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SYNOPSIS OF BIOLOGICAL DATA ON PACIFIC OCEAN PERCH *Sebastodes alutus*

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UNITED STATES DEPARTMENT OF COMMERCE
Maurice H. Stans, *Secretary*

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ABSTRACT

This synopsis has information on the taxonomy, life history, population structure, and harvesting of a species that is being intensively fished and studied by the United States, Canada, the U.S.S.R., and Japan. This synopsis includes data from scientific papers either printed in English or translated from Japanese and Russian into English.

INTRODUCTION

The Fisheries Biology Branch of FAO has formed a "Synopsis Association," composed of fishery agencies willing to contribute to the preparation of synopses on fishes and other aquatic organisms of commercial value. Several organizations, including the BCF (Bureau of Commercial Fisheries), have agreed to collaborate with FAO in this undertaking. Under this agreement, BCF has assigned the preparation of synopses on various economically important species to a number of its laboratories. These synopses will be published in the BCF Circular series and will follow the format prescribed by H. Rosa, Jr. (1965).

The primary purpose of the synopses is to make existing information readily available to fishery scientists according to a standard pattern, which will draw attention to gaps in knowledge. The synopses will guide scientists who investigate these or other species and provide a basis for the comparative study of fishery resources.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Sebastodes alutus (Gilbert), Cramer (1895).

1.12 Synonymy

Sebastichthys alutus Gilbert (1890)

Acutomentum alutus Eigenmann and Beeson (1893)

Acutomentum alutum Eigenmann and Beeson (1895)

Sebastes alutus Matsubara (1943)

1.2 Taxonomy

1.21 Affinities

Suprageneric
Phylum Chordata
Class Teleostomi
Order Perciformes
Family Scorpaenidae
Generic

Sebastodes Gill (1861)

Genotype:

Sebastes paucispinis Ayres (1854a)

The generic concept used here is that of Cramer (1895: 589-590):

"Body and head somewhat compressed; head large, $2\frac{2}{5}$ to $3\frac{2}{3}$ in length of body; depth $2\frac{1}{4}$ to $3\frac{3}{4}$ in length of

> body; mouth moderate or large, with the jaws equal or the lower more or less projecting; the maxillary reaching middle of eye or beyond, sometimes beyond posterior edge of orbit, its length from 1¾ to 3 in length of head; teeth in villiform bands on jaws, vomer, and palatines. Head more or less evenly scaled, without dermal flaps; interorbital space convex or concave, widening markedly with age; cranial ridges more or less developed, one or more of the following pairs always present, usually ending in spines: preocular, supraocular, postocular, tympanic, coronal, parietal and nuchal. Five preopercular and two opercular spines; one to three spines on the suprascapula. Suborbital stay moderate, usually not reaching preopercle. Gill-rakers various, very long and slender to very short. Scales moderate or small, mostly ctenoid, 35 to 100 transverse series. Dorsal fin continuous, emarginate, its formula XIII-12 to 16. Anal fin III, 5 to 9. Pectorals well developed, the base broad or narrow, the lower rays undivided. Caudal slightly rounded, truncate or slightly forked; soft parts of vertical fins more or less scaly. Pyloric coeca 6 to 11. Vertebrae 12 + 15. Species of varied, often brilliant colors, mostly red. Sexes colored alike."

Hitz (1965) extended the dorsal fin formula to XIII, rarely XI, XII, or XIV—11 to 18.

The species in the genus *Sebastodes* have previously been assigned to as many as 14 genera. Richardson (1844), Ayres (1854b, 1859), and Girard (1854a, 1854b, 1856) described several species of rockfishes from the Pacific Coast of North America and placed them all in the genus *Sebastes* (rockfish is the common name for fish in the genus *Sebastodes*). Gill (1861) proposed the genus *Sebastodes* for *Sebastes paucispinis* of Ayres, and Gill (1862) placed all other Pacific Coast rockfishes in a new genus *Sebastichthys*. Ayres (1862) accepted the genus *Sebastodes* but redefined it to include *ovalis, flavidus, melanops,* and *rosaceus*. (Note: This early-day *rosaceus* has apparently been synonymized with another species and is not *Sebastodes rosaceus* [Jordan and Gilbert, 1882].) Ayres retained the remaining species in the genus *Sebastes*. Gill (1864) divided the rockfish species into four genera: *Sebastodes, Sebastichthys, Sebastomus,* and *Sebastosomus*. Jordan and Gilbert (1880) retained *Sebastodes* as a separate genus but placed the remaining species in the genus *Sebastichthys*. Jordan and Gilbert (1882) proposed that all species belonged in the single genus *Sebastodes*. Jordan (1887) again reverted to two genera—*Sebastodes* and *Sebastichthys*. Eigenmann and Beeson (1893) revised the rockfishes into eight genera: *Sebastodes, Sebastichthys, Sebastomus, Sebastosomus, Acutomentum, Acutospina, Primospina,* and *Pteropodus*. Cramer (1895) consolidated all species into the single genus *Sebastodes* Gill, 1861. Jordan, Evermann, and Clark (1930) listed 14 genera: *Sebastodes, Sebastichthys, Sebastomus, Sebastosomus, Acutomentum, Acutospina, Pteropodus, Rosicola, Eosebastes, Hispaniscus, Zalopyr, Emmelas, Sebastopyr,* and *Sebastocarus*. Matsubara (1943) claimed that the reasons for separating the genera *Sebastodes* and *Sebastes* are insufficient and that all species assigned to *Sebastodes* belong in the genus *Sebastes*. In the present synopsis *Sebastodes* is treated as a separate genus containing the 54 species listed in table 1.

Specific

The type specimen is *Sebastichthys alutus* Gilbert (1890) from south of Santa Cruz Island, Calif. The following species diagnosis for adult specimens is quoted from Phillips (1957: 78).

> "Body color—Light red including fins; a dark oliveaceous area on back under soft dorsal, and a smaller dark area on caudal peduncle; some light olive stippling on sides. Mouth and gill cavities —Mouth mainly pink, but with some duskiness; gill cavity pink, with considerable black blotching in adults. Peritoneum—Gray with black dots or black. Top of head, at mid-orbits—Slightly convex to flat. Spines on top of head—Nasal, preocular, supraocular, postocular,

Table 1.—Species in the genus *Sebastodes*

1.	*Sebastodes aleutianus*	28.	*S. maliger*
2.	*S. alutus*	29.	*S. melanops*
3.	*S. atrovirens*	30.	*S. melanostomus*
4.	*S. auriculatus*	31.	*S. miniatus*
5.	*S. aurora*	32.	*S. mystinus*
6.	*S. brevispinis*	33.	*S. nebulosus*
7.	*S. carnatus*	34.	*S. nigrocinctus*
8.	*S. caurinus*	35.	*S. ovalis*
9.	*S. chlorostictus*	36.	*S. paucispinis*
10.	*S. chrysomelas*	37.	*S. phillipsi*
11.	*S. ciliatus*	38.	*S. pinniger*
12.	*S. constellatus*	39.	*S. polyspinis*
13.	*S. crameri*	40.	*S. proriger*
14.	*S. dalli*	41.	*S. rastrelliger*
15.	*S. diploproa*	42.	*S. reedi*
16.	*S. elongatus*	43.	*S. rhodochloris*
17.	*S. emphaeus*	44.	*S. rosaceus*
18.	*S. entomelas*	45.	*S. ruberrimus*
19.	*S. eos*	46.	*S. rubrivinctus*
20.	*S, flavidus*	47.	*S. saxicola*
21.	*S. gilli*	48.	*S. semicinctus*
22.	*S. goodei*	49.	*S. serranoides*
23.	*S. helvomaculatus*	50.	*S. serriceps*
24.	*S. hopkinsi*	51.	*S. umbrosus*
25.	*S. jordani*	52.	*S. vexillaris*
26.	*S. levis*	53.	*S. wilsoni*
27.	*S. macdonaldi*	54.	*S. zacentrus*

tympanic and parietals usually present, but small and weak (a tympanic or supraocular spine may be absent occasionally). Coronal and nuchal spines absent. Parietal ridges—Low and thin. The five preopercular spines—Moderately strong, sharp, usually radially-directed but sometimes with upper two directed backward. The two opercular spines—Moderately strong, thin and sharp, the upper-most usually longer. Supracleithral and cleithral spines—Strong to weak. Lower margin of suborbital bone—Two small, sharply triangular spines, or rounded lobes present. Lower posterior edge of gill cover—Spines present. Symphyseal knob—A prominent, pointed, forward-projecting knob is present. Raised patch of teeth on tip of lower jaw—A strongly raised patch of teeth present; not completely included by snout when jaws are closed. End of maxillary—Under mid-orbit or rear of pupil. Maxillaries—Covered with scales. Mandibles—Covered with scales. Branchiostegals—With scales. Ends of pectoral and ventral fins—Tips of pectorals extend to tips of ventrals, or slightly beyond, sometimes reaching anus. Second anal fin spine—Usually twice as thick as third, occasionally only slightly thicker. Tip of second fails to reach tip of third by about one-sixth of orbit width (spines depressed). Spinous dorsal fin membrane—Moderately incised. Posterior profile of caudal fin—Strongly indented. Terminal profile of anal fin—Nearly vertical, or with slight posterior slant."

Sebastodes alutus (fig. 1) can be differentiated from the closely related species *Sebastodes crameri* and *Sebastodes reedi* by the color of the mouth, which is red in *alutus* and has blotches of black and pink in *crameri,* and blotches of black and yellow in *reedi* (Westrheim and Tsuyuki, 1967). Phillips (1957) and

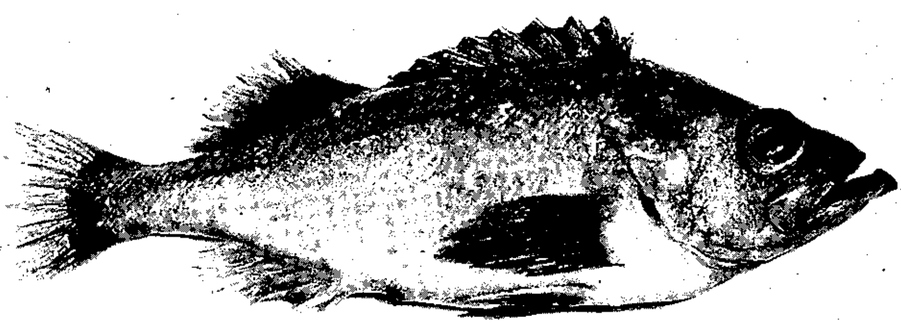


Figure 1.—*Sebastodes alutus* (Gilbert). Photograph furnished by Washington State Department of Fisheries.

Hitz (1965) published keys for the identification of species in the genus *Sebastodes.*

1.22 Taxonomic status

This is a morpho-species, and it is polytypic,

1.23 Subspecies

Barsukov (1964) suggested that *Sebastodes alutus* be divided into two subspecies: (1) the American *S. a. alutus* (Gilbert) distributed from California northward through the Gulf of Alaska to the Komandorskiy Islands and (2) the Asian *S. a. paucispinosus* (Matsubara) distributed from Honshu Island into the Bering Sea and eastward perhaps as far as Bristol Bay. The ranges of these two subspecies overlap in the region of the Aleutian and Komandorskiy Islands. Barsukov recognized, however, that this division was provisional and that the problem needed further study.

1.24 Standard common names, vernacular names.

United States and Canada—Pacific ocean perch
U.S.S.R.—Tikhookeanskii morskoi okun
Japan—Arasuka menuke

1.3 Morphology

1.31 External morphology

Phillips (1957) derived a series of proportional body measurements from 11 adult specimens and meristic counts from 15 specimens all taken off California (table 2). Barsukov (1964) extended some of the meristic counts presented by Phillips; his findings are shown in brackets in table 2. Barsukov did not, however, present proportional measurements for comparison with those by Phillips. He explained that his specimens, most of which were smaller than the California specimens used by Phillips, exhibited erratic size-related variability, which made it impossible to predict the proportional measurements for specimens larger than the ones available to him—and made it impossible, therefore, to compare the proportional measurements of fish from the various areas.

1.32 Cytomorphology

No information

1.33 Protein specificity

Electrophoretic separation of hemoglobins in starch gel media shows distinct differences between the *Sebastodes* species *alutus, crameri, reedi,* and *zacentrus.* Hemoglobin patterns remain consistent intraspecifically; variant forms appear in *crameri* and *reedi* (Westrheim and Tsuyuki, 1967).

2 DISTRIBUTION

2.1 Total area

Pacific ocean perch live along the eastern and northern rim of the Pacific Ocean from La Jolla, Calif. (FAO marine area INE), to the Komandorskiy and Kurile Islands and in the Bering Sea (FAO marine area INW—see

Table 2.—Proportional measurements (11 specimens) and meristic counts (15 specimens) from Pacific ocean perch, 33 to 45 cm. long, taken off California (Phillips, 1957; data in brackets from Barsukov, 1964)

Measurement	Frequency of measurement into:		Frequency of orbit width into measurement
	Standard length	Head length	
Length of head	2.6- 2.8	—	—
Depth of body at origin of ventral fin	2.8- 3.4	1.1-1.2	2.8-3.5
Depth of body at origin of anal fin	3.7- 4.6	1.4-1.6	2.1-2.7
Length of base of anal fin	6.1- 7.1	2.4-2.6	1.4-1.6
Length of snout	10.0-11.3	3.8-4.2	0.8-1.0
Width of orbit	9.3-10.1	3.4-3.8	—
Width of interorbital space	—	4.6-4.9	0.7-0.8
Width of suborbital bone	—	—	0.1-0.2
Length of upper jaw	5.6- 6.2	2.1-2.3	1.6-1.8
Amount that lower jaw projects	—	—	0.2-0.4
Thickness of body	—	—	1.4-1.7
Width of base of pectoral fin	—	—	0.8-0.9
Longest pectoral fin ray	3.6- 4.1	1.3-1.5	2.4-2.8
Longest ventral fin ray	—	1.8-2.0	1.8-2.1
Length of ventral fin spine	—	2.9-3.4	1.0-1.2
Length of first anal fin spine	—	—	0.4-0.6
Length of second anal fin spine	8.3-10.8	3.5-4.2	0.9-1.0
Length of third anal fin spine	—	—	0.9-1.1
Longest anal fin ray	5.9- 6.6	2.3-2.4	1.5-1.6
Longest dorsal fin spine	7.9- 8.9	2.9-3.4	1.1-1.2
Longest dorsal fin ray	6.7- 7.8	2.5-2.9	1.2-1.5
Least depth of caudal peduncle	10.6-12.3	4.1-4.5	0.8-1.1
Ventral length of caudal peduncle	—	1.8-2.0	1.8-1.9
Dorsal length of caudal peduncle	—	2.5-2.8	1.3-1.5
Posterior of anus to origin of anal fin	—	—	0.3-0.6
Longest raker on first gill arch	—	—	0.4-0.6
Number of rays in dorsal fin	14 or 15 (rarely 16 or 17)		
Number of rays in anal fin	8 or 9 [6-9]		
Number of rays in each pectoral fin	18 (occasionally 17) [15-19]		
Unbranched rays in each pectoral fin	8 (occasionally 6, 7, or 9) [5-10]		
Number of rakers on first gill arch	33-38 [33-40]		
Number of pores in lateral line	44-51 [44-53]		
Diagonal rows of scales below lateral line	49-55		

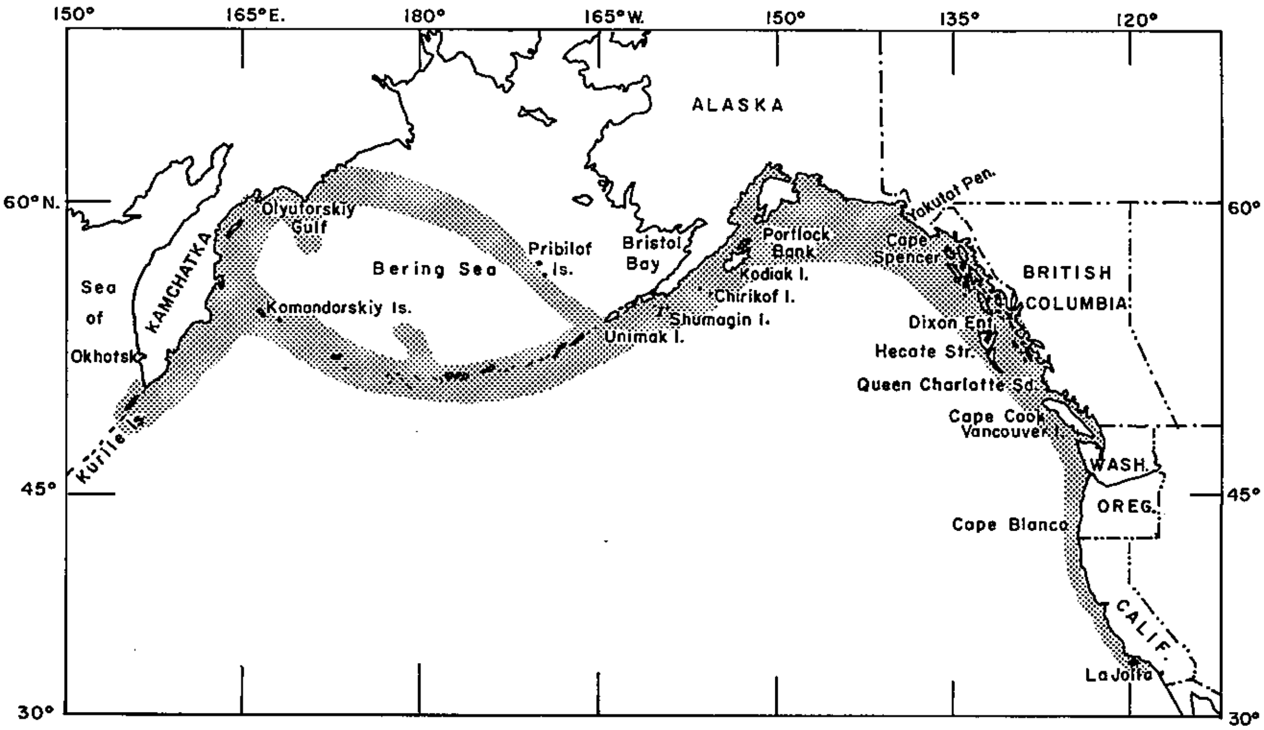


Figure 2.–Distribution of Pacific ocean perch.

fig. 2). According to Alverson, Pruter, and Ronholt (1964), no fish of the genus *Sebastodes* appears to have penetrated the Bering Strait. If the Asiatic rockfish—hypothesized by Barsukov (1964) to be *Sebastodes alutus paucispinosus*—are eventually shown to be *Sebastodes alutus* or a genuine subspecies, the range will extend southward to the Pacific Coast of Honshu Island, Japan. This synopsis is derived from scientific papers dealing with *S. alutus* that inhabit the area from La Jolla, Calif., to the Komandorskiy Islands and the central Bering Sea. Information is lacking about the stocks in the waters adjacent to the Kamchatka Peninsula and the Kurile Islands.

Pacific ocean perch are commonly found along the outer continental shelf and on the upper continental slope at depths of 150 to 460 m. They are usually near the 180-m. contour. The species is common in and along gullies, canyons, and submarine depressions of the upper continental slope. These areas characteristically have a gravel or rocky bottom and frequently contain large boulders deposited during glacial periods. Typical invertebrate animals taken in the trawl fishery for Pacific ocean perch are Alaska coral; varieties of deepwater starfish; and sea urchins (Alverson and Westrheim, 1961).

2.2 Differential distribution

2.21 Larvae and juveniles

Studies of the larvae of *S. alutus* and other rockfishes are hampered by the inability of investigators to identify larvae to species. Aron (1958), for example, was unable to identify to species young *Sebastodes* taken up to 480 km. from shore in the Gulf of Alaska. Some of these were larvae as small as 6 mm. Ahlstrom (1965) reported *Sebastodes* larvae to be abundant off California but was able to identify only *S. paucispinis*, 1 of at least 50 species that inhabit this region. Some question exists concerning the species identification in the following reports that deal with the distribution of larval *S. alutus*:

Since the Pacific ocean perch is by far the dominant rockfish species caught in the Bering Sea and the Gulf of Alaska, Soviet scientists have generally assumed that rockfish larvae and juveniles taken there are *S. alutus*. Paraketsov (1963) found that ocean perch larvae in the Bering Sea, after their birth in the spring, are swept by a circular current from their area of birth (south and southeast of the Pribilof Islands) toward the shores of Alaska and the Aleutian Islands. Lisovenko (1964) made an ichthyoplankton survey from Unimak Island to the Strait of Juan de Fuca during April to July 1963. He found free-swimming ocean perch larvae in the Gulf of Alaska over the continental shelf and slope as far as 130 to 160 km. from shore. Greatest concentrations were near the outer continental slope over depths of 180 to 700 m. Lisovenko estimated the absolute abundance of ocean perch larvae in different areas off the coast of Alaska as follows:

Area	Total number of larvae
Yakutat Peninsula	$3,475 \times 10^8$
Kodiak Island	$1,933 \times 10^8$
Shumagin Islands	761×10^8
Unimak Island	233×10^8

The full significance of the estimates is difficult to interpret because Lisovenko did not report the dimensions of the four areas. The estimates appear to be dependent on density of larvae rather than on differences in the dimensions of the areas—maximum larvae per $m.^2$ were 100 to 120 in the Yakutat area, 40 to 50 in the Kodiak area, 20 to 30 in the Shumagin area, and 10 to 15 in the Unimak area. Ocean perch larvae appear in late April and May over the entire Gulf of Alaska in waters over bottom depths of 200 to 250 m. Lisovenko found them until early June in the western area of his survey and as late as mid-July in the eastern part of the region.

The problem of identification that plagues the study of rockfish larvae also applies to the juveniles. No key is available for juvenile rockfish; until the fish are about 20 cm. long, they cannot be identified with certainty. Here again, a question exists about the accuracy of the species identification in the following reports about juvenile *S. alutus*:

Powell and Hildebrand (1950) and Powell, Alverson, and Livingstone (1952) reported large numbers of *S. alutus* 20 to 50 mm. long in stomachs of albacore, *Thunnus alalunga*, taken during the summer several hundred kilometers off the Oregon and Washington coasts. Most were 20 to 30 mm. long and were presumed to be progeny born during the preceding winter.

Alverson and Westrheim (1961), combining the preceding information with the knowledge that young *S. alutus* have been observed to "ball" at the surface, concluded that the young fish appear to lead a pelagic existence, dispersed in offshore waters at considerable distances from the fishing banks. They further interpreted the regurgitation of living young by albacore to mean that Pacific ocean perch inhabit surface waters, at least during daylight.

During the first year after birth young ocean perch are plantonic, and their distribution is determined by the movement of the water into which they were born. During their second year, however, young *S. alutus* take up life near the ocean bottom (Paraketsov, 1963). Here they remain in waters from 125 to 150 m. deep until they reach the age of sexual maturity. Schools of juvenile perch are usually found over more shallow bottoms than are the adults, and consequently, the occurrence of immature perch in the commercial catch is small. Occasionally, however, the catch is composed entirely of small fish (Moiseev and Paraketsov, 1961; Paraketsov, 1963).

Westrheim (1965[1], 1966a[2], 1966b[3]) rarely found juvenile fish at depths greater than 250 m. off Washington, Oregon, and British Columbia. Juveniles were often mixed with adults, however, indicating that the segregation of

[1] Westrheim, S. J. 1965. Catch rates and size composition of Pacific ocean perch (*Sebastodes alutus*) caught in the eastern North Pacific Ocean by the *G. B. Reed*, July to September, 1963-64. Fish. Res. Bd. Can., Biol. Sta., Nanaimo, B.C., Manuscr. Rep. Ser. (Biol.) 812, 23 pp. [Processed.]

[2] 1966a. Catch rates, size composition, and sex ratio of Pacific ocean perch (*Sebastodes alutus*) caught in the eastern North Pacific Ocean (Cape Spencer, Alaska, to Cape Blanco, Oregon) by the *G. B. Reed*, August-September 1965. Fish. Res. Bd. Can., Biol. Sta., Nanaimo, B.C., Manuscr. Rep. Series (Biol.) 867, 28 pp. [Processed.]

[3] 1966b. Catch rates, size composition, and sex ratio of Pacific ocean perch (*Sebastodes alutus*) caught in the eastern North Pacific Ocean by the *G. B. Reed*, January-March, 1963-65. Fish. Res. Bd. Can., Biol. Sta., Nanaimo, B.C., Manuscr. Rep. Series (Biol.) 869, 17 pp. [Processed.]

mature and immature fish reported by Moiseev and Paraketsov (1961) in the Bering Sea is not a universal characteristic.

Kibesaki (1965) stated that American and Japanese commercial fishermen rarely capture juvenile ocean perch between 15 and 20 cm. long, and almost never take fish less than 15 cm. long. He attributed this scarcity of small fish to either the mesh size of the nets, which permits small fish to pass through, or to a difference in habitat.

Lyubimova (1964) demonstrated a relation between body length and vertical distribution of fish (fig. 3); smaller fish are generally taken in shallower water. Westrheim (see footnotes 1, 2, and 3) reported similar findings.

2.22 Adults

Moiseev and Paraketsov (1961) reported that from January to May in the Bering Sea, the densest concentrations of ocean perch are in Bristol Bay and just south of the Pribilof Islands. During the rest of the year the concentrations extend into the central Bering Sea as far north as lat. 59° N.

Lyubimova (1963, 1965) reported that the Gulf of Alaska population is concentrated near Unimak Pass from May to September but that the fish are also around Kodiak and Chirikof Islands and in the northern Gulf of Alaska near the region of the Yakutat Peninsula during the rest of the year.

2.3 Determinants of distribution

Relative abundance of Pacific ocean perch varies widely within the total range of the species. Their preference for gullies and canyons has already been described (section 2.1). We have also mentioned the relation between size and bathymetric distribution (smaller fish are in shallower water). Other factors that apparently influence distribution are the availability of the preferred food items (section 3.42), the state of maturity as it affects migration (3.51), oxygen content of the water, and temperature of the water. Lyubimova (1965) related the vertical distribution of concentrations of perch in the Gulf of Alaska over the course of a year to the layer of oxygen deficiency (fig. 4). Rockfish concentrations remain above the layer of oxygen deficiency, and maximum depth of concentrations varies from 350 m. in summer to 420 m. in winter. She also reported that 4.0° to 6.5° C. is the temperature range acceptable to adult perch. Young perch (14-26 cm.) may be found at lower temperatures (2.5°-3.5° C.).

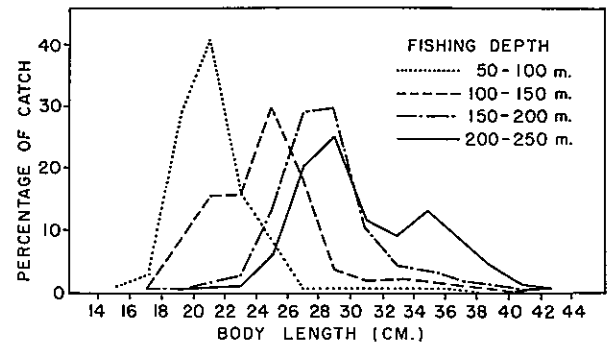


Figure 3.—Body lengths of Pacific ocean perch taken in the Gulf of Alaska at various depths (from Lyubimova, 1964).

2.4 Hybridization

No information

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Pacific ocean perch are heterosexual and without apparent sexual dimorphism.

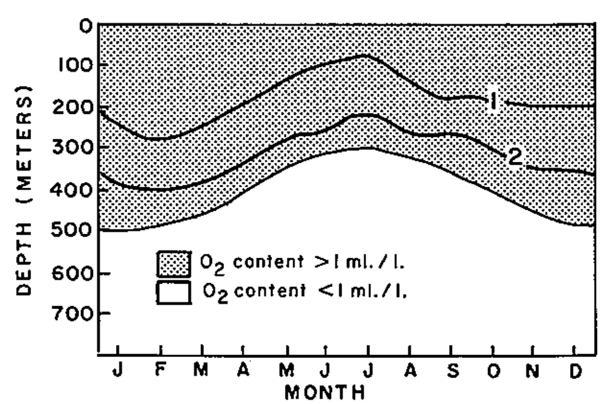


Figure 4.—The vertical distribution of Pacific ocean perch in the Gulf of Alaska relative to the layer of oxygen deficiency. Numbers 1 and 2 indicate the upper and lower limits of the perch distribution (adapted from Lyubimova, 1965).

3.12 Maturity

Paraketsov (1963) reported that in the Bering Sea females mature at 6 to 7 years and at a length of 22 to 25 cm. Lyubimova (1965) found that in the Gulf of Alaska 8 percent of the male perch matured in their fourth year and all had matured by their eighth year; 19 percent of the females matured in their fifth year, and practically all were mature by age 8.

Westrheim (1958) noted that nearly all females captured by Oregon trawlers off the coasts of Washington and Oregon were mature. These fish were 26 to 48 cm. long and from 6 years to more than 21 years old.[4]

After comparing length-fecundity curves from the west coast of North America, the Bering Sea, and Gulf of Alaska, Lisovenko (1965) concluded that Gulf of Alaska fish attain sexual maturity earlier than do those from other areas.

3.13 Mating

Mating has not been observed, but the deposition of spermatozoa by the males into the bodies of the females (section 3.14) strongly suggests that mating (copulation) is by pairs. Whether ocean perch are monogamous, polygamous, or promiscuous is not known.

Paraketsov (1963) reported January and February as the mating period for ocean perch in the Bering Sea and noted a 1:1 sex ratio at time of mating; Lyubimova (1963) found that Gulf of Alaska fish mated from September through November.

3.14 Fertilization

The Pacific ocean perch is an ovoviviparous species; i.e., eggs are fertilized internally and are retained within the ovary during incubation.

Whether fertilization occurs at mating or at a considerably later time is not clearly understood and has given rise to contradictory views. To understand the development of the opposing points of view, it is necessary to begin with the work of Sorokin (1961) with *Sebastes marinus*—the closely related redfish in the Atlantic Ocean. Sorokin, apparently working with samples from the Barents and Norwegian Seas, claimed that fertilization did not occur until 6 months after the male inseminated the female.

Paraketsov (1963) stated that for *S. alutus* in the Bering Sea, mating and fertilization take place simultaneously and noted that this was in contrast with *S. marinus*.

Lyubimova (1963) reported, on the other hand, that for *S. alutus* in the Gulf of Alaska, considerable time passes in the maturation of the egg before the moment of fertilization by spermatozoa stored in the ovary. According to Lyubimova (1965), mating is followed by a period of egg maturation lasting 3 to 4 months after which the eggs are fertilized by spermatozoa preserved within the ovary.

Sorokin (1967), who examined the gonads from 8 male and 12 female ocean perch captured in the Gulf of Alaska, found that mass maturation of the testes and mass mating occur in September and October and that most of the females have been impregnated by November. He stated conditionally that the females matured, ovulated, and were fertilized in October and November. In other words, there is little or no delay between mating and fertilization.

3.15 Gonads

Westerheim (1958) determined the length-fecundity relation for 13 female *S. alutus* taken off the coasts of Washington and Oregon (fig. 5). Observed values ranged from 31,000 eggs for a 324-mm. (8-year-old) fish to 305,000 for a 436-mm. (21-year-old) fish. The fecundity relation is expressed by the following formula:

$$F = (4.8556 \times 10^{-15}) L^{6.33454}$$

where F is thousands of yolked eggs and L is the fork length in millimeters.

According to Paraketsov (1963), the average number of emergent larvae of Pacific ocean perch in the Bering Sea was 80,000 to 150,000,

[4] Since his 1958 study and his 1961 paper with Alverson (Alverson and Westrheim, 1961), Westrheim has determined (personal communication, June 1968) that 1 year should be added to the ages presented in those two papers. We have made these corrections in this synopsis.

Table 3.—Spawning areas and time of spawning for *S. alutus*

Area	Spawning season	Water temperature	Reference
		°C.	
Bering Sea (south and southeast of the Pribilof Islands)	March-May	3.8-4.2	Paraketsov (1963)
Gulf of Alaska (north)	March-April	--	Lyubimova (1963)
Gulf of Alaska (south)	May-June	--	Lyubimova (1963)
Coastal waters off southwest Vancouver Island, British Columbia ..	March	--	Westrheim, Harling, and Davenport (1968)[1]
Coastal waters off Washington-Oregon	January-March	6.0-8.0	Snytko (1968)

[1] Westrheim, S. J., W. R. Harling, and D. Davenport. 1968. Preliminary report on maturity, spawning season, and larval identification of rockfishes *(Sebastodes)* collected off British Columbia in 1967. Fish. Res. Bd. Can., Biol. Sta., Nanaimo, B.C., Manuscr. Rep. Ser. (Biol.) 951, 22 pp.

but fecundity varied from 30,000 to 350,000, both quantities depending on the length of the female. The number of larvae released is usually fewer than the number of eggs.

Lisovenko (1965) said that the fecundity of *S. alutus* in the Gulf of Alaska ranged from 2,000 to 69,000 eggs. Fecundity-length and fecundity-weight relations for the Gulf of Alaska population were described by the following formulas:

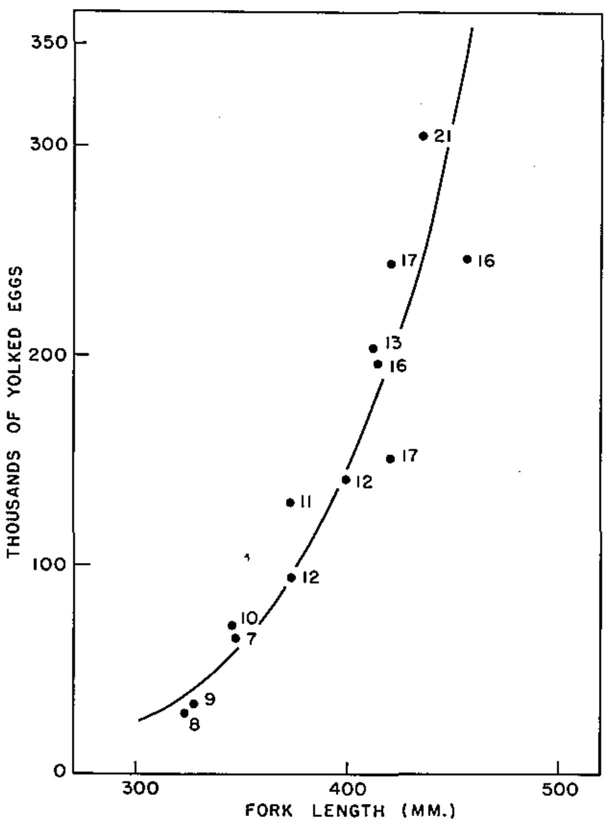


Figure 5.—Relation of fecundity to length in Pacific ocean perch. Dots indicate observed values, and numerals indicate age of each fish (adapted from Westrheim, 1958).

$$F = (2.2 \times 10^{-4})L^{5.3} \text{ and } F = 2.075P^{1.56}$$

where L is length in centimeters, P is fish weight in grams, and F is number of eggs. Lisovenko noted that the fecundity of *S. alutus* increases less with length in the Gulf of Alaska population than in other populations that have been studied.

3.16 Spawning[5]

Pacific ocean perch spawn once a year; table 3 summarizes areas and time of spawning.

On the main Bering Sea spawning grounds (south and southeast of the Pribilof Islands), individual spawning schools consist of females with larvae at equal stages of development (Paraketsov, 1963). Although the spawning season of the species extends from March to May, the spawning of a particular school is completed within 3 to 3½ hours. Paraketsov observed that the first spawning is later in the northern spawning grounds than in the southern regions.

Area	Time of first spawning
Lat. 54°30′-55°10′	March
Lat. 55°30′-56°30′	April
Lat. 56°30′-57°00′	May
North of lat. 58°30′	No spawning reported

Moiseev and Paraketsov (1961) described spawning; that is, the release of larvae by the female ocean perch in the Bering Sea as it was observed in a series of echograms obtained on April 17, 1960. The activities occurred over bottom depths of 390 to 400 m. What the authors assumed to be spawning females were concentrated in a layer 25 to 30 m. off the bot-

[5] Spawning, as used here, refers to the release of larvae.

tom. A massive liberation of the larvae began at twilight (1730 hours) and was visible on the echogram as a foglike trace above the concentration of adult females. During the ensuing 1.5 to 2 hours, the number of larvae increased and ascended to 125 to 150 m. off the bottom. By 2010 hours an accumulation of larvae was recorded in a layer between 120 and 175 m. off the bottom. These observations were substantiated by catches of ocean perch larvae in egg nets.

3.17 Eggs and sperm

Sorokin (1967) examined the gonads of 8 males and 12 females taken in the Gulf of Alaska, July 23 to August 15, 1960. Histological examination showed that both males and females were at varying stages of development. Spermatogonia in different phases of mitotic division predominated in the testes of one group of males, spermatids and spermatozoids were being formed in the testes of another group, and spermatozoids had formed in most of the cysts of the testes and had begun to flow into the lumina of the seminiferous canals of the third group.

Females with the most developed ovaries had maturing oocytes enclosed in two-layered follicles with well-developed envelopes and zona radiata in the process of formation. The second group included females whose ovaries were composed mainly of oocytes in which cytoplasm yolk had begun to form, building up at the peripheral zone of the oocytes in the form of granules. A third group included fishes whose ovarian oocytes were in the two-layered follicle stage; lipoid inclusions were scattered throughout the ooplasm, but the largest were in the nuclear zone. Yolk formation apparently had not yet begun, or was in an incipient stage. The peripheral zone had bluish granular formations.

3.2 Preadult phase

3.21 Embryonic phase

No data.

3.22 Larval phase

The melanophore patterns of larvae extruded from adult females (fig. 6) have been described by Lisovenko (1964); DeLacy, Hitz, and Dryfoos (1964); and Westrheim et al. (footnote 1, table 3). DeLacy et al. differentiated 13 species of rockfish by melanophore patterns, and Westrheim et al. differentiated 6 species. The latter authors noted, however, that their specimens of *S. alutus* did not have the multiple rows of melanophores on the ventral surface present in the specimens of DeLacy et al. They also noted that the ventral row stopped short of the anus by at least four myotomes, whereas DeLacy et al. reported that the ventral row stopped short by two myotomes.

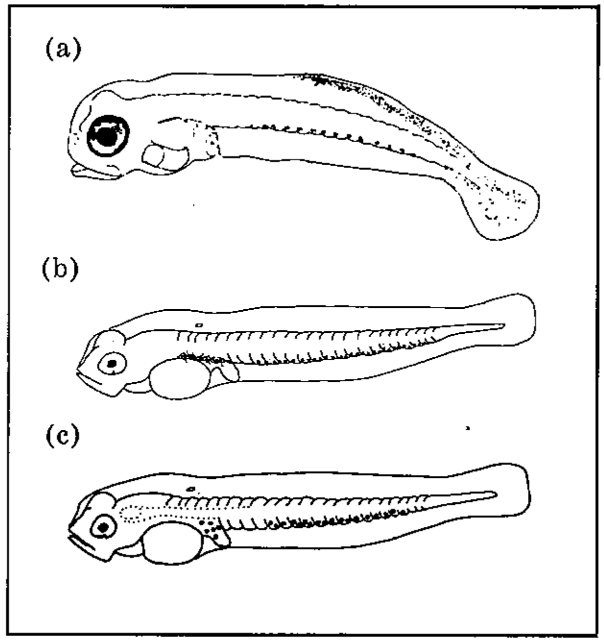


Figure 6.—Diagrammatic sketches of larval Pacific ocean perch. (a) Lisovenko, 1964; (b) DeLacy et al., 1964; and (c) Westrheim et al. (see footnote 1, table 3).

Length of larvae at the time of emergence has been reported as 6 to 8 mm. by Paraketsov (1963), 5 to 8 mm. by Lisovenko (1964), and 6.1 mm (average) by Westerheim et al. (footnote 1, table 3).

No information is available about the advanced larval or postlarval stages.

3.23 Juvenile phase

Little is known about the pelagic and benthic phases of juvenile ocean perch. Powell and Hildebrand (1950) reported that pelagic forms have blue backs, silvery sides, and a purple blotch on the operculum. Paraketsov (1963) found that before the fish move to the bottom in their second year, the principal food items are planktonic crustaceans. After they pass to the bottom, the basic food changes progressively from Euphausiidae to Pandalidae. Section 2.22 describes the distribution of juveniles.

3.3 Adult phase

3.31 Longevity

Pacific ocean perch are slow growing and have a long life span. Westrheim (1958) found that the males, although they grow faster than females, have a shorter life span. He estimated maximum age to be 30 years for males and 35 for females. Paraketsov (1963) reported a 29-year-old fish from the Bering Sea.

3.32 Hardiness

No information.

3.33 Competitors

Although direct information is lacking, many species probably compete with the Pacific ocean perch, since its principal foods—euphausiids, small crustaceans, and shrimp—are the favorites of many species.

3.34 Predators

Thompson (1915) reported *S. alutus* as one of the important constituents in the diet of halibut, *Hippoglossus stenolepis.* Tomilin (1957) reported that rockfish *Sebastodes* spp. were found in stomachs of 3 of 110 sperm whales, *Physeter catodon,* captured in the Kurile Island region.

The junior author has observed adult *S. alutus* in the stomachs of large sablefish, *Anoplopoma fimbria,* taken off the coast of Oregon.

3.35 Parasites, diseases, injuries, and abnormalities

Parasites of *S. alutus* are listed in table 4. Wilkes (1957), who examined *S. alutus* specimens caught off Oregon for presence and incidence of parasitic copepods, found seven species and identified six—four of which were listed as probable new species (table 4). Regions of infestation included gill filaments, eye muscles, stomach, pyloric caeca, intestine, visceral cavity, and gut wall.

Liston, Peters, and Stern (1960) found that the parasitic trematodes, *Prosorhynchus* spp. and *Porrocaecum decipiens,* and an unidentified copepod of rockfishes cause considerable economic loss in the fishing industry. These

Table 4.—Parasites of *Sebastodes alutus*

Type of parasite	Reference
Platyhelminthes:	
Cestodes:	
Bothriocephalus scorpii	Alverson and Westrheim (1961)
Bothriocephalus spp. (larval)	Arai (1969)
Unidentified (two larval types in plerocercoid stages)	Alverson and Westrheim (1961)
Trematodes:	
Lepidapedon spp.	Alverson and Westrheim (1961)
Megalocotyle trituba	Alverson and Westrheim (1961)
Podocotyle spp. (immature)	Arai (1969)
Porrocaecum decipiens	Liston, Peters, and Stern (1960)
Prosorhynchus spp.	Alverson and Westrheim (1961); Liston et al. (1960)
Nemathelminthes:	
Nematodes:	
Two unidentified species (one in larval form)	Alverson and Westrheim (1961)
Anisakis spp. (larval)	Arai (1969)
Arthropoda:	
Copepods:	
Chondrocanthus pinguis Wilson	Wilkes (1957)
Chondrocanthus spp. (probable new species)	Wilkes (1957)
Clavellopsis spp. (tentative new species)	Wilkes (1957)
Colobomatus spp. (probable new species)	Wilkes (1957)
Haemobaphes theragrae Yamaguti	Wilkes (1957)
Peniculus spp. (probable new species)	Wilkes (1957)

parasites are not known to be harmful to man, but their presence in fillets is esthetically objectionable. In 1958, incidence of parasitization for *S. alutus* was the highest (39 percent) in the area of Hecate Strait, British Columbia; moderate (21 percent) in the area from Cape Cook, Vancouver Island, to the Columbia River; and lowest (15 percent) in the area from the Columbia River to Cape Blanco, Oreg. The corresponding percentages in 1959 were 45, 44, and 27 (Liston and Hitz, 1961).

Liston et al. (1960) mentioned two theories for the greater abundance of the major parasite, *Prosorhynchus,* in the northern than in the southern area: (1) abundance of the parasite varies inversely with the intensity of fishing, and (2) there is a geographical limit on the parasite or on one of its hosts.

Abnormalities

So-called blemishes, resembling a kernel of unpolished rice in size and appearance and occurring in muscles of Pacific ocean perch, were identified as aberrant cartilaginous tissues (Liston et al., 1960). More than half of the fillets examined by Liston and Hitz (1961) contained blemishes, but the aberrancy is harmless and does not affect edibility.

3.4 Nutrition and growth

3.41 Feeding

Because of the inaccessibility of the natural habitat of the adult Pacific ocean perch to observation and the (so far) insurmountable difficulties in bringing viable specimens to the surface for aquarium study, reports on the feeding of *S. alutus* are generally based upon examination of the stomachs of dead specimens. Lyubimova (1963) reported that the study of the feeding habits of *S. alutus* is hindered by the "explosion" of the stomachs when the fish are brought to the surface. She noted, however, that the Gulf of Alaska population forages in the summer (May-September) near Unimak Island. This area has high biological productivity associated with the mixing of Bering Sea and Pacific Ocean water. Secondary foraging areas lie just southwest of the Shumagin Islands, east of Kodiak Island, and southwest of Portlock Bank (fig. 7). Lyubimova contended that during the rest of the year (October-April) mature perch almost wholly abstain from feeding. Perch captured during the winter are leaner than those taken during the foraging period and their quality is inferior (Lyubimova, 1965). Figure 8 shows the percentages of full stomachs over the course of a year. The large increase in the percentage of full stomachs from May through September, indicates the high intensity of feeding during this period (Lyubimova, 1963). Immature fish feed year-round. Moiseev and Paraketsov (1961) reported that in the Bering Sea, 65 percent of the nonexploded stomachs examined in May-September were full. Of the nonexploded stomachs collected from fish accumulated on the spawning grounds, 98 percent were empty. They concluded that *S. alutus* do not feed during the prespawning period. Snytko (1968) reported that in the Vancouver Island-Oregon region, perch feed from spring to late autumn.

Skalkin (1964) showed that intensity of feeding is not constant during the 24-hour period. In specimens collected from 0800 hours until 2000 hours on June 21, 1960, at depths from 140 to 150 m., the intensity of feeding was greatest at noon, least in the morning, and at an intermediate level in the evening. He noted a different pattern in specimens collected from below 200 m.; with these, the greatest intensity of feeding occurred in the morning, declined during the day, and increased again in the evening but not to the level of the morning. Skalkin suggested that the changes might be related to the availability of food organisms.

3.42 Food

The food of the Pacific ocean perch is not different from that of many other groundfishes. Paraketsov (1963) reported that pelagic juvenile ocean perch fed on planktonic crustaceans, whereas benthic juveniles ate euphausiids and pandalids. Moiseev and Paraketsov (1961) found that the composition of the stomach contents of Pacific ocean perch was 75 percent crustaceans (euphausiids and pandalids), 15 percent squids, and 6 to 7 percent fish. Skalkin (1964) listed food items of Pacific ocean perch in the Bering Sea (table 5) and reported that immature fish feed mostly on calanoids, whereas mature fish feed mainly on euphausiids.

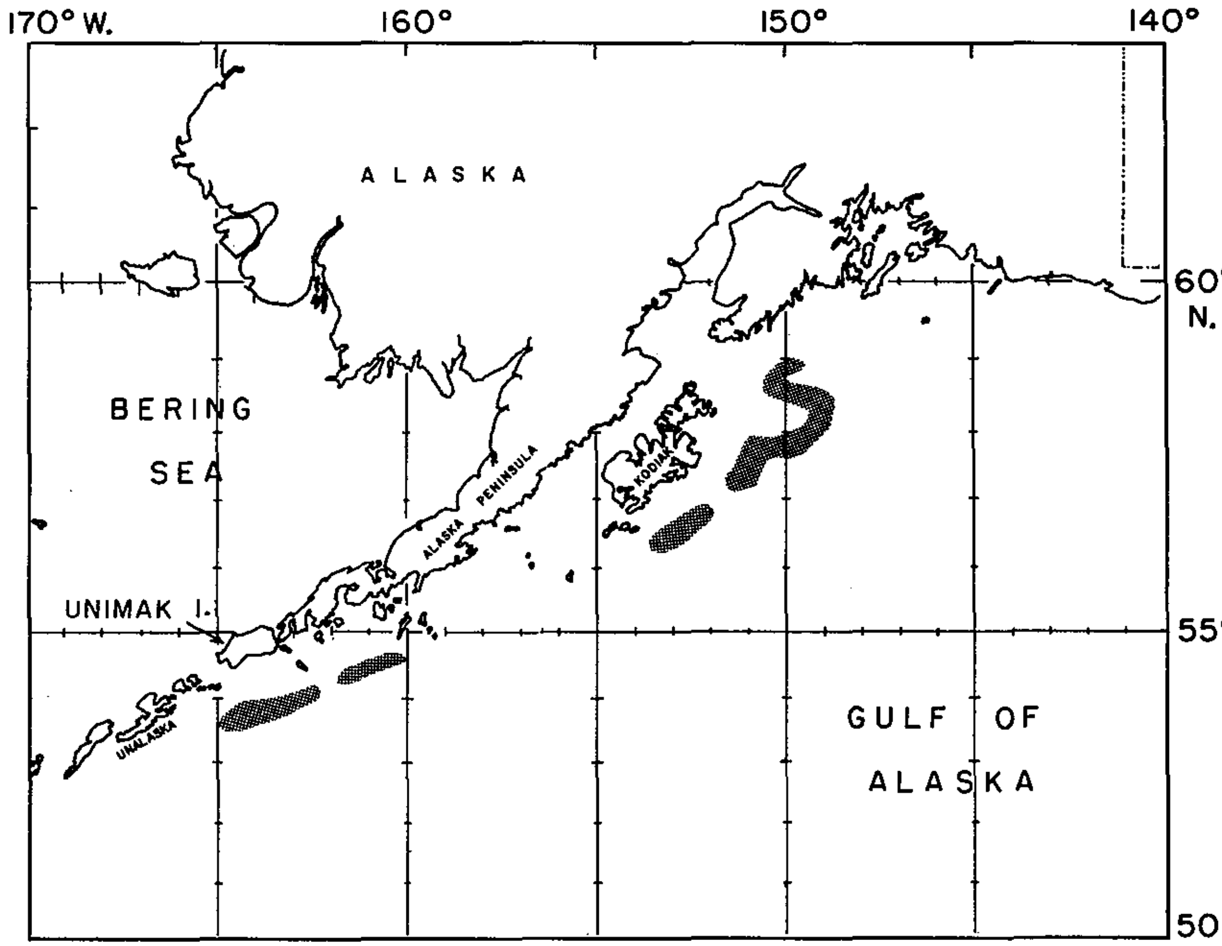


Figure 7.—Distribution of Pacific ocean perch in the Gulf of Alaska during the principal feeding period (from Lyubimova, 1965).

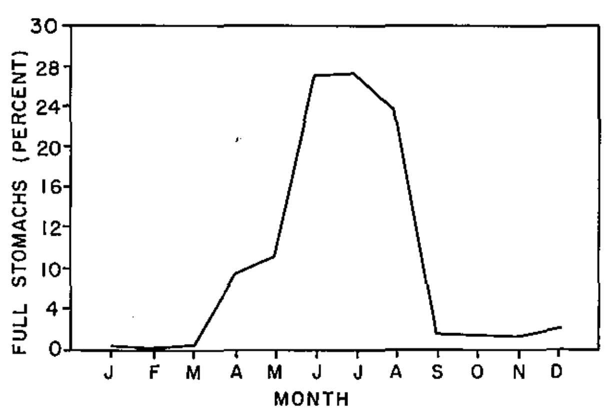


Figure 8.—Percentage of full stomachs in samples of Pacific ocean perch taken each month in the Gulf of Alaska (from Lyubimova, 1963).

3.43 Growth rate

Investigators have reported on the growth rate of Pacific ocean perch from various areas within the range of the species.

In the Bering Sea, *S. alutus* attained an average length of 31.5 cm. at 10 years of age and 42 cm. at 20 years (fig. 9); the oldest fish, 29 years, was 48 cm. long (Paraketsov, 1963). Gritsenko (1963), also working with fish from the Bering Sea, found that linear growth was greatest during the first 5 to 7 years. The relative annual increase in length was similar for both males and females and declined from 54 percent initially to 10 percent in the 7th year; from the 8th year onward the relative annual increment of growth did not exceed 10 percent, and toward the 16th to

Table 5.—Composition of food of Pacific ocean perch sampled in the Bering Sea (from Skalkin, 1964)

Item	Maximum weight	Maximum frequency of occurrence
	Percent	*Percent*
Calanus cristatus V	86.4	100.0
Calanus plumchrus V	85.6	100.0
Calanus glacialis V	30.0	72.0
Eucalanus bungii V	4.7	28.7
Pareuchoeta japonica V	1.2	4.8
Thysanoessa longipes	100.0	100.0
Thysanoessa raschii	84.6	100.0
Thysanoessa inermis	98.6	100.0
Euphausia pacifica	2.1	7.2
Mysidae spp. (3 species)	84.8	95.0
Themisto spp.	5.3	66.7
Anonyx nygax	--	--
Amphipoda spp.	3.6	38.1
Pandalidae spp. (2 species)	10.7	14.3
Sagitta elegans	17.2	41.7
Beroe cucumis	6.7	11.1
Polychaeta spp. larva	Insignificant	8.3
Cephalopoda spp. (2 species)	47.4	75.9
Clione limacina	--	--
Gastropoda larva	--	--
Oicopleura spp.	--	--
Gorgonocephalus spp.	Insignificant	5.0
Ophiura leptoctenia	Insignificant	1.9
Macruridae spp. fry	17.6	66.9
Scopeliformes ("luminous anchovy")	1.4	2.9

17th years this increment declined to about 2 percent.

Lyubimova (1964) found that in the Gulf of Alaska, *S. alutus* grew 5.4 to 2.7 cm. per year during the first 5 or 6 years and then growth gradually decreased to 2.2 to 1.4 cm. per year.

Westrheim (1958) reported that *S. alutus* grows very slowly off Washington and Oregon, particularly after the 11th year. Maximum length increment is in the first year for both sexes; maximum weight increment is in the sixth year for males and in the seventh year for females. Table 6 shows Bertalanffy constants calculated from the Pacific ocean perch data.

Westrheim (1958) depicted the age/length and age/weight relations by sex as shown in figures 10 to 13. He determined the length-weight relation as follows:

$$\text{Males: } W = (7.2510 \times 10^{-9}) L^{3.24960}$$
$$\text{Females: } W = (1.5339 \times 10^{-8}) L^{3.11877}$$

where W = weight in pounds and L = fork length in millimeters. Figure 14 shows these relations.

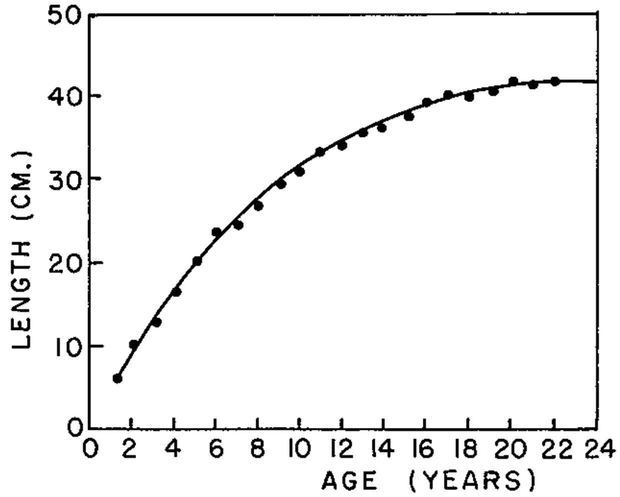


Figure 9.—Growth of Pacific ocean perch in the Bering Sea (Paraketsov, 1963).

3.44 Metabolism

No information

3.5 Behavior

3.51 Migrations and local movements

The extensive "migrations" described in this section are not based on tagging but presumably on changes in distribution and abundance. Until supported by tagging studies, the migrations reported here must be regarded as hypothetical.

Moiseev and Paraketsov (1961) reported that from January to May in the Bering Sea, the densest concentrations of *S. alutus* are in Bristol Bay and in the spawning area just south of the Pribilof Islands. Depths in these areas range from 340 to 420 m. Except for distinct daily vertical migrations, the schools are relatively immobile. From May to Sep-

Table 6.—Bertalanffy constants calculated from Pacific ocean perch growth data obtained from the scale method of growth analysis (adapted from Westrheim, 1958)

Constants	Males	Females
t	1-14	1-14
L_{∞}	403 mm.	432 mm.
K	0.20	0.18
W_{∞}	0.93 kg.	1.15 kg.
t_0	−0.71 year	−1.09 years
t_{λ}	30 years	35 years

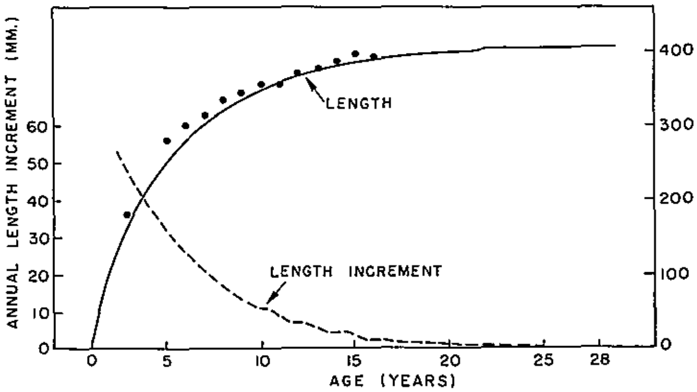


Figure 10.—Age-length relation for male Pacific ocean perch taken off Washington and Oregon, based on the Bertalanffy method of growth analysis. Dots indicate observed values obtained from the direct method of growth analysis (adapted from Westrheim, 1958).

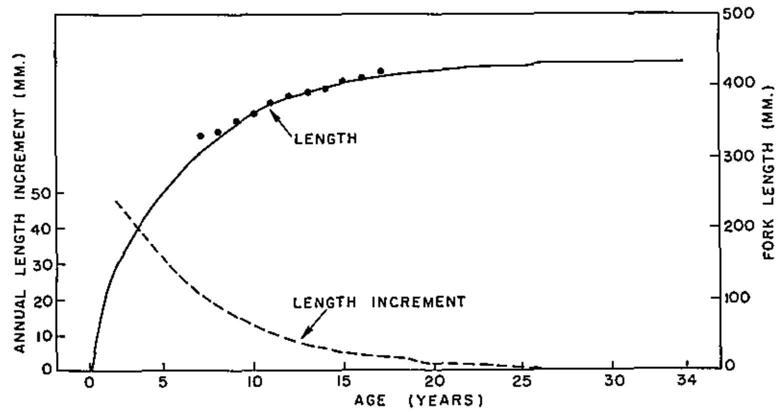


Figure 11.—Age-length relation for female Pacific ocean perch off Washington and Oregon, based on the Bertalanffy method of growth analysis. Dots indicate observed values obtained from the direct method of growth analysis (adapted from Westrheim, 1958).

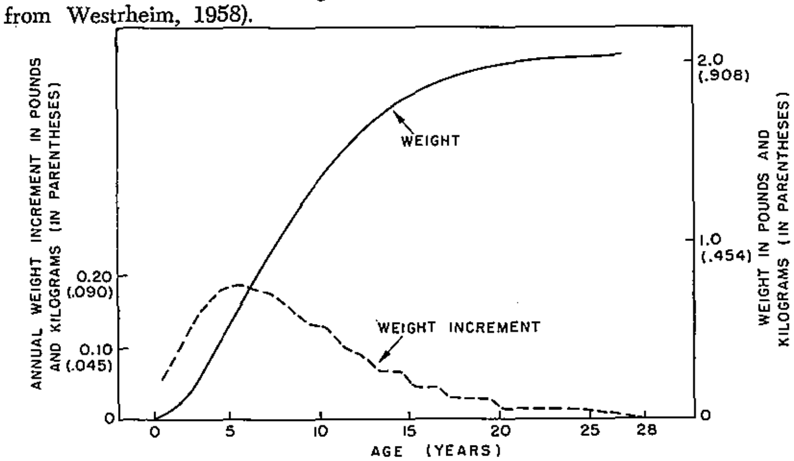


Figure 12.—Age-weight relation for male Pacific ocean perch off Washington and Oregon, based on the Bertalanffy method of growth analysis (adapted from Westrheim, 1958).

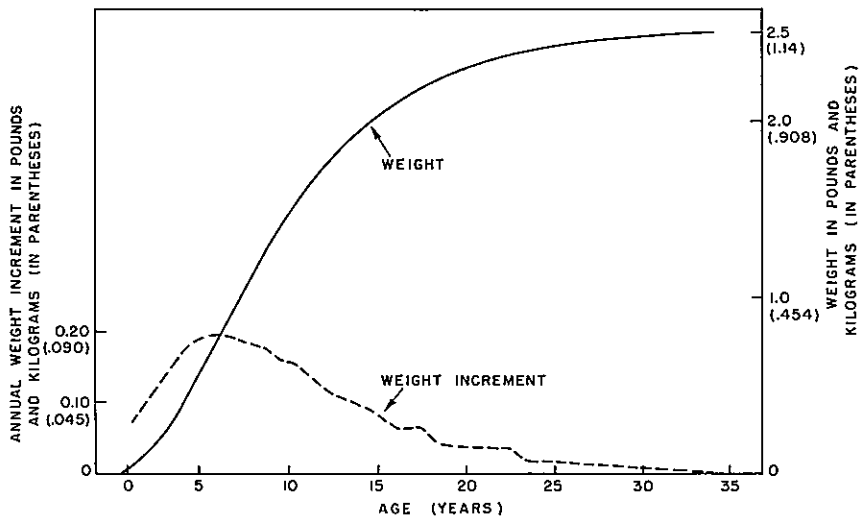


Figure 13.—Age-weight relation for female Pacific ocean perch off Washington and Oregon based on the Bertalanffy method of growth analysis (adapted from Westrheim, 1958).

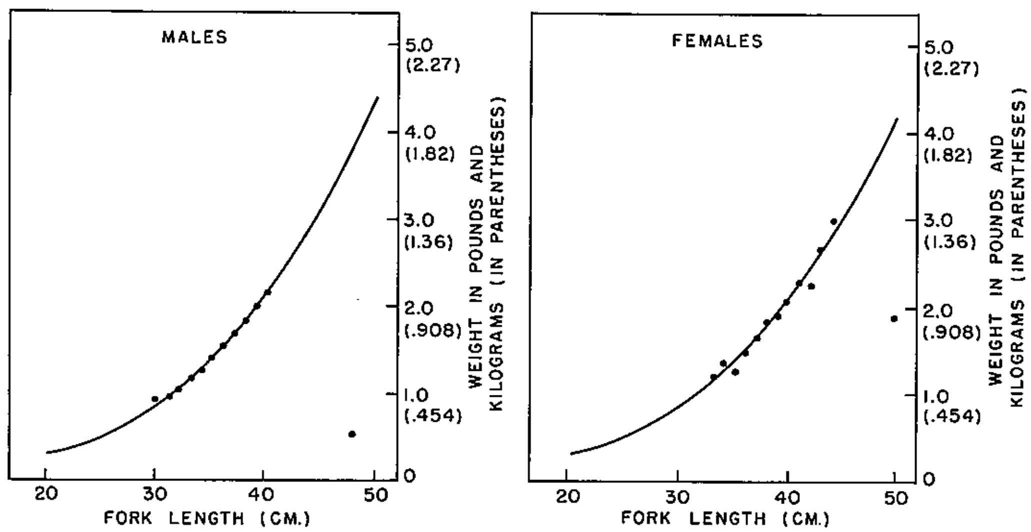


Figure 14.—Length-weight relation for male and female Pacific ocean perch off Washington and Oregon. Solid dots indicate observed values from which each curve was calculated (from Westrheim, 1958).

tember the fish make an intensive foraging migration to the central Bering Sea; from September to January they return. During migration the schools are in shallower water but at a greater range of depths (140-360 m.). Figure 15 shows the depth distribution in the Bering Sea in summer and winter.

In the Bering Sea, *S. alutus* rarely forage north of lat. 59° N., and populations off the east coast of Kamchatka do not go north of the Olyutorskiy Gulf (Paraketsov, 1963). No movement across the deep part of the Bering Sea has been reported.

The observations of Lestev (1961) are not in agreement with those of Moiseev and Paraketsov (1961). Lestev reported that in the Bering Sea, rockfishes (primarily Pacific ocean perch) do not make long migrations; each stock occupies one region, which it does not leave.

Table 7.—Size composition of Pacific ocean perch landed in Vancouver from Queen Charlotte Sound, 1960-63 (modified from Westerheim, text footnote[1])

Fork length	Year				Total fish	Size composition
	1960	1961	1962	1963		
Cm.	*Number of fish*				*Number*	*Percent*
20	--	--	--	--	--	--
2	1	2	1	1	5	0.08
4	1	4	6	1	12	0.20
6	5	14	36	5	60	0.98
8	27	36	46	21	130	2.13
30	78	94	108	43	323	5.29
2	135	135	183	108	561	9.18
4	230	223	352	337	1,142	18.69
6	252	262	428	379	1,321	21.62
8	204	191	304	344	1,043	17.07
40	184	118	170	260	732	11.98
2	128	66	97	138	429	7.02
4	45	32	93	75	245	4.01
6	26	10	30	24	90	1.47
8	9	1	3	1	14	0.23
50	2	--	--	--	2	0.03
2	1	--	--	--	1	0.02
4	1	--	--	--	1	0.02
Total no. of fish[1]	1,329	1,188	1,857	1,737	6,111	

[1] Numbers sampled.

his work generally corroborates previous information that the modal size is larger in the Washington-Oregon and British Columbia areas (34-42 cm.) than in the Gulf of Alaska (most commonly 30 cm.).

The 54-cm. specimen landed in Vancouver from Queen Charlotte Sound in 1960 (table 7) appears to be the longest on record.

4.2 Abundance and density

4.21 Average abundance

Alverson et al. (1964) derived estimates of standing crop of *S. alutus* (table 8).

Table 8.—Estimated weights of standing crops of *S. alutus*, by depth interval, in different regions; a dash (—) indicates that no estimate was made because of limited sampling effort, and a plus (+) indicates that the given weight is a minimal estimate (modified from Alverson et al., 1964)

Region	Depth interval (m.)			Total weight
	2-90	91-180	181-420	
	Metric tons			
Washington-Oregon	—	3,175	46,266	49,441+
British Columbia and Southeastern Alaska	—	—	249,476	[1] 333,393+
Gulf of Alaska	454	83,461	40,823	124,738
Alaska Peninsula	0	6,803	13,154	19,957
Bering Sea (Eastern)	0	—	—	+
Total weight	454+	[1] 177,354+	349,719+	527,529+

[1] Estimated total.

4.22 Changes in abundance

Studies of changes in abundance of Pacific ocean perch have not been published, but unpublished evidence assembled by scientists of the United States and Soviet Union suggests that abundance has declined markedly after intensive fishing in certain parts of the Gulf of Alaska and off the northwestern United States.

4.23 Average density

No information.

4.24 Changes in density

Lestev (1961), in describing the schooling characteristics of *S. alutus* (sec. 3.52), noted that a typical school was in contact with the bottom and was denser at the base than at the top. He also stated that in winter and spring, when the fish gather in prespawning aggregations, catches are larger and more consistent than in the summer, when the fish are feeding.

See also sections 2.2, 3.51.

4.3 Natality and recruitment

4.31 Reproduction rate

No information.

4.32 Factors affecting reproduction

Food supply, predation, parasitism, and physical factors of the environment undoubtedly affect reproduction of the population, but the extent is unknown.

4.33 Recruitment

According to Westrheim (1958), some 3- to 6-year-old ocean perch appear in trawl catches taken by the U.S. fleet off Washington and Oregon; appreciable numbers, however, are not captured until age 7. Alverson and Westrheim (1961) concluded that full recruitment probably does not occur until the 12th or 13th year. The age composition in the Bering Sea and the Gulf of Alaska (figs. 17 and 18) suggests that full recruitment occurs at about age 13 in the Bering Sea and at about age 8 in the Gulf of Alaska—at least with the gear that the Soviet fishermen were using at the time the samples were collected. Because 8-year-old fish in the Gulf of Alaska are the same size as age-6-year-old fish off Washington-Oregon, we might assume that age-6 fish are being fully recruited in the fishery initiated by the Soviet fleet off Washington-Oregon in 1966.

According to Pereyra,[7] age-2 fish are harvestable with the nets of smaller mesh size used by the Soviet fishermen off Washington and Oregon. He calculated that 11,069 metric tons of age-2 fish are recruited to this fishery annually.

See also sections 4.12, 4.13.

4.4 Mortality and morbidity

4.41 Mortality rates

Westrheim (1958) estimated that the natural mortality was 32 percent off the coasts of Washington and Oregon. Pereyra (see footnote 7) used the data from Westrheim (1958) to calculate an age-specific fishing mortality rate of 0.10 for the fully recruited age groups (12 and older) of the Washington-Oregon population under conditions of the U.S. fishery. The rate (0.10) is the same under conditions of the Soviet fishery, but it includes fully recruited age groups 6 and older.

4.42 Factors causing or affecting mortality

Predators are discussed in section 3.34. The total effect of predators on the population is unknown.

4.43 Factors affecting morbidity

Parasites are discussed in section 3.35.

4.44 Relation of morbidity to mortality rate

No information.

4.5 Dynamics of the population as a whole

Pereyra (see footnote 7) calculated the maximum equilibrium yield of the Washington-Oregon stock at 16,084 metric tons under conditions of the U.S. fishery and 24,381 metric tons per year under conditions of the Soviet fishery. He reasons that because of moderate natural mortality and slow growth, the biomass of a year class reaches its maximum relatively early (in the sixth year). Assuming that the natural mortality is moderate at all levels of stock size and that recruitment would not be adversely affected by reduced size of the parent stock, Pereyra determined that physical equilibrium yield would be obtained if the stocks were fished at an early age. The dynamics of the Gulf of Alaska and Bering Sea populations have not been similarly examined.

4.6 The population in the community and the ecosystem

Alverson et al. (1964: 157-158) presented the following information concerning the role of *S. alutus* in the demersal fish community of the northeastern Pacific Ocean:

> "Pacific ocean perch was the dominant form in the aggregate species catch throughout the arc of the northeastern Pacific Ocean from southern Oregon to Unimak Pass at depths from 100 to 149 fathoms, and ranked among the top five species in the 150- to 199-fathom depth zone." (See table 9)

The importance of *S. alutus* in the rockfish community is even more pronounced; Alverson et al. (1964: 94-96) state further:

> "Pacific ocean perch, the most important single species of rockfish harvested in the north-eastern Pacific, dominated the rockfish catches on the other (sic) continental shelf and upper continental slope in the regions between southern Oregon and Unimak Pass. It was the dominant species contributing to the rockfish catches in regions south of Cape Spencer in depth zones from 50 to 299 fathoms, and in the Gulf and Peninsula regions in depth zones between 1 and 199 fathoms.
>
> "Its importance in the rockfish community on the upper continental slope at depths from 100 to 149 fathoms throughout the geographic area between southern Oregon and Unimak Pass is indicated by the fact that it accounted for

[7] Walter T. Pereyra, Deputy Director for Research, Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, Seattle, Wash. Personal communication. January 1969.

Table 9.—The five most abundant demersal fish taken from the northeastern Pacific Ocean and their percentage of total catch by regions and depth intervals (adapted from Alverson, Pruter, and Ronholt, 1964)

Region	Fishing depth									
	1-90 m.		91-181 m.		182-273 m.		274-365 m.		366-547 m.	
	Species	Percentage	Species	Percentage	Species	Percentage	Species	Percentage	Species	Percentage
Oregon-Washington:										
	*	*	*Merluccius productus*	25	*S. alutus*	47	*S. alutus*	34	*Anoplopoma fimbria*	37
	*	*	*Atheresthes stomias*	15	*Microstomus pacificus*	14	*Microstomus pacificus*	21	*Microstomus pacificus*	19
	*	*	*Microstomus pacificus*	13	*Atheresthes stomias*	9	*Anoplopoma fimbria*	14	*S. alutus*	13
	*	*	*Glyptocephalus zachirus*	4	*Anoplopoma fimbria*	8	*Merluccius productus*	6	*Sebastolobus* spp.	5
	*	*	*Anoplopoma fimbria*	4	*Squalus acanthias*	3	*Atheresthes stomias*	5	*Atheresthes stomias*	4
British-Columbia-southeastern Alaska:										
	*	*	*Atheresthes stomias*	19	*S. alutus*	47	*S. alutus*	55	*	*
	*	*	*S. alutus*	19	*Atheresthes stomias*	15	*Atheresthes stomias*	14	*	*
	*	*	*Squalus acanthias*	11	*Theragra chalcogrammus*	7	*Microstomus pacificus*	5	*	*
	*	*	*S. brevispinis*	9	*Microstomus pacificus*	5	*Hydrologus colliei*	5	*	*
	*	*	*Microstomus pacificus*	9	*S. rubrivinctus*	4	*S. rubrivinctus*	3	*	*
Gulf of Alaska:										
	Platichthys stellatus	14	*Atheresthes stomias*	31	*S. alutus*	32	*Atheresthes stomias*	48	Coryphaenoides (Fam. Macrouridae)	32
	Lepidopsetta bilineata	13	*S. alutus*	16	*Atheresthes stomias*	28	*S. alutus*	19	*Atheresthes stomias*	24
	Gadus macrocephalus	12	*Hippoglossoides elassodon*	9	*Theragra chalcogrammus*	6	*Microstomus pacificus*	10	*Microstomus pacificus*	18
	Raja spp.	10	*Theragra chalcogrammus*	9	*Hippoglossoides elassodon*	6	*Hippoglossoides elassodon*	6	*Anoplopoma fimbria*	11
	Atheresthes stomias	9	*Gadus macrocephalus*	7	*Anoplopoma fimbria*	5	*Hippoglossus stenolepis*	5	*S. alutus*	10
Alaska Peninsula:										
	Lepidopsetta bilnieata	29	*Atheresthes stomias*	19	*Atheresthes stomias*	45	*Atheresthes stomias*	64	Coryphaenoides (Fam. Macrouridae)	45
	Hippoglossus stenolepis	19	*Hippoglossoides elassodon*	11	*S. alutus*	19	*Theragra chalcogrammus*	12	*Atheresthes stomias*	33
	Gadus macrocephalus	5	*Gadus macrocephalus*	9	*Hippoglossoides elassodon*	12	*Anoplopoma fimbria*	6	*Glyptocephalus zachirus*	6
	Atheresthes stomias	5	*Lepidopsetta bilineata*	7	*Theragra chalcogrammus*	10	*S. alutus*	5	*Anoplopoma fimbria*	5
	Hippoglossoides elassodon	4	*Theragra chalcogrammus*	7	*Glyptocephalus zachirus*	3	*Hippoglossoides elassodon*	2	*Sebastolobus* spp.	5
Bering Sea:										
	Limanda aspera	43	--	--	--	--	--	--	--	--
	Lepidopsetta bilineata	26	--	--	--	--	--	--	--	--
	Theragra chalcogrammus	13	--	--	--	--	--	--	--	--
	Hippoglossoides elassodon	4	--	--	--	--	--	--	--	--
	Platichthys stellatus	4	--	--	--	--	--	--	--	--

* Inadequate sampling.

77 to 98 percent of the total rockfish catches. In waters between Cape Spencer and Unimak Pass it accounted for over 62 percent of the aggregate rockfish catches made at depths between 1 and 199 fathoms. In the Gulf and Peninsula regions the percentage contribution of Pacific ocean perch to the total rockfish catch was considerably greater on the continental shelf than in more southern waters. The increase in the percentage importance of Pacific ocean perch in the shallow portion of its depth range in more northern waters is due in part to a decline in the number of other *Sebastodes* inhabiting the region. The Pacific ocean perch occurred in all inside areas surveyed. However, it did not play as important a role in the rockfish catches in inside areas as in the comparable depth intervals in adjacent offshore regions."

Lyubimova (1963) cited the work of V. I. Troinin, who noted that the distribution of Pacific ocean perch in the Gulf of Alaska coincides with the distribution of humpback whales, *Megaptera nodosa*. The similarity in distribution is explained by the similarity in food: both the humpback whale and *S. alutus* feed on zooplankton—mainly Euphasiidae and Calanidae that live in depths of 150 to 200 m. in the area.

5 FISHING

5.1 Fishing equipment

5.11 Gear

Bottom trawls of various types towed by a variety of vessels are the only type of gear used to catch significant quantities of ocean perch. According to Alverson (1959), trawls used on the west coast of the United States and Canada vary considerably in size and design, depending on the geographic area and national background of the fishermen. The trawls are essentially the same, however, as those used in the world's major trawl fisheries. Figure 23 and table 10 depict the details of the standard bottom trawl. These nets are usually set directly over the stern of the fishing vessel and retrieved over the starboard side.

Lestev (1964) reported that Russian fishermen, after extensive testing of several types of trawls in the Bering Sea in 1960, concluded that herring trawls of the Polish or Kaliningrad types (fig. 24) were most successful for catching *S. alutus*. He found that because *S. alutus* are so often found over rough, coral bottom, it was necessary to rig the trawls as lightly as possible. The corkline and leadline should be rigged so that (1) the pressure of the net on the bottom will be as little as possible, (2) the groundline scarcely touches the bottom, and (3) the leadline moves above the bottom.

The nets used by fishermen of the U.S.S.R. for harvesting Pacific ocean perch are generally of lighter material and rigged fuller in the belly than trawls used by fishermen of Canada and the United States (Alverson, 1967). The U.S.S.R. trawls have additional floats, and droppers about 2 m. long with heavy weights

Table 10.—Details of a standard 400-mesh east coast trawl used off the west coast of North America (adapted from Greenwood, 1958);[1] the trawl webbing can be of either light or heavy material

	Otter trawl 400 mesh eastern type
Web material:	
Light weight:	
Wings, square, belly	48 thread, 4¼" mesh cotton webbing
Intermediate	72 thread, 3½" mesh cotton webbing
Cod-end	96 thread, 3½" mesh cotton webbing
Heavy weight:	
Wings, square, belly	60 thread, 4¼" mesh cotton webbing
Intermediate	84 thread, 3½" mesh cotton webbing
Cod-end	120 thread, 3½" mesh cotton webbing
Ropes and lines:	
Head rope	71 feet plus eyes, of ⅜" 6x19 galvanized wire rope wrapped with 6-thread manila line.
Footrope	94 feet plus eyes, of ½" 6x24 galvanized wire rope wrapped with 27-thread manila line.
Breast lines	7 feet including eyes, of ⅜" galvanized wire rope wrapped with 6-thread manila line.
Rib lines	8 each, of 27-thread manila line, one along each seam and one along top and bottom center, and one from the corners at each bosom on top and bottom running diagonally to join side rib lines.
Hanging of net:	
Head rope	Wings hung 4 bars to 7¼" hangings. Bosom hung 4 meshes to 5¼" hangings.
Footrope	Lower bosom: 4 meshes hung to 9½" on 21-thread manila hanging line. 9½" of the hanging line hung to 7" on footrope. Lower wing: 4 bars hung to 10½" on 21-thread manila hanging line. 10½" of hanging line hung to 7½" on the footrope.

[1] Nylon and polypropylene have almost replaced cotton as the web fabric.

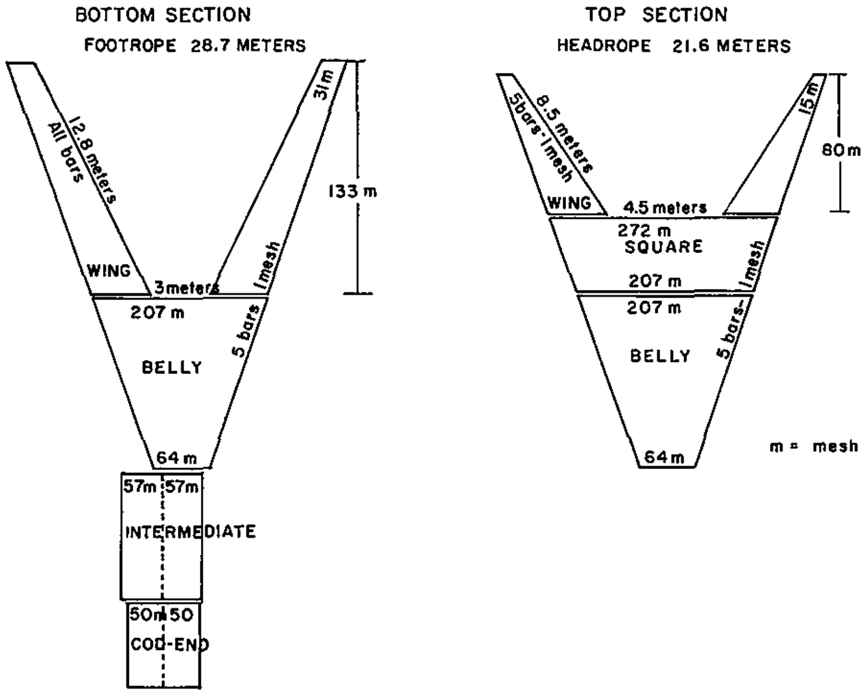


Figure 23.–Dimensions of a standard 400-mesh eastern-type otter trawl used off the west coast of North America (Greenwood, 1958). See table 10 for details.

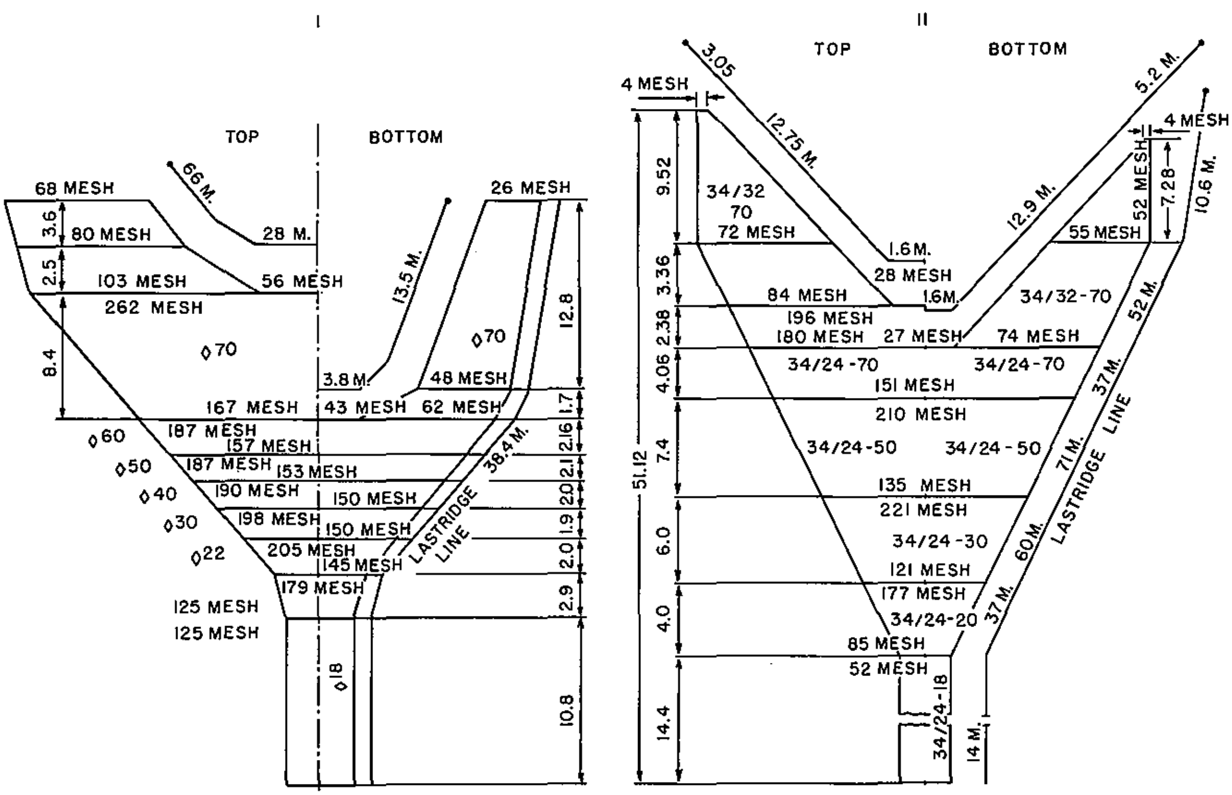


Figure 24.–Polish (I) and Kaliningrad (II) trawls used by U.S.S.R. fishermen in the Bering Sea (from Lestev, 1964).

attached are placed on the groundlines. This arrangement allows the net to skim over the bottom. The vertical opening of the net is about 8 to 10 m. (Lestev, 1961).

The Japanese use four basic fishing techniques in the Bering Sea—the Danish seine method, bull trawling, sideset trawling, and stern-ramp trawling (Alverson et al., 1964). The Danish seine and its operation are depicted in figures 25 and 26 and the bull trawl and its operation in figures 27 and 28. The nets fished by the stern-ramp trawlers of Japan and the U.S.S.R. are probably larger versions of the standard bottom trawl. These nets are cast and retrieved through a ramp in the stern of the vessel.

North American and Japanese trawls are of 8.9-cm. stretched mesh webbing. Nets used by fishermen of the Soviet Union are believed to be of 4.1-cm. webbing in the cod-end.

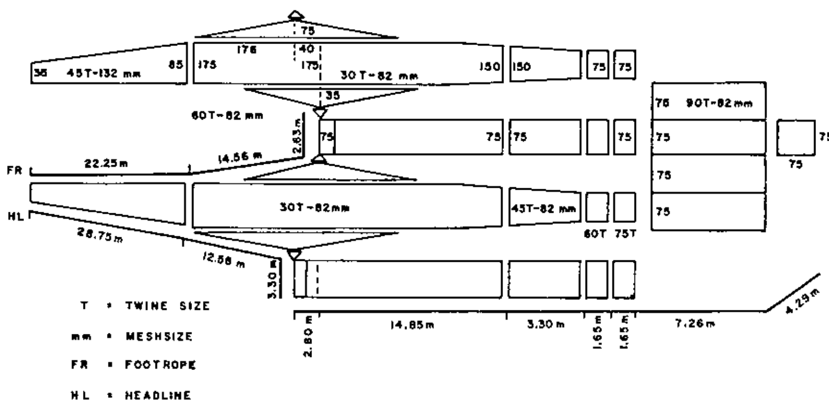


Figure 25.—Dimensions and construction characteristics of a Danish seine (from Tominaga, 1963).

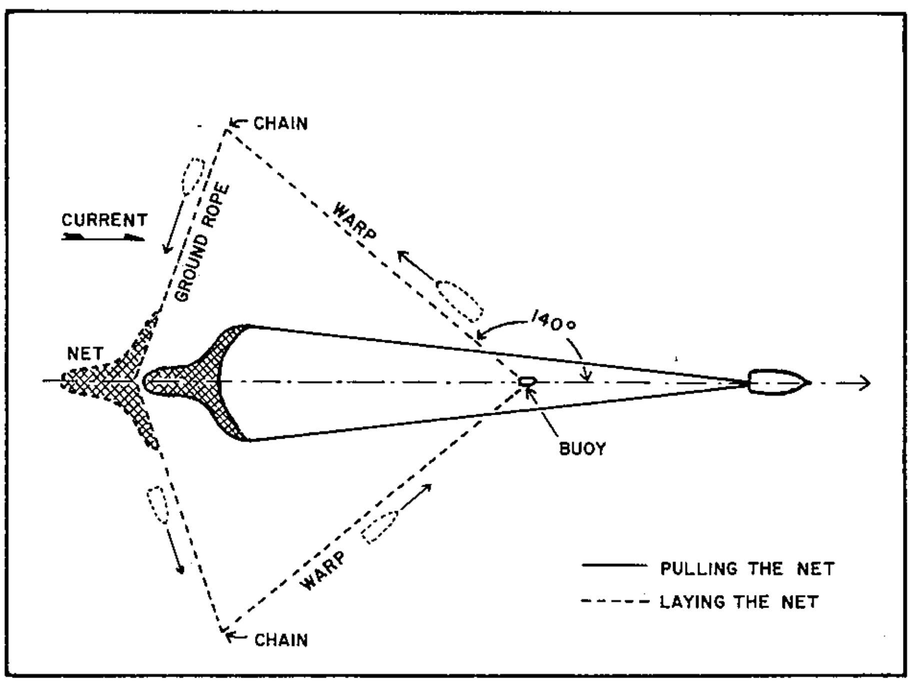


Figure 26.—Operation of Danish seine (from Bourgois, 1951).

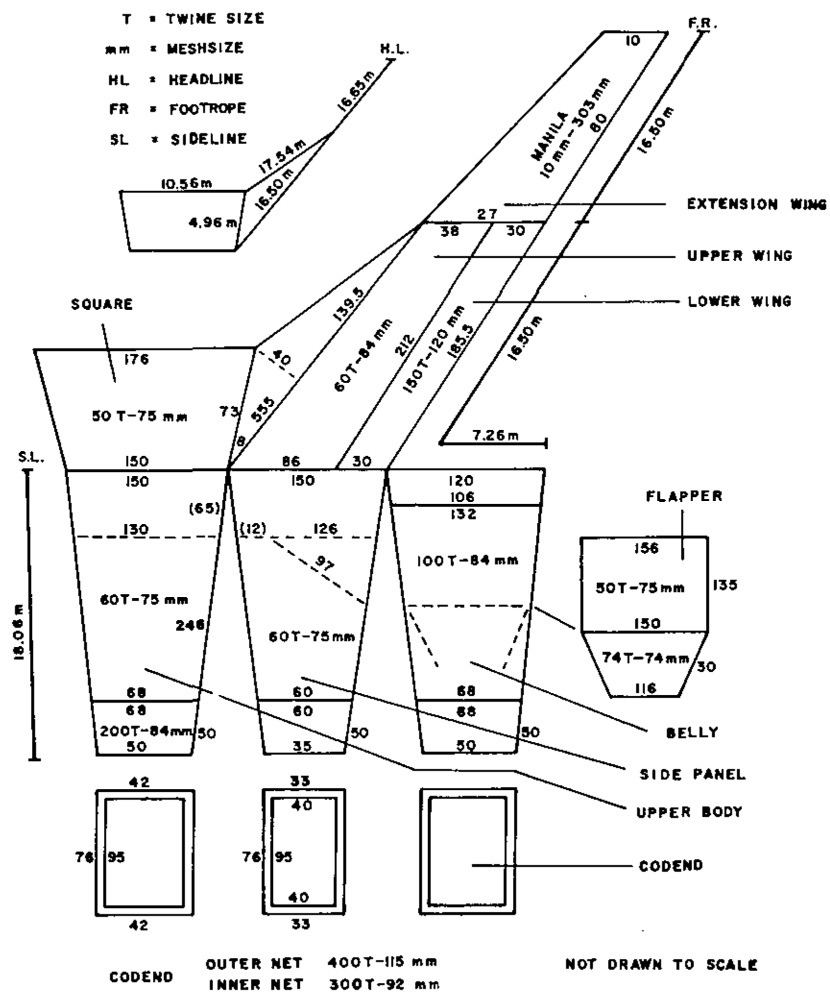


Figure 27.–Dimensions and construction characteristics of a typical Japanese bull trawl (from Tominaga, 1963).

Echosounders are used by fishermen of all nations to locate schools of fish. Lestev (1961) reported that the Russians use echosounders continuously in the search for Pacific ocean perch to determine bottom relief, density of schools, and size of probable catch. Once a school is detected, its location is marked with a radio buoy. Conventional buoys are useless in the foggy Bering Sea.

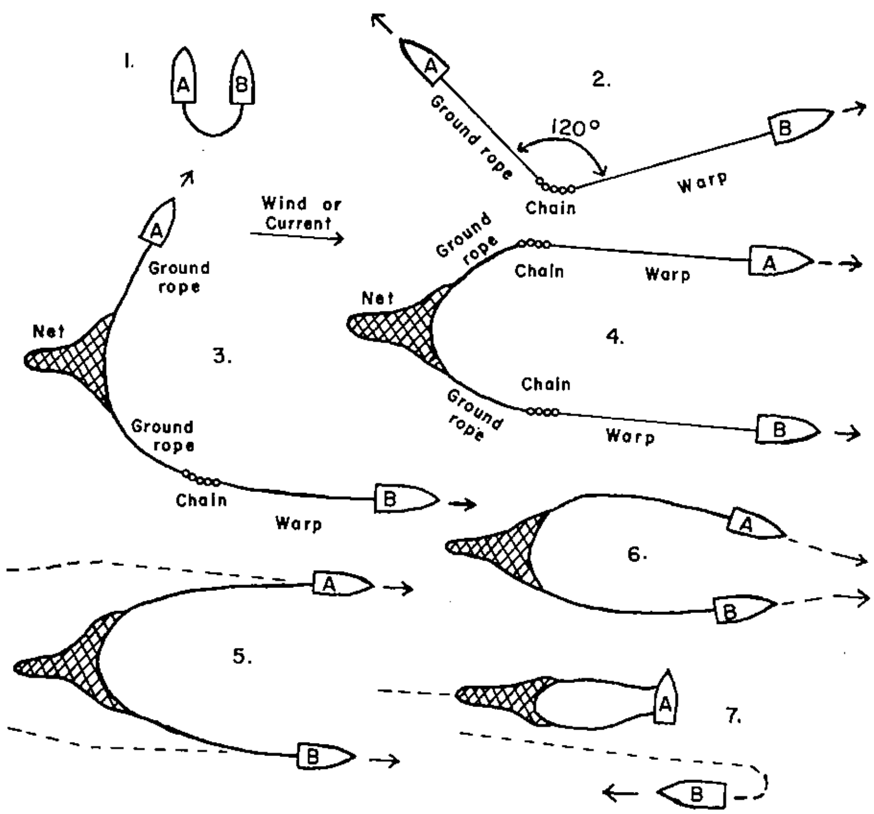
5.12 Boats

A wide variety of boats are used by Canadian and United States fishermen to trawl for ocean perch. According to Alverson (1959) the vessels most commonly used are converted salmon seiners and halibut schooners which average about 18 m. long (fig. 29).

Figure 30 shows types of vessels used by the U.S.S.R. to trawl for Pacific ocean perch. Japan uses similar vessels. Unlike the United States and Canadian vessels, which usually fish alone, Russian and Japanese vessels usually operate in fleets. A fishing fleet consists of fishing vessels, tankers, freezers, factory ships, and supply and service vessels.

5.2 Fishing areas

Almost all the larger concentrations of *S. alutus* from Cape Blanco, Oreg., to the Komandorskiy Islands and the Bering Sea are now being fished. Figure 31 shows major grounds, most of which were delineated by Alverson and Westrheim (1961) and Moiseev (1964).



(1) Trawler B sends its warp to A which shackles it to the ground rope
(2) Trawler B lays the warp; trawler A lays the ground rope
(3) Trawler A has cast its net and lays the portside ground rope, trawler B waits
(4) A has laid the portside warp; the tow begins
(5) Towing the bull trawl
(6) End of the tow; the trawlers approach each other
(7) Hauling in the net

Figure 28.—Operation of a bull trawl (from Bourgois, 1951).

Trawling for Pacific ocean perch by United States and Canadian vessels (Alverson and Westrheim, 1961) has been carried out mainly at depths of 92 to 549 m.; however, the bulk of the catch is taken at depths of 146 to 366 m.

Depths for trawling vary with season and area. In the Gulf of Alaska the most suitable depths for commercial fishing for rockfish are between 180 and 350 m. in summer and 250 and 420 m. in winter (Lyubimova, 1964). Alverson and Westrheim (1961) reported that major catches were taken in summer between 150 and 300 m. and in the winter between 275 and 400 m. Lestev (1961) found a similar distribution in the Bering Sea.

Lestev (1964) fished experimentally at depths of 300 to 700 m., but it is not known if commercial fishermen have fished at these depths in the Bering Sea.

Information is given elsewhere on areas of greatest abundance (section 2.22), hydrograph-

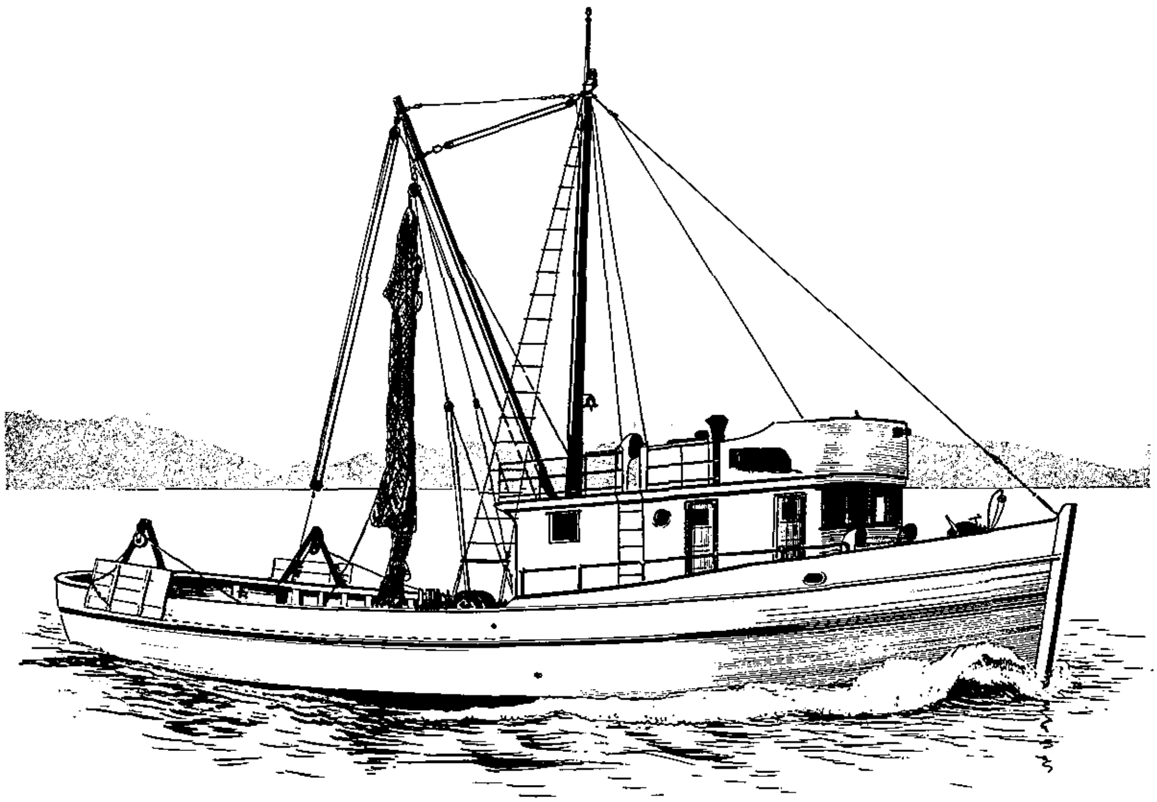


Figure 29.–Type of vessel used by North American fishermen to catch Pacific ocean perch. Length 15-30 m. (from Sundstrom, 1957).

ical features associated with high abundance (section 3.41), and changes in the location of the fishery during its development (section 5.41).

5.3 Fishing seasons

Fishing seasons for Pacific ocean perch are not regulated by law but rather by weather and economic factors. Lestev (1961) reported that extremely bad weather north of 57° N. in the Bering Sea prevents fishing from November through May. In areas to the southward fishing can be considered a year-round activity especially when carried out by the large ships used by the Japanese and U.S.S.R. fishermen. During winter and spring the mature fish move to deeper water so that the duration of the fishing season in a particular area depends on the ability and willingness of the fleets to pursue the fish into deeper waters and on the economic feasibility of such fishing.

There is little agreement between authorities as to the best time of year for the catching of Pacific ocean perch. In the Bering Sea, catches made during winter and spring were larger and more consistent than those made during summer (Lestev, 1961). Lyubimova (1964) reported that in the western Gulf of Alaska near Unimak Pass, commercial catches were greatest from June to October. Westrheim (footnote 3) found that Pacific ocean perch were scarce in the northern and eastern parts of the Gulf of Alaska during winter. He also reported that test fishing during the winter in Queen Charlotte Sound in 1963-65 yielded few Pacific ocean perch in areas with a commercial fishery during the summer, whereas good catches were made in deeper waters off Vancouver Island during the entire year.

Differences in schooling and migratory behavior seem to explain why catches may be larger in some areas during certain seasons than at other times.

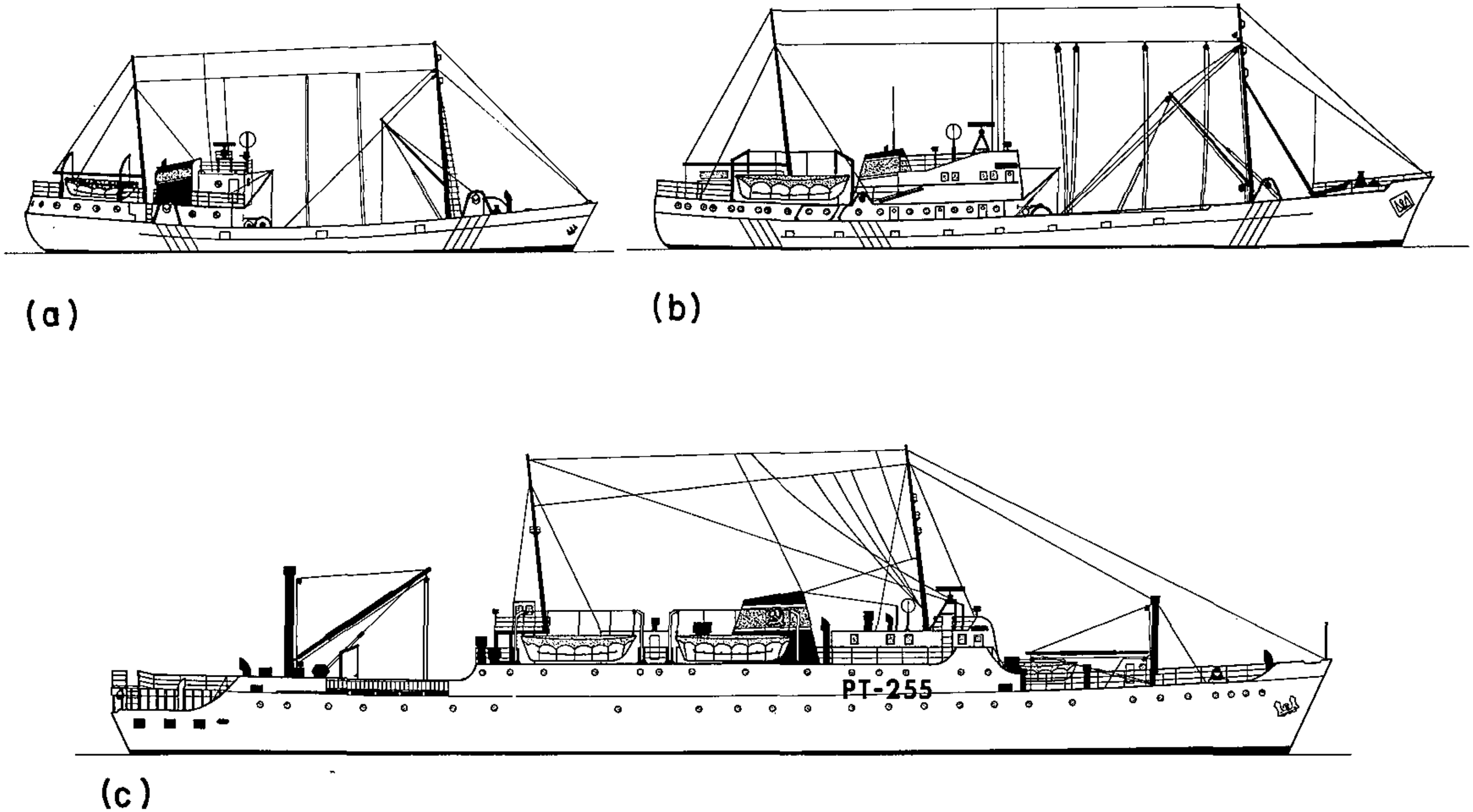


Figure 30.–Types of vessels used by the U.S.S.R. to harvest Pacific ocean perch: (a) side trawler, length 38-44 m., (b) side trawler, length 54.2 m., and (c) stern-ramp trawler, length 84.5 m. (from Hitz, 1968).

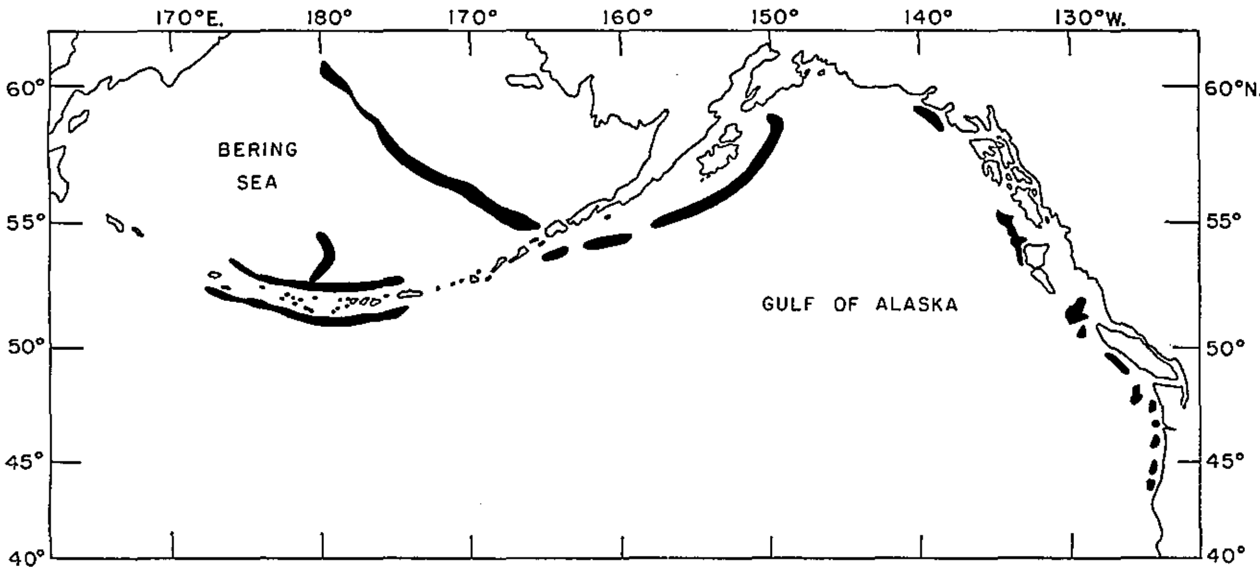


Figure 31.—Locations of major fishing grounds for Pacific ocean perch (Alverson and Westrheim, 1961; Moiseev, 1964).

5.4 Fishing operations and results

5.41 Effort and intensity

Active commercial fishing for Pacific ocean perch in the northwestern United States began in 1946 (Alverson and Westrheim, 1961). Until that time, ocean perch were incidental in catches of other fish. From 1946 to 1951, most boats fished off Oregon and Washington. After 1951, however, the fishery expanded rapidly, and soon trawlers were fishing from Oregon northward to Queen Charlotte Sound, British Columbia. Trawlers operating out of Washington and Oregon ports have had the fishery almost exclusively to themselves, having taken at least nine times the Canadian catch each year except 1958.

Alverson and Westrheim (1961) predicted that the waters off southeastern Alaska and the Aleutian Islands were potential grounds for expanding the Pacific ocean perch fishery. Their prediction was quickly realized. The U.S.S.R., from an initial trawling effort in the Bering Sea in 1959 (30-40 trawlers), had by 1962 begun to harvest *S. alutus* in the Gulf of Alaska. In June 1962 about 50 Soviet trawlers and 9 refrigerated ships moved from the Bering Sea into the Gulf of Alaska. Later in 1962, this fleet increased to about 70 vessels.

In 1963 the U.S.S.R. fleet returned to the Gulf of Alaska and also began to fish for ocean perch near the Aleutian Islands. About 135 medium trawlers and 12 stern-ramp trawlers were fishing in the Gulf of Alaska in 1963 and about 5 stern-ramp trawlers in the Aleutian Island area. In 1964 about 150 U.S.S.R. vessels were in the Gulf of Alaska and about 20 near the Aleutian Islands; in 1965 about 130 ships were in the Gulf and 20 near the Aleutians. The fleet moved as far south as Dixon Entrance in 1965. In [May] 1966, the Soviet perch fleet in the Gulf of Alaska reached a peak of 131 vessels. In February 1966, some of these vessels moved south to British Columbia, fishing from Dixon Entrance to Queen Charlotte Sound; in early April, two stern-ramp trawlers and 23 side trawlers began fishing for ocean perch off Newport, Oreg. They remained there until catches apparently dropped off in early May. In 1967, the maximum size of the fleet in the Gulf of Alaska was about 94 vessels. Up to 105 vessels were operating off the coasts of British Columbia, Washington, and Oregon. How many were fishing for Pacific ocean perch is not known.

The Japanese have had massive trawling operations in the Bering Sea since 1954, primarily for pleuronectids, and only since 1960 have Pacific ocean perch appeared in their catch reports. Although information on the number of ships and effort expended by Japan on ocean perch in the Bering Sea is not available, the catch statistics indicate that the effort on ocean perch is minor in relation to the total Bering Sea effort. If we assume that the catch per unit of effort has been relatively stable from year to year since 1960, we can interpret the increasing catches to mean increasing effort.

Japanese fishing vessels first moved into the Gulf of Alaska in 1960. The size of the fleet gradually increased to 13 vessels in 1965, 6 of which were stern-ramp trawlers (see footnote 6). By 1965 Japanese vessels were fishing off the Washington and Oregon coasts.

To date no comprehensive catch-per-unit-of-effort data have been published for any of the major Pacific ocean perch fisheries, although several authors have reported information on the gross catch per hour. Alverson and Westrheim (1961) found that the average catch per hour for Washington-based trawlers for the late 1950's ranged from 0.36 to 0.91 metric ton with a general increase towards the northern extremity of the fishing ground (Queen Charlotte Sound, British Columbia). This trend, they cautioned, may have been influenced to some extent by greater efficiency of vessels fishing the northern grounds. Alverson et al. (1964) presented information on average catch per hour by depth for research vessels sampling in four areas—Washington-Oregon, British Columbia-southeastern Alaska, Gulf of Alaska, and Alaska Peninsula. The highest average catch per hour was in the Washington-Oregon coastal areas (0.768 metric ton per hour). Average catch per unit of effort is probably higher in the Bering Sea and the Gulf of Alaska. Data provided by Moiseev and Paraketsov (1961), Lestev (1961, 1964), and Lyubimova (1963, 1964, and 1965) suggest that the average catch per unit of effort was about 5 metric tons per hour, at least in the early years of the fisheries in those areas.

5.42 Selectivity

Washington, Oregon, and British Columbia trawlers are now using 8.9-cm. stretched mesh webbing. This gear does not take significant amounts of Pacific ocean perch less than 25 cm. in fork length. The Japanese use essentially the same gear in the Gulf of Alaska. The Russian fishermen are believed to use 4.1-cm. webbing in the cod-end and thus take younger (smaller) fish if they are available to the trawls.

5.43 Catches

Table 11 gives catches of Pacific ocean perch for the North American nations (Canada and the United States), the U.S.S.R., and Japan; section 4.5 discusses maximum equilibrium yield.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

6.11 Limitation or reduction of total catch

No limitations on total catch.

Table 11.—Catches of *S. alutus* by year and nation, 1946-68

Year	United States and Canada[1]	U.S.S.R.[2]	Japan[3]	Total
	Metric tons			
1946	44	--	--	44
1947	74	--	--	74
1948	96	--	--	96
1949	474	--	--	474
1950	691	--	--	691
1951	842	--	--	842
1952	2,918	--	--	2,918
1953	2,792	--	--	2,792
1954	4,950	--	--	4,950
1955	2,388	0	--	2,388
1956	3,703	3,801	--	7,504
1957	3,578	6,601	--	10,179
1958	2,674	3,301	--	5,975
1959	4,018	1,400	--	5,418
1960	4,369	17,502	430	22,301
1961	5,773	20,603	13,077	39,453
1962	8,317	61,610	13,622	83,549
1963	11,188	129,921	30,626	171,735
1964	9,962	275,746	58,613	344,321
1965	14,272	391,900	75,050	481,222
1966	12,325	247,900	110,984	371,209
1967	16,180	162,000	101,788	279,968
1968	12,610	98,494	121,468	232,572

[1] Data for 1946-55 from Alverson and Westrheim (1961), and data for 1956-68 from Pacific Marine Fisheries Commission (1964-68).

[2] U.S.S.R. catches include small but unknown quantities of other rockfishes. Data for 1955-64 from Food and Agricultural Organization of the United Nations (1956-65) and International Commission for the Northwest Atlantic Fisheries (1957-66). FAO statistics for U.S.S.R. ocean perch catches were for the Atlantic and Pacific Oceans combined; ICNAF (Atlantic Ocean) catches were subtracted from the FAO totals to yield the Pacific Ocean catches. Data for 1965 and 1966 from International North Pacific Fisheries Commission (1967) and for 1967 and 1968 from Herbert A. Larkins, Fishery Biologist, Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash. (Personal communication, December 1, 1969).

[3] Data from International North Pacific Fisheries Commission (1961-69).

6.12 Protection of portions of population

No regulations exist in North America for limitations of size or efficiency of gear or craft, closed seasons, or sex or condition of fish.

Closed areas—the United States provides some protection to fish resources by prohibiting fishing by foreign vessels within 12 nautical miles of the coast. Canada similarly protects the stocks adjacent to her coast, except that United States fishermen fish in Queen Charlotte Sound.

Restrictions on use of fish—in California, trawl-caught fish, including Pacific ocean perch, are taxed 5 cents per 45.4 kg. (100 pounds) if used for any purpose other than human consumption.

ACKNOWLEDGMENT

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