Habitat, age, and diet of a forage fish in southeastern Alaska: Pacific sandfish (*Trichodon trichodon*)

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Forage fish are an important part of Alaska's marine ecosystems and coastal areas. Forage fish are a critical food source for numerous groundfish, marine mammals, and seabirds (Wespestad[1]; Allen and Smith, 1988; Paul et al., 1997; Yang and Nelson, 2000; Mecklenburg et al., 2002). Little is known, however, about the life history characteristics or habitat of many forage fish species in Alaska, including Pacific sandfish (*Trichodon trichodon*; Fig. 1). Only two articles have been published on the life history characteristics of Pacific sandfish in Alaska. Paul et al. (1997) investigated size-weight-age profiles, size at maturity, and fecundity of Pacific sandfish in the northern Gulf of Alaska, and Bailey et al. (1983) examined size and diet of juvenile (<55 mm fork length [FL]) Pacific sandfish in southeastern Alaska. Some Pacific sandfish catch data are also available for the Bering Sea, Prince William Sound, and southeastern Alaska (Isakson et al., 1971; Orsi and Landingham, 1985; Allen and Smith, 1988; Brodeur and Livingston, 1988; Sturdevant et al.[2], Orsi et al., 2000). Pacific sandfish burrow into sand, usually at depths shallower than 150 m, and can reach a maximum size of about 300 mm (Marliave, 1980; Mecklenburg et al., 2002).

Pacific sandfish are commonly found in nearshore waters of the southeastern Bering Sea and Gulf of Alaska. There is no commercial fishery for Pacific sandfish in Alaska, but sailfin sandfish (*Arctoscopus japonicus*) are commercially fished and cultured in Japan and Korea (Okiyama, 1990). In particular, information is scarce on the biology and habitat of Pacific sandfish, especially for southeastern Alaska. Shoreline development and global climate change (e.g., increased water temperature and sea level) may adversely affect Pacific sandfish populations because of the relatively specialized nearshore spawning sites and one-year incubation period of this species (Marliave, 1980).

The focus of our study was to provide new information on the general biology of a little known forage fish species. Objectives were to determine habitat preference, age, size, and diet of Pacific sandfish. To accomplish this, from 2001 to 2004, we captured Pacific sandfish with a beach seine in July and March and with a mid-water trawl in May near The Brothers Islands in southeastern Alaska.

Materials and methods

Fish capture and habitat

Pacific sandfish were captured with a beach seine at The Brothers Islands in southeastern Alaska (Fig. 2). We seined 10 sites in summer (July 2001–2003) and in winter (March 2002–2004) in a variety of nearshore habitat types (Table 1). Habitats sampled included steep bedrock outcroppings, rocky bottoms with understory kelps (e.g., *Laminaria*), eelgrass (*Zostera marina*), and sand beaches. We used a 37-m variable-mesh beach seine that tapered from 5 m wide at the center to 1 m wide at the ends. Outer panels were each 10 m of 32-mm stretch mesh, intermediate panels were each 4 m of 6-mm square mesh, and the bunt was 9 m of 3.2-mm square mesh. We set the seine as a "round haul" by holding one end on the beach, backing around in a skiff with the other end to the beach about 18 m from the starting point, and pulling the seine onto shore. The seine had a lead line and a float line so that the bottom contacted the substratum and the top floated on the surface. All seine sites were sampled during daylight and within two hours of low tide (range +1.0 to −1.5 m below mean lower low water). After retrieval of the net, the entire catch was sorted, identified to species, counted, and a subsample was measured for length.

[1] Wespestad, V. G. 1987. Population dynamics of Pacific herring (*Clupea pallasii*), capelin (*Mallotus villosus*), and other coastal pelagic fishes in the eastern Bering Sea. *In* Forage fishes of the southeastern Bering Sea; proceedings of a conference, November 1986, Anchorage, AK, p. 55–60. U.S. Dep. Interior, Minerals Management Service, OCS Study MMS 87-0017.

[2] Sturdevant, M. V., T. M. Willette, S. C. Jewett, E. Debevec, L. B. Hulbert, and A. L. J. Brase. 1999. Forage fish diet overlap, 1994–1996. APEX Project: Alaska predator ecosystem experiment in Prince William Sound and the Gulf of Alaska, 103 p. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 98163C), Auke Bay Laboratory, National Marine Fisheries Service, 11305 Glacier Highway, Juneau, Alaska.

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Figure 1
Pacific sandfish (*Trichodon trichodon*) captured in southeastern Alaska.

Table 1
Habitat characteristics of sites (see Fig. 2) at The Brothers Islands in southeastern Alaska where Pacific sandfish (*Trichodon trichodon*) were captured with a beach seine from 2001 to 2004. Substrata are listed in decreasing order of abundance from left to right. For vegetation, algae were mostly *Ulva*, eelgrass was *Zostera marina*, and kelps were mostly Laminariales (e.g., *Laminaria*, *Alaria*, and *Cymathere*). PSS = practical salinity scale. Catch = number of sandfish.

						Catch	
Site	Substrate	Vegetation	Slope	Temperature (ºC)	Salinity (PSS)	July 2001–03	March 2002–04
1	sand, shell	algae	gentle	4.0–9.5	32–33	6	110
2	large cobble, small cobble, gravel, shell	kelp	moderate	9.0	33	14	0
3	large cobble, sand	kelp	gentle	12.0	24	1	0
4	sand, shell, gravel, small cobble	eelgrass	gentle	12.0	33	1	0
5	small cobble, large cobble, sand, gravel	kelp	moderate	4.9–9.5	33	2	1
6	bedrock outcrop	kelp	steep	4.2–10.0	31–33	900	300
7	bedrock outcrop	kelp	steep	4.2–10.0	31–33	68	500
8	bedrock outcrop	kelp	steep	4.2	33	0	1120
9	bedrock outcrop	kelp	steep	4.0	33	0	5000
10	bedrock outcrop	kelp	steep	4.0–10.0	30–33	35	7200
					Total	1027	14,231

The number of larvae (≤30 mm) in large catches in winter was estimated visually. Water temperature and salinity (practical salinity scale; PSS) were measured at each site at a depth of 20 cm with a thermometer and a hand-held refractometer.

Pacific sandfish were also captured with a mid-water rope trawl in May 2001 in Frederick Sound, midway between the mouth of Pybus Bay and The Brothers Islands, and in May 2003 in Pybus Bay (about 12 km from The Brothers Islands) (Fig. 2). In 2001, the midwater trawl was a 164 Nordic rope trawl with 1.5-m^2 alloy doors; it was 7 m high and 17 m wide and was equipped with a 19-mm codend liner. In 2003, because a different vessel was used, the trawl was a mesh wing 25/21/64

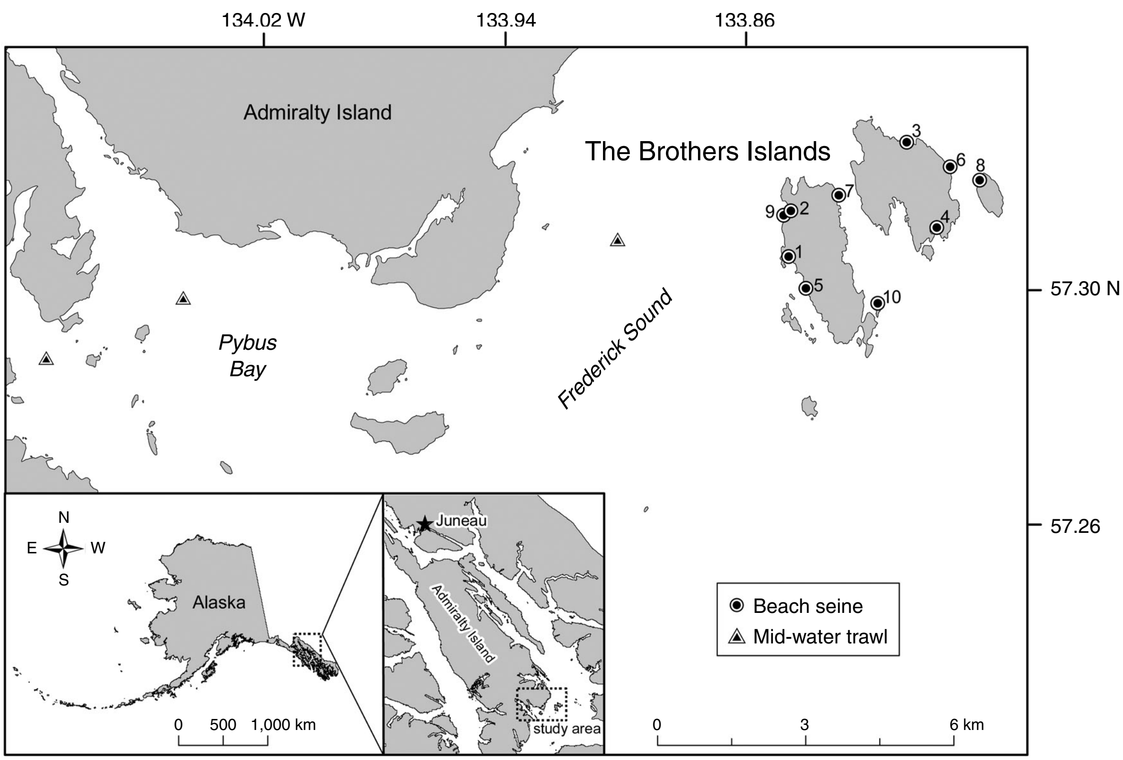

Figure 2

Location of sites (see Table 1 for habitat characteristics) sampled for Pacific sandfish (*Trichodon trichodon*) near The Brothers Islands, southeastern Alaska, 2001 to 2004. Sampling methods included beach seining and mid-water trawling.

trawl with 3.0-m^2 alloy doors; it was 11 m high and 29 m wide and was equipped with a 32-mm mesh codend liner. In Frederick Sound, water depth was about 74 m, and the trawl was fished at a depth of 14 m. In Pybus Bay, water depth was about 70 m and the trawl was fished at depths from 50 to 64 m about 400 m offshore. Water temperature and salinity were obtained from deployment of a CTD (conductivity-temperature-depth) profiler in Pybus Bay in 2003.

Age and size

A sample of Pacific sandfish was frozen and brought to the laboratory where sagittal otoliths were removed and stored in 95% ethanol. Fish used for otolith collections covered a range of sizes in the catch (Table 2). Fish were measured to the nearest mm FL, and larvae were measured to the nearest mm total length (TL). A sample of fish was individually weighed to the nearest gram. Because a sample of larvae captured with a seine and preserved (10% formalin) in 2002 was not measured until 2004, a shrinkage factor of 10.3% was applied to the lengths to adjust for storage in formalin (Marliave, 1980). The left otolith of each fish was cut into thin sections by using standard methods described in the otolith manual for microstructural examination (Secor et al., 1991). The otolith was attached to a glass slide, medial side down, with thermal resin. The surface of the otolith was then ground to the primordium with 1000-grit silicon carbide paper. Care was taken to leave the edge of the otolith intact and not to grind through the primordium in the center. The otolith was then polished with an 8000- and 12,000-grit cloth on both sides to reveal the internal microstructure. Otoliths collected in 2001 were aged separately by two biologists. When age estimates differed, otoliths were re-examined together by both readers, and an age was agreed upon. Otoliths collected in 2002 were aged by one biologist three different times. If age readings differed between any of the three readings, the otolith was re-examined and a best estimate of the age was determined. For both years, otoliths were examined without knowledge of fish size or collection date.

Diet

A sample of Pacific sandfish (>age-0) was preserved in 10% formalin and analyzed for stomach contents. Preserved fish were measured to the nearest mm FL, weighed to the nearest 0.1 g, and stomachs were excised. Stomachs were weighed before and after removal of contents to obtain an estimate of wet weight by subtraction. Contents were examined with a dissecting microscope and identified to major taxonomic groups.

Table 2

Size and age based on surface observations of annual rings on otoliths of Pacific sandfish (*Trichodon trichodon*) from nearshore waters of The Brothers Islands, and from Pybus Bay and Frederick Sound, southeastern Alaska from 2001 to 2003. Fish from Frederick Sound and Pybus Bay were captured with a mid-water trawl, whereas all other fish were captured with a beach seine. Asterisk denotes total length (mm). n = number of sandfish in the sample.

			Fork length (mm)			
Date	Location	n	Mean	Range	Mean weight (g)	Age (yr)
July 2001	The Brothers Islands	22	80	70–95	6.4	1
May 2001	Frederick Sound	1	120	—	24.0	4
May 2001	Frederick Sound	1	190	—	82.0	6
March 2002	The Brothers Islands	9	16*	14–18*	—	0
July 2002	The Brothers Islands	24	70	55–79	4.3	1
July 2002	The Brothers Islands	1	135	—	32.0	5
May 2003	Pybus Bay	1	121	—	23.5	4
May 2003	Pybus Bay	10	141	129–152	37.2	5
May 2003	Pybus Bay	7	160	156–166	58.3	6

Frequency of occurrence (% FO) was determined for each taxonomic group based on the percentage of stomachs in which that taxonomic group occurred. Percent volume (% Vol) of each taxonomic group was estimated visually and total weights per taxon were estimated by multiplying the percent volume by the total stomach weight.

Results

Fish catch and habitat

Total catch of Pacific sandfish was 15,431 fish. Most (99%) fish were captured with a seine: 1027 fish in July (total for all years) and 14,231 larvae in March (total for all years; Table 1). Total trawl catch was 173 fish; 2 fish in Frederick Sound in May 2001 and 171 fish in Pybus Bay in May 2003.

Most Pacific sandfish captured with a seine in July and March each year were found adjacent to steep bedrock outcroppings with attached kelp (Table 1). Water temperatures in summer and winter for all years were about 10°C and 4°C, and salinity ranged from 30 to 33 PSS. Larvae were captured in March at many of the same sites where juveniles were captured in July (sites 1, 9–11, 14; Table 1; Fig. 2). The few adult Pacific sandfish (>130 mm FL) captured with a seine in July 2002 and 2003 were found exclusively in low gradient, sandy habitat (site 1; Fig. 2). Most adult Pacific sandfish were captured in Pybus Bay with a trawl at least 400 m offshore of any land mass and at depths between 14 and 64 m; at the depth (50 m) most fish were captured, temperature was 6.5°C and salinity was 31.5 PSS.

Age and size

Nearly all Pacific sandfish captured with a seine in July (all years) were juveniles; only larvae were captured in March (all years). Approximately 14,000 Pacific sandfish larvae were captured in March (Table 1); mean TL was 16.2 mm (13.1 to 23.2 mm; Fig. 3). Of nine larvae aged from March 2002, all were age-0 (Table 2). Mean FL of Pacific sandfish captured with a seine in July was 86 mm (62 to 150 mm; Fig. 3). Of 47 Pacific sandfish aged from seine catches in July, 46 were age-1 (mean FL=75 mm) and one was age-5 (FL=135 mm) (Table 2).

All trawl-caught Pacific sandfish were adults or subadults. Mean FL of Pacific sandfish from trawl catches was 150 mm (120 to 190 mm; Fig. 3). The 21 fish aged from trawl catches in May (both years) were age-4, age-5, and age-6 (mean FL=121, 141, and 164 mm) (Table 2). No age-2 or age-3 fish were captured in trawls.

Diet

From analysis of 195 stomachs, we found that Pacific sandfish were both planktivorous and piscivorous. Percent weight of stomach contents for age-1 Pacific sandfish varied between years (Fig. 4). For both 2001 and 2002 combined, decapods, fish, and euphausiids accounted for about 90% of stomach content weight. Fish made up 50% of the weight in 2001, but only 7% in 2002. The other two heaviest items, decapods and euphausiids, ranged from 30% to 50% and from 17% to 25% of the weight in 2001 and 2002, respectively. Diet of adult Pacific sandfish (2003; ≥age-4) consisted of four food items and was dominated by fish and decapods (Fig. 4). Fish accounted for 75% of the weight of stomach contents for ≥age-4 fish. Frequency of occur-

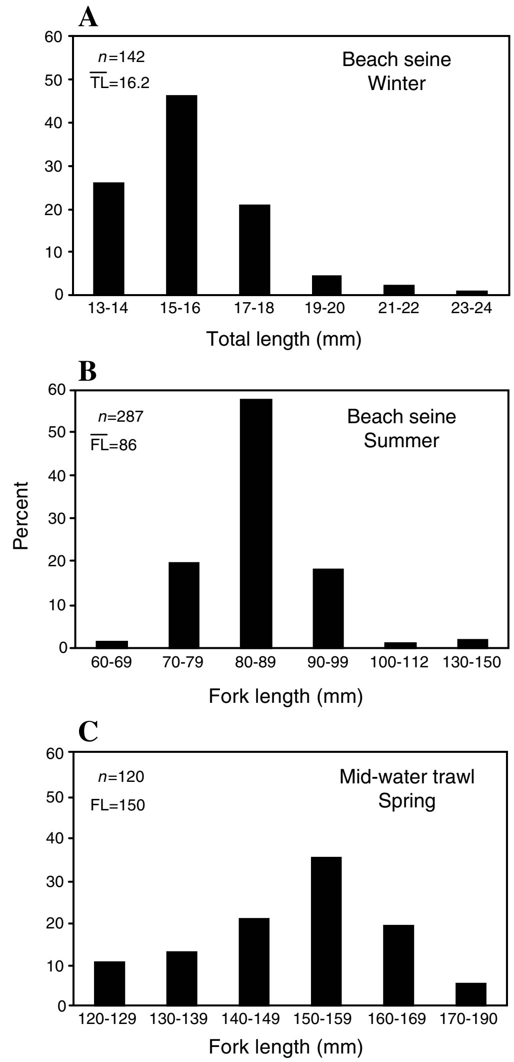

Figure 3

Length frequency of Pacific sandfish (*Trichodon trichodon*) near The Brothers Islands, southeastern Alaska. (**A**) Larvae were captured in March, 2002–2004, (**B**) juveniles and subadults were captured in July, 2001–2003, and (**C**) subadults and adults were captured in May 2001 and May 2003. Total length was measured for larvae and fork length for juveniles, subadults, and adults.

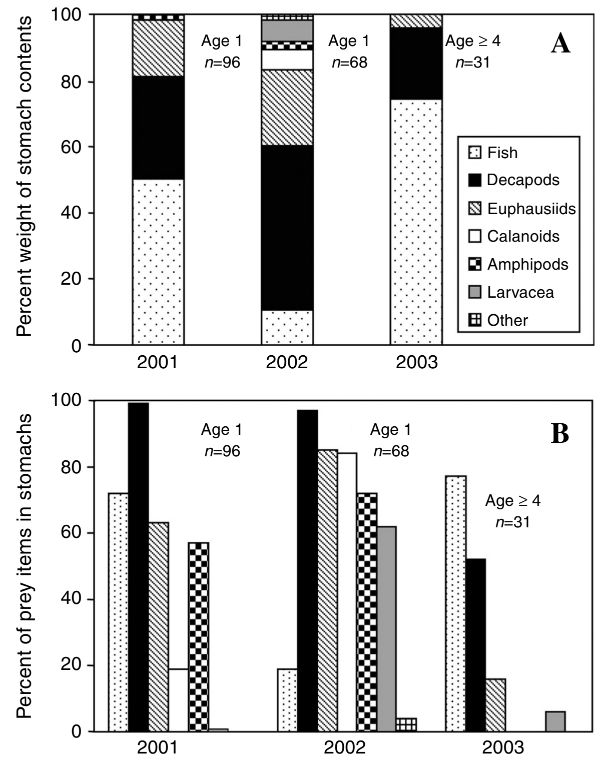

Figure 4

(**A**) Percent weight of stomach contents and (**B**) percent frequency of occurrence of prey items in stomachs of Pacific sandfish (*Trichodon trichodon*) near The Brothers Islands, southeastern Alaska. Data for 2001 and 2002 represent age-1 fish captured with a beach seine in July, and data for 2003 represent fish ≥age 4 captured with a mid-water trawl in Pybus Bay and Frederick Sound in May. See Figure 2 for site locations.

rence of food items in stomachs varied among years for age-1 Pacific sandfish (Fig. 4). Occurrence of fish in stomachs of age-1 fish ranged from 72% in 2001 to 19% in 2002, and occurrence of larvacea ranged from 62% in 2001 to 1% in 2002. Nearly all identifiable fish in juvenile stomachs were gadids. For 2001 and 2002 combined, decapod larvae occurred in about 98% of stomachs, euphausiids in 74%, and amphipods in 65%. For adults (2003; ≥age-4), fish were the most frequently occurring food item and were present in 77% of stomachs.

Discussion

Pacific sandfish larvae and juveniles use shallow, nearshore habitats, whereas most adults occupy deeper waters farther from shore. Larvae were similar in size and anatomical features to larvae (0–29 day-old) described by Marliave (1980). Thus, we estimate that the larvae we captured probably hatched between early February and early March—a hatching period similar to that reported by Clemens and Wilby (1967) for British Columbia, Canada, but 1–2 months earlier than hatching dates estimated by Bailey et al. (1983) for northern southeastern Alaska. Pacific sandfish spawn on rocky intertidal shorelines, eggs incubate for about one year, and larvae develop in shallow nearshore areas (Marliave, 1980). Because of the relative high abundance of Pacific sandfish larvae in the shallow nearshore waters of The Brothers Islands, this area appears to be an important spawning and nursery area for Pacific sandfish. The length of time that larvae remain in shallow nearshore areas, however, appears to be limited because we captured no age-0 fish in July.

Pacific sandfish have been caught incidentally in a variety of habitats in Alaska. In southeastern Alaska, Orsi and Landingham (1985) caught Pacific sandfish in low-gradient beaches composed of sand, gravel, cobble, or a combination of these substrates, and Orsi et al. (2000) caught Pacific sandfish with a rope trawl in deeper waters. In the Aleutian Islands, Isakson et al. (1971) reported that Pacific sandfish were a prominent species in the inshore sand and gravel community. Pacific sandfish are known to burrow into soft substrates, but most of the juveniles that we captured were close to shore and adjacent to bedrock outcroppings—area and substrate similar to those observed by Bailey et al. (1983). Although Mecklenburg (2003) reported that Pacific sandfish generally burrow in sand during the day and are active at night, we observed large schools of juvenile Pacific sandfish actively feeding near the surface during the day.

Age of Pacific sandfish varied with time of capture. We captured mostly age-1 Pacific sandfish in July; mean size of age-1 fish in our study (75 mm FL) was similar to the size of age-1 fish captured in the northern Gulf of Alaska (71 mm FL; Paul et al., 1997). In spring we captured subadult and adult Pacific sandfish, and in winter we caught only larval Pacific sandfish. Notably absent in all of our catches were age-2 and age-3 fish. Paul et al. (1997) captured age-2 and age-3 Pacific sandfish by a variety of methods in the northern Gulf of Alaska. Most of their sampling, however, occurred in August and in deeper waters (29–55 m). Pacific sandfish may segregate into different habitat types depending on age and size, which may explain the absence of some age classes in our catches.

Diets consisting of crustaceans and fish have been reported for Pacific sandfish similar in size to those in our study (Paul et al., 1997; Sturdevant et al.[2]). Percent FO of fish in the diet of Pacific sandfish was 66% in the Gulf of Alaska (Paul et al., 1997), 100% in Prince William Sound (Sturdevant et al.[2]), and 56% in our study. For crustaceans, the highest % FO was for shrimp (19%) in the Gulf of Alaska (Paul et al., 1997), gammarids (46%) in Prince William Sound (Sturdevant et al.[2]), and crab larvae (83%) in our study. Near Kodiak Island, Alaska, stomach contents of 26 Pacific sandfish in July were dominated by fish (70% by number and 97% by weight; Rogers et al.[3]).

Percent FO of fish in Pacific sandfish stomachs was nearly four times greater in 2001 than in 2002, which probably reflects the abundance of prey. Based on seine catches at The Brothers Islands, the relative abundance of young-of-the-year (YOY) gadids, the dominant fish identified in Pacific sandfish stomachs, was over six times greater in 2001 than in 2002 (Thedinga et al., 2006). In addition, mean length of Pacific sandfish was about 5 mm longer in 2001 than in 2002, which may reflect the increased presence of fish in the diet of Pacific sandfish, or could be due to increased growth time because we sampled 10 days later in 2001 than in 2002.

Diet differed by fish size. Larger Pacific sandfish (mean FL 150 mm) ate mostly fish, whereas smaller Pacific sandfish (mean FL 86 mm) ate mostly decapods. Paul et al. (1997) also observed a change in diet based on fish size; % FO of fish in the diet of Pacific sandfish greater than 115 mm FL was 90% compared to 14% for fish less than 99 mm. Also in their study, mean % FO of non-fish food items was 5% for larger fish compared to 24% for smaller fish.

Bailey et al. (1983) reported observing juvenile Pacific sandfish in mixed schools with pink salmon (*Oncorhynchus gorbuscha*) fry, but we caught Pacific sandfish with YOY walleye pollock (*Theragra chalcogramma*), YOY Pacific cod (*Gadus macrocephalus*), YOY Pacific herring (*Clupea pallasii*), and juvenile chum salmon (*Oncorhynchus keta*). Apparently, Pacific sandfish exhibit schooling behavior as larvae and juveniles and co-occur with a variety of forage species, sometimes preying on those that are of consumable size. High predation rates of juvenile walleye pollock by Pacific sandfish have been reported for the Bering Sea and Gulf of Alaska (Guénette, 2005).

Shallow nearshore waters provide important nursery and spawning habitat for Pacific sandfish. Pacific sandfish diet varied between size classes and years which was probably dependent on abundance of YOY walleye pollock. Pacific sandfish are a nutritious forage fish with moderately high oil, protein, and caloric content (Anthony et al., 2000; Logerwell and Schaufler, 2005) and could therefore be important to some predators at certain times of the year. For example, Pacific sandfish occurred in up to 64% of Steller sea lion (*Eumetopias jubatus*) scats in the Aleutian Islands (Sinclair and Zeppelin, 2002). The dependence of Pacific sandfish upon nearshore areas for spawning, egg incubation, and larval rearing, coupled with the greater sensitivity to pollutants of early life stages than adults (Carls et al., 1999), warrant the protection of nearshore areas from shoreline development and pollutants to maintain healthy forage fish populations.

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[3] Rogers, D. E., D. J. Rabin, B. J. Rogers, K. Garrison, and M. Wangerin. 1979. Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island including ichthyoplankton, meroplankton (shellfish), zooplankton, and fish. Environmental Assessment of the Alaskan Continental Shelf, p. 529–662, vol. IV. Receptors, Fish, Littoral, Benthos. Outer Continental Shelf Environmental Assessment Program, Boulder, CO.

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Literature cited

Allen, J., and G. B. Smith.
1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-66, 151 p.

Anthony, J. A., D. D. Roby, and K. R. Turco.
2000. Lipid content and energy density of forage fishes from the northern Gulf of Alaska. J. Exp. Mar. Biol. Ecol. 248:53–78.

Bailey, J. E., B. L. Wing, and J. H. Landingham.
1983. Juvenile Pacific sandfish, *Trichodon trichodon*, associated with pink salmon, *Oncorhynchus gorbuscha*, fry in the nearshore area, southeastern Alaska. Copeia 2:549–551.

Brodeur, R. D., and P. A. Livingston.
1988. Food habits and diet overlap of various eastern Bering Sea fishes. U.S. Dep. Commer., NOAA Tech. Memo. NMFS/NWC-127, 76 p.

Carls, M. G., J. E. Hose, R. E. Thomas, and S. D. Rice.
1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (*Clupea pallasii*). Environ. Toxicol. Chem. 19(6): 1649–1659.

Clemens, W. A., and G. V. Wilby.
1967. Fishes of the Pacific coast of Canada, 433 p. Fish. Res. Board Can., Bull. 68.

Guénette, S.
2005. Models of Southeast Alaska. *In* Food web models and data for studying fisheries and environmental impacts on Eastern Pacific ecosystems (S. Guénette, and V. Christensen, eds.), p. 106–178. Fisheries Centre Research Report 13.

Isakson, J. S., C. A. Simenstad, and R. L. Burgner.
1971. Fish communities and food chains in the Amchitka area. BioScience 21:666–670.

Logerwell, E. A., and L. E. Schaufler.
2005. New data on proximate composition and energy density of Steller sea lion (*Eumetopias jubatus*) prey fills seasonal and geographic gaps in existing information. Aquat. Mamm. 31:62–82.

Marliave, J. B.
1980. Spawn and larvae of the Pacific sandfish, *Trichodon trichodon*. Fish. Bull. 78:959–964.

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson.
2002. Fishes of Alaska, 1037 p. Am. Fish. Soc., Bethesda, MD.

Mecklenburg, C. W.
2003. Family Trichodontidae Bleeker 1859—sandfishes. Calif. Acad. Sci., Annotated checklists of fishes no. 15, 4 p.

Okiyama, M.
1990. Contrast in reproductive style between two species of sandfishes (family Trichodontidae). Fish. Bull. 88:543–549.

Orsi, J. A., and J. H. Landingham.
1985. Numbers, species, and maturity stages of fish captured with beach seines during spring 1981 and 1982 in some nearshore marine waters of southeastern Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-86, 34 p.

Orsi, J. A., M. V. Sturdevant, J. M. Murphy, D. G. Mortensen, and B. L. Wing.
2000. Seasonal habitat use and early marine ecology of juvenile Pacific salmon in southeastern Alaska. NPAFC Bulletin 2:111–122.

Paul, J. M., A. J. Paul, T. J. Vogeler, and J. P. Doyle.
1997. Biological investigations on Pacific sandfish (*Trichodon trichodon*) in the northern Gulf of Alaska. *In* Proceedings of the international symposium on the role of forage fishes in marine ecosystems, p. 87–94. Alaska Sea Grant College Program Report no. 97-01.

Secor, D. H., J. M. Dean, and E. H. Laban.
1991. Manual for otolith removal and preparation for microstructural examination. Technical Publication 1991–01, 85 p. Belle Baruch Institute for Marine Biology and Coastal Research, Columbia, SC.

Sinclair, E. H., and T. K. Zeppelin.
2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). J. Mamm. 83:973–990.

Thedinga, J. F., S. J. Johnson, and D. J. Csepp.
2006. Nearshore fish assemblages in the vicinity of two Steller sea lion haul-outs in southeastern Alaska. *In* Proceedings of the 22nd Wakefield Fisheries Symposium Sea lions of the world: conservation and research in the 21st century, p. 269–284. Alaska Sea Grant College Program, Univ. Alaska, Fairbanks, AK.

Yang, M-S., and M. W. Nelson.
2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.