the early 1980s for the California market squid, *Loligo opalescens*, whose range expanded northward for several years before contracting southward again (Wing and Mercer, 1990).

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