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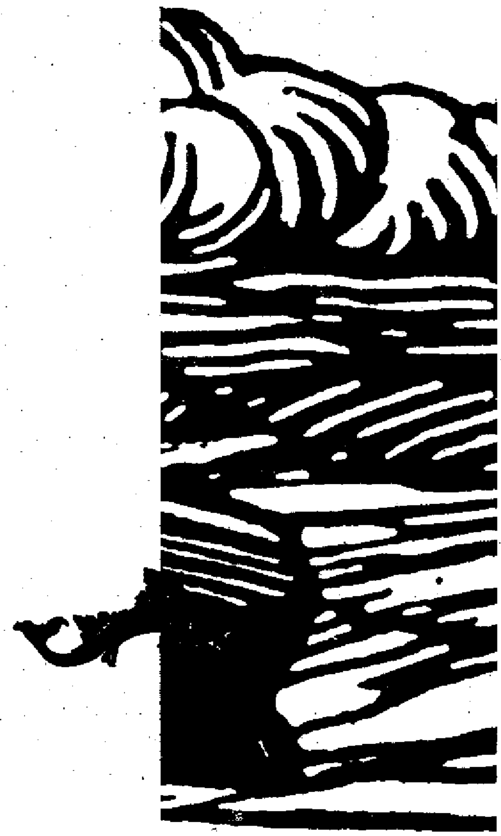

Marine Fish Culture and Enhancement Bibliography:

Focus on Puget Sound

Robert R. Stickney, Ervin J. Schumacker and Michael B. Rust, Editors

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Introduction

In 1993, in response to the fact that stocks of non-salmonid marine fish stocks in Puget Sound, Wash., had fallen to historic lows, a workshop was held in Seattle during October[1] to examine the situation and develop recommendations aimed at resolving the problem. The Marine Fish Culture and Enhancement Workshop was sponsored by Washington Sea Grant Program, National Marine Fisheries Service, University of Washington, and the Washington Fish Growers Association. Included in the recommendations was a list of species that might hold potential for enhancement in Puget Sound. The present study was initiated to collect background information on many of the species on that list, plus others (Table 1), to help investigators determine which fishes might be suitable for enhancement culture and to provide an indication of the amount of information currently available on those fishes. The study was funded by Marine Advisory Services, Washington Sea Grant Program.

To simplify use, this report is organized by family followed by species-specific information. The citations listed for each species are in alphabetical order by author. A summary of information from each reference is provided.

A significant amount of information is available on Pacific halibut, *Hippoglossus stenolepis*, but that species is not included in this report. Pacific halibut are not commonly found throughout Puget Sound, but inhabit the Strait of Juan de Fuca and the Pacific Ocean of Washington. Research has been underway for some time to investigate the feasibility of producing halibut postlarvae for commercial aquaculture or enhancement. Thus, the species does not fit within the objectives of the current study.

[1] Nosho, T., and K. Freeman (Eds.). 1994. Marine fish culture and enhancement conference proceedings. Washington Sea Grant Program, University of Washington, Seattle WSG-WO 94-1. 64 p.

Species List[2]

Family	Common Name	Scientific Name
Hexagrammidae	Lingcod	*Ophiodon elongatus*
	Kelp greenling	*Hexagrammos decagrammus*
Cottidae	Cabezon	*Scorpaenichthys marmoratus*
Gadidae	Pacific (true) cod	*Gadus macrocephalus*
Anoplopomatidae	Sablefish	*Anoplopoma fimbria*
Pleuronectidae	Petrale sole	*Eopsetta jordani*
	Flathead sole	*Hippoglossoides elassodon*
	Dover sole	*Microstomus pacificus*
	English sole	*Parophrys vetulus*
	Sand sole	*Psettichthys melanostictus*
Scorpaenidae	Brown rockfish	*Sebastes auriculatus*
	Copper rockfish	*Sebastes caurinus*
	Yellowtail rockfish	*Sebastes flavidus*
	Quillback rockfish	*Sebastes maliger*
	Black rockfish	*Sebastes melanops*
Embiotocidae	Pile perch	*Rhacochilus vacca*
	Striped seaperch	*Embiotoca lateralis*

Abbreviations

FL	Fork length
HUFA	Highly unsaturated fatty acids
ID	Inside diameter
LHRH	Luteinizing hormone-releasing hormone
MJ	Megajoule
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
ppt	Parts per thousand
SL	Standard length
TL	Total length

[2] The listed species are those for which individual papers in the bibliography have been included. Additional species are included in some cases under the "General" subheading.

FAMILY HEXAGRAMMIDAE

General

Kendall, A. W. and B. Vinter. 1984. Development of hexagrammids (Pisces; Scorpaeniformes) in the northeast Pacific ocean. NOAA Tech. Rep. National Marine Fisheries Service, Washington, D.C. 2. 44 p.

Larval development and morphological details of several hexagrammids, including lingcod and kelp greenling, are described in detail.

Lingcod, *Ophiodon elongatus*

Bargmann, G. G. 1982. The biology and fisheries for lingcod (*Ophiodon elongatus*) in Puget Sound. Washington Department of Fisheries Technical Report No. 66. Washington Department of Fisheries, Olympia. 26 p.

The primary emphasis of this report is on the lingcod fishery; its history, regulations, methods and statistics. Management needs for the future of the fishery are discussed at length and recommendations are presented.

Giorgi, A. E. 1981. The environmental biology of the embryos, egg masses and nesting sites of the lingcod, *Ophiodon elongatus*. Ph.D. dissertation, University of Washington, Seattle. 99 p.

Male lingcod establish nesting grounds from November through January primarily in near-shore, rocky habitats. Females appear at nest sites to spawn and then leave. Egg masses are formed by the addition of a clear, gelatinous matrix that is extruded into cracks and crevices with the eggs. Incubation time varies from 42 to 59 days with the male guarding the nest the entire time. Fecundities range from 60,000 to 518,000 eggs.

Epipelagic larvae are found in the upper 3 meters of the water column from March through May. Standard length at hatch ranges from 8.5mm to 11.5mm. First food includes small copepods and their eggs. Larval fish are eaten as the young lingcod grow larger.

Juveniles become demersal at approximately 3 months of age (80mm). In the Puget Sound region they seem to prefer sandy or partly rocky substrate with depths of less than 20 meters where they feed on crustaceans and small fish. At approximately 350mm they begin moving to rocky areas.

Egg masses were hatched at the NMFS Manchester laboratory in filtered, UV sterilized seawater at ambient temperature and salinity.

Circular fiberglass tanks (122cm diameter) with current velocity greater than 50cm/sec and adequate depth to cover the eggs were used as incubators. Temperature ranged from 7.9 C to 9.5 C.

Giorgi, A. E. and J. Congleton. 1984. Effects of current velocity on development and survival of lingcod, *Ophiodon elongatus*, embryos. Env. Biol. Fish. 10: 15-27.

This study provides information on the current velocities needed to maintain adequate dissolved oxygen levels inside lingcod egg masses. Ammonia levels and embryonic respiration were also studied.

Grosse, D. J. 1982. An experiment in the artificial rearing of lingcod (*Ophiodon elongatus* Girard) for purposes of enhancement. M.S. Thesis, University of Washington, Seattle. 84 p.

The thesis examines the biological and technical feasibility of rearing juvenile lingcod for two months in floating cages. Juveniles were caught over sandy flats at depths from 4 to 10 meters. They were raised in net pens measuring 1.2m x 1.2m by 1.8m deep with 0.64cm mesh netting. Partial sunshade was provided.

Juveniles were acclimated to eating frozen herring chunks. Once acclimated, young lingcod were offered large Oregon Moist Pellets (OMP), University of Washington moist salmon pellets (UW), and pastes made from krill or herring. Feeding regimes were established for the growth study.

Feeding behavior was characterized by larger fish eating most of the offered herring and smaller fish eating little or none. Many of the smaller fish were feeding on crustaceans drifting through the cages. No overt aggressive behavior was observed during feeding.

Most mortalities were attributable to cannibalism. Satiation ranged from 3% to 10% of fish weight per feeding with the rate varying inversely with feeding frequency.

Lingcod fed readily on herring and krill pastes. Some ate the UW pellets and none ate OMP. Differences in growth rates of young lingcod in the same pen were attributed to social feeding hierarchies that developed early in the study.

Feeding seemed to be characterized by "gorging" followed by reduced appetite at the time of the following meal. When fed above a wet weight ration of 1.7%, weight gain was shown to increase linearly with food intake.

Houk, J.L. 1980. A diver-operated snagging device for capturing lingcod, *Ophiodon elongatus*. Cal. Fish and Game, 66: 187-188.

The device described in this paper has potential for live-capture of adult lingcod, cabezon and kelp greenling.

Ilg, J., J.M. Walton and R.M. Buckley. 1979. An annotated bibliography on the lingcod, *Ophiodon elongatus*. Washington Dept. Fish. Tech. Rep. 51. Washington Dept. Fish., Olympia. 25 p.

The available literature on lingcod from 1905 to mid-1979 was reviewed. Over 100 references are listed alphabetically and indexed by subject. Most of the references deal with management of the lingcod fishery.

Jagielo, T.H. 1990. Movement of tagged lingcod *Ophiodon elongatus* at Neah Bay, Washington. Fish. Bull. 88: 815-820.

This paper reports on movement of lingcod tagged in nearshore waters in the western Strait of Juan de Fuca near Neah Bay. The results could be helpful in designing studies to monitor recruitment of cultured lingcod released to enhance fisheries along the Washington coast.

Lariviere, M.G., D.D. Jessup, and S.B. Mathews. 1981. Lingcod, *Ophiodon elongatus*, spawning and nesting in San Juan Channel, Washington. Cal. Fish and Game, 67: 231-239.

Lingcod nesting behavior was studied in detail. Territoriality of the males was described as was predation on the nests by other fish, gastropods, crustaceans and echinoderms. In the 35 nests studied, a 40% hatching success rate was estimated.

Phillips, J. B. 1959. A review of the lingcod, *Ophiodon elongatus*. Cal. Fish and Game, 45: 19-27.

This paper contains general life history information on lingcod.

Phillips, A. C., and W. E. Barraclough. 1977. On the early life history of the lingcod (*Ophiodon elongatus*.). Can. Fish. and Mar. Serv. Res. Dev. Tech. Rep. 756, Nanaimo, B.C. 35 p.

Information on distribution, abundance and development of lingcod is presented. In-depth information is provided on the food of various sizes (especially young) lingcod, showing the progression from small to larger foods as the fish grow.

In aquaria, 70mm juveniles readily adapted to captivity and were not adversely affected by moderate changes in water temperature or handling. The fish accepted live, 30mm herring after which they consumed frozen herring, live or frozen sand lance, and salmon fry. In a brief experiment in which groups of lingcod were fed frozen herring, food conversion (wet weight consumed/wet weight gain) was 2.0.

The diet of a young lingcod appears to be largely governed by the size of its mouth. If a prey item can be swallowed, the lingcod will try to eat it.

Shaw, W. M. and T. H. Hassler. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest). Lingcod. U.S. Dept. of Interior Biol. Rep. 82, Washington, D.C. 19 p.

General biological and fishery information is presented in this report. The spawning season extends from mid-December to mid-March but peaks between December and January. Males establish nests in nearshore rocky habitat with strong currents. Females deposit eggs in a gelatinous mass which is sprayed with milt by the male. After spawning the female leaves the area and the male remains to guard the nest. Adults have been reported to stay near their home sites for the duration of their lives.

Larvae are approximately 7mm to 11.5mm long at hatching with yolk sac absorbed about 10 days after hatch. The primary larval food is copepods and their eggs with larger foods, such as fish larvae, eaten as fish size increases. The pelagic larvae are dependent on zooplankton in the 250mm to 512mm size range. Open water growth is approximately 1mm per day. At about 70mm to 80mm lingcod begin feeding on juvenile herring. Juvenile lingcod kept in aquaria feed and grow readily on live or frozen herring. Total length of juveniles in the wild is 1cm to 3cm by April and 17cm to 35cm by December. Average size is 27cm at one year and 47cm at two years.

Both males and females start maturing at approximately 58cm TL. Life spans average 12 to 14 years for males and 15 to 16 years for females.

Lingcod fishery statistics up to 1982 are presented. The only attempt at aquaculture up to that point was by Grosse (1982).

Adults feed primarily on fish supplemented with available squid, octopus, gastropods and crustaceans. Parasites and general environmental requirements are described for larvae and adults.

Vincent-Lang, D. 1995. Recruitment of lingcod populations near Seward, Alaska, during 1993 and 1994. Alaska Dept. Fish and Game, Anchorage. Fish. Manusc. No. 95-1. 25 p.

Lingcod were collected near Seward, Alaska to assess recruitment. A length-weight relationship was calculated.

Wespestad, V.G., G. Bargman, and D.E. Hay. 1993. Opportunities for the enhancement of the ling cod (*Ophiodon elongatus*) in Puget Sound and Georgia Straits. In: Programme and Abstracts. Danielssen, D.S., Moksness, E., conveners. International Symposium Sea Ranching of Cod and Other Marine Species, Arendal, Norway, 15-18 June, p. 55.

The growing Puget Sound human population is placing increasing pressure on the marine resources of Puget Sound through habitat degradation, pollution and increased harvest. Increased direct and indirect human use of Puget Sound has led to reductions in most fish species. Two of the marine species sought by recreational fishermen are Pacific cod and lingcod. Both are currently at extremely low levels of abundance. The paper indicates that sea ranching of the species would be economically and biologically viable.

Kelp greenling, *Hexagrammos decagrammus*

DeMartini, E.E. 1986. Reproductive coloration, paternal behavior and egg masses of kelp greenling, *Hexagrammos decagrammus*, and whitespotted greenling, *H. stelleri*. Northw. Sci. 60: 32-35.

The kelp greenling spawns in Puget Sound during the fall, primarily in October and November. The species exhibits sexual dichromatism. Males have a grayish to deep navy-blue coloration with irregular blue iridescent spots on head and anterior body. Females are orange to brownish with darker spots "freckled" over their body.

The blue eggs are laid in adhesive masses ranging from golf ball to tennis ball size. Most of the egg masses are deposited among encrusting epifauna on the substrate. A few are laid on bare rock. The mean egg number per mass was estimated at 4,340. Eggs ranged from 2.2mm to 2.5mm. Embryos required about 30 days to hatch when held at 10 C. Males guard the eggs until hatching.

FAMILY COTTIDAE

Cabezon, *Scorpaenichthys marmoratus*

Lauth, R. R. 1987. Spawning ecology and nesting behavior of the cabezon, *Scorpaenichthys marmoratus* (Ayers), in Puget Sound, Washington. M.S. Thesis, University of Washington, Seattle. 104 p.

The cabezon is the largest of 36 cottid species in Puget Sound. It can attain a length of 990mm and a weight of 11.4kg. Depth range is from nearshore tidepools to approximately 76 meters. The fish are demersal and solitary. They live over rock, gravel or sand bottoms and are often associated with reefs, kelp, algae or eel-grass beds.

Spawning begins in late November and lasts through early September with a peak in March and April. Females may spawn at least twice during a single season. Newly deposited eggs are covered by a viscous, translucent white substance and are easily crushed. Older batches have no covering and are firm.

Incubation time ranged from 33 to 61 days with an average of 42 days. Water temperature during incubation varied from 8 C to 10 C. Hatching success varied between 48% and 71%.

Lauth, R.R. 1989. Seasonal spawning cycle, spawning frequency, and batch fecundity of the cabezon, *Scorpaenichthys marmoratus*, in Puget Sound, Washington. Fish. Bull. 87: 145-154.

Seasonal embryo mass abundance and ovarian condition indicated that the spawning season started in November and continued 10 months through the following September. Peak spawning activity occurred during March and April. Females may spawn more than once during a single spawning season.

O'Connell, C. P. 1953. The life history of the cabezon (*Scorpaenichthys marmoratus*). Cal. Dept. of Fish and Game, Fish Bull. 93: 1-76.

This report is an in-depth study of the life history of the cabezon, especially with respect to California coastal waters. Catch statistics for the California coast are reported through 1950. Copepods were found in many of the pelagic larval stomachs and crustaceans were a major part of the cabezon's diet throughout its life. Other important food items were fish and molluscs.

The author fertilized and incubated one batch of stripped eggs from a boat-caught cabezon. The egg mass was incubated in running seawater in a 3.8L jar. After a 17-day incubation period, one healthy larva measuring 5.85mm was obtained. Larval body development was detailed from wild-caught samples. Age and growth for the first year were calculated and age determination using otoliths described. Further growth was also well described as were external and internal muscle tissue color.

FAMILY GADIDAE

Pacific cod, *Gadus macrocephalus*

Note: Some information on a similar species (Atlantic cod, *Gadus morhua*) is included in this section as it may be applicable to Pacific cod.

Alderdice, D.F., and C.R. Forrester. 1971. Effects of salinity, temperature and dissolved oxygen on early development of the Pacific cod (*Gadus macrocephalus*). J. Fish. Res. Bd. Can. 28: 883-902.

Effects of various combinations of levels of salinity, temperature and dissolved oxygen on incubation of Pacific cod (*Gadus macrocephalus*) eggs were investigated in the laboratory. Larval size at mean hatching time, and percentages of total hatch, viable hatch and postmature eggs that failed to hatch, were optimized at intermediate salinities (about 15ppt), low temperatures (3 C to 5 C), and over a wide range of dissolved oxygen concentrations. Pacific cod eggs were judged to be euryhaline, uryoxic and stenothermal. As long as temperatures were within the range of about 3 C to 5 C, the developing egg were tolerant of a wide range of salinities, and of dissolved oxygen levels to a minimum of about 2ppm or 3ppm.

Temperature seemed to be a major factor in egg development. Reasonable egg viability and incubation success was estimated to extend from about 2.5 C to 8.5 C.

Blom, G., H. Otterå, T. Svåsand, T.S. Kristiansen, and B. Serigstad. 1991. The relationship between feeding conditions and production of cod fry (*Gadus morhua* L.) in a semi-enclosed marine ecosystem in western Norway, illustrated by use of a consumption model. ICES Mar. Sci. Symp. 192: 176-189.

The study described was one of a group conducted in a dammed seawater pond (270,000 m^3) in western Norway. Zooplankton biomass and cod growth and survival were estimated from weekly samples during the period from release of cod larvae in the pond to beyond metamorphosis. Cod fry production appeared to be dependent on the production of microzooplankton. Inadequate and unfavorable zooplankton conditions seemed to have a dramatic effect on cod fry survival.

Dunn, J.R., and A.C. Matarese. 1984. Gadidae: Development and relationships. In: H.G. Moser, H.G., editor. Ontogeny and systematics of fishes. Am. Soc. Ichthyol. Herpetol. Spec. Publ. 1; p 283-299.

Pacific cod become demersal when they reach lengths greater than 35mm.

Dunn, J.R., and A.C. Matarese. 1987. A review of the early life history of northeast Pacific gadoid fishes. Fish, Res. 5: 163-184.

The paper reviews the information available on *Gadus macrocephalus* and other gadids. Pacific cod lay demersal eggs that are 1.0mm to 1.2mm in diameter. Length at hatching is from 3.0mm to 4.0mm and larvae can be found in association with the bottom of the water column. Length at first feeding was not determined, but the fish become demersal at lengths >35mm. Fecundity for 60cm females ranges from 889,000 to 1,250,000 eggs. Maturity occurs at an age of 2 to 3 years and at FL of 48cm to 49cm.

Folkvord, A. 1991. Growth, survival and cannibalism of cod juveniles (*Gadus morhua*): Effects of feed type, starvation and fish size. Aquaculture 97: 41-59.

The effects of feed type, starvation and fish size on growth, survival and cannibalism in pond-reared cod juveniles were studied. Groups of 0.2g and 8g cod showed survival rates of 93.5% to 97% over four weeks when fed live zooplankton. Cannibalism was higher among starved 0.2g cod than fed 0.2g cod. Cannibalism ceased after the addition of live zooplankton.

Initial size differences within a cohort may have dramatic effects on the rate of cannibalism. Early harvest of juveniles from rearing ponds is recommended to improve weaning and to reduce losses due to cannibalism.

Foucher, R.P., and A.V. Tyler. 1990. Estimation of the fecundity of Pacific cod (*Gadus macrocephalus*). Can. Manuscr. Rep. Fish. Aquat. Sci. No. 2088. 52 p.

Fecundity was determined for 350 Pacific cod from British Columbian waters.

Foucher, R.P., and S.J. Westrheim. 1990. The spawning season of Pacific cod on the west coast of Canada. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 2072. 28 p.

The spawning season of Pacific cod in British Columbia is mainly from January through March. Spawning was essentially complete by May.

Foucher, R.P., A.V. Tyler, J. Fargo, and G.E. Gillespie. 1989. Reproductive biology of Pacific cod and English sole from the cruise of the FV *Blue Waters* to Hecate Strait, January 30 to February 11, 1989. Can. Man. Rep. Fish. Aquat. Sci. No. 2026. 85 p.

Pacific cod and English sole were sampled for length, maturity, body and ovary weight, fecundity (Pacific cod), and histology (English sole). The gonosomatic index for Pacific cod varied from 3.59 to 22.93; the index for English sole ranged from 0.30 to 1.65.

Garatun-Tjeldstø, O., I Opstad, T. Hansen, and I. Huse. 1989. Fish roe as a major component in start-feed for marine fish larvae. Aquaculture 79: 353-362.

Cod and plaice larvae were start-fed in laboratory tanks with diets containing fish roe as a major component. Results were compared with those from larvae start-fed *Calanus* diets, yeast-based diets, microencapsulated diets and several experimental diets from various commercial sources. Roe-based start diets were consumed by the larvae and gave better growth rates and longer survival times than the other dry feeds.

Garrison, K.J., and B.S. Miller. 1982. Review of the early life history of Puget Sound fishes. Fisheries Research Institute, University of Washington, Seattle. 729 p.

Length and age at maturity for Pacific cod are 48cm to 49cm FL and 2 to 3 years.

Giske, J., D.L. Aksnes, U. Lie, and S.M. Wakili. 1991. Computer simulation of pelagic production in Masfjorden, western Norway, and its consequences for production of released 0-group cod. ICES Mar. Sci. Symp. 192: 161-175.

An ecosystem model including nutrients, phytoplankton, herbivores, two groups of pelagic carnivores, sublittoral gobies and 0-group cod was developed.

Hatori, T., Y. Sakurai, and K. Shimazaki. 1992. Maturation and reproductive cycle of female Pacific cod in waters adjacent to the southern coast of Hokkaido, Japan. Bull. Jpn. Soc. Sci. Fish. 58: 2245-2252.

The maturation process and reproductive cycle of female Pacific cod, *Gadus macrocephalus*, were examined in waters adjacent to the southern and southeastern coasts of Hokkaido, Japan. Peak spawning was assumed to occur from late December through January. The age at first maturation of females was estimated to be 4 years.

Jobling, M., R. Knudson, P.S. Pedersen, and J. Dos Santos. 1991. Effects of dietary composition and energy content on the nutritional energetics of cod, *Gadus morhua*. Aquaculture 92: 243-257.

Both feed utilization efficiency (g gain per MJ feed) and protein efficiency ratio (g gain per g dietary protein) were better for cod fed wet feeds than for those fed the moist diets. Best growth and feed efficiencies were achieved by cod fed a mixture of chopped herring and wet feed.

Cod of 1.5kg or larger can grow well when fed on diets with protein energy:total energy ratios of 0.40-0.45, without excessive deposition of liver lipid. The diets should be supplied in the form of coarsely ground, low-energy feeds.

Karp, W.A. 1982. Biology and management of Pacific cod (*Gadus macrocephalus* Tilesius) in Port Townsend, Washington. Ph.D. Dissertation, University of Washington, Seattle. 120 p.

Length-at-time estimates for Pacific cod were 27.0cm, 43.6cm, 55.5cm, and 64.2cm at ages 1, 2, 3 and 4 years, respectively. Estimates of fecundity were 6.61×10^5, 1.28×10^6, and 2.20×10^6 eggs per female at total lengths of 40cm, 50cm, and 60cm, respectively.

Ketchen, K.S. 1961. Observations on the ecology of the Pacific cod (*Gadus macrocephalus*) in Canadian waters. J. Fish. Res. Bd. Can. 18: 513-558.

In Canadian waters, Pacific cod are close to the southern limit of their range and appear to inhabit depths where temperatures are between 6 C and 9 C. Seasonal variations in depth distribution are not as pronounced as those in the northwestern Pacific. The relatively higher temperatures in Canadian waters appear to be responsible for a more rapid initial growth rate and a much shorter life span than elsewhere. Maturity is reached at 2 to 3 years of age, which is several years earlier than in cooler regions of the North Pacific.

Kjesbu, O.S., J. Klungsøyr, H. Kryvi, P.R. Witthames, and M. Greer Walker. 1991. Fecundity, atresia, and egg size of captive Atlantic cod (*Gadus morhua*) in relation to proximate body composition. Can. J. Fish. Aquat. Sci. 48: 2333-2343.

Captive Atlantic cod were fed at four levels: starvation, maintenance, moderate and to excess for periods of six to nine months prior to and during spawning. Cod with high condition factors produced more previtellogenic oocytes than those with low condition factors. Fecundity of fish deprived of food during the spawning period was between 20% and 80% of potential fecundity.

Kjørsvik, E., T. Van der Meeren, H. Kryvi, J. Arnfinnson, and P.G. Kvenseth. 1991. Early development of the digestive tract of cod larvae, *Gadus morhua* L., during start-feeding and starvation. J. Fish Biol. 38: 1-15.

Atlantic cod larvae were reared in the laboratory and released to a large marine enclosure four to five days after hatching at a water temperature of 6 C to 8 C. The development of the digestive system was studied until day 24 after hatching. Morphological investigations of the jaw apparatus and the digestive tract showed that the larvae were able to absorb ingested food well before the yolk sac was completely absorbed. The foregut, and especially the midgut, were particularly active in lipid absorption. During the first days of feeding, no distinct prey organisms were observed in the gut, and signs of food absorption in the epithelial cells of the gut were sparse. In starved larvae, signs of degeneration of the gut tissue were first visible in the foregut. If larvae are starved longer than about nine days, they probably will not survive.

Kristiansen, T.S., and T. Svåsand. 1992. Comparative analysis of stomach contents of cultured and wild cod, *Gadus morhua* L. Aquacult. Fish. Man. 23: 661-668.

In a cod enhancement project in a small fjord in western Norway, two groups of fingerlings were released six months apart. Stomachs from wild and recaptured reared fish of similar size were collected. The last-released cod had learned to catch the same prey types in the same relative proportions as the wild cod by the second week after release. The first-released group of reared cod, which had spent six months in the fjord, appeared to feed as efficiently on wild prey as did wild cod.

Mukhacheva, V.A., and O.A. Zvigina. 1960. Development of Pacific cod, *Gadus morhua macrocephalus* (Tilesius). Tr. Inst. Okeanol., Akad. Nauk. SSSR, 31: 145-165. [English translation, Fish. Res. Bd. Can. Ser. 393.]

Pacific cod eggs are demersal and range in size from 1.0mm to 1.2mm. The eggs are 3.0mm to 4.0mm at hatching.

Naas, K.E. 1990. Extensive startfeeding of marine fry. In: Saunders, R.L., editor. Proc. Canada-Norway Finfish Aquaculture Workshop, September 11-14, 1989. Can. Tech. Rep. Fish. Aquat. Sci. 1761. p. 137-141.

First-feeding is one of the most critical phases in the cultivation of marine fishes. Due to the superior nutritional quality of natural zooplankton, zooplankton-fed larvae grow faster and experience higher survival rates than larvae fed such things as brine shrimp nauplii and rotifers.

Highly productive landlocked fjords have been used for the early rearing of cod in Norway. Potential predators are killed with rotenone and then the larval cod are released.

Prepared feed is offered when the plankton community has been reduced. In Austevoll, 30% to 50% of the released larvae reach metamorphosis, though results by commercial culturists have not been as good. Problems have been associated with maintaining high levels of zooplankton production, estimating the larvae/fry production, weaning, and fry harvesting. Cod fry are highly cannibalistic.

Nordeide, J.T., and A. G.V. Salvanes. 1991. Observations on reared newly released and wild cod (*Gadus morhua* L.) and their potential predators. ICES Mar. Sci. Symp. 192: 139-146.

Comparisons were made between the stomach contents and liver weights of newly released reared cod and wild cod stocked within a bay of a fjord. During the three days after release, the reared cod fed mainly on gastropods, bivalves and Actinaria, while wild juvenile cod fed mainly on Gobiidae, Brachyura and Mysidacea.

Nordeide, J.T., and T. Svåsand. 1990. The behaviour of wild and reared juvenile cod, *Gadus morhua* L., towards a potential predator. Aquacult. Fish. Man. 21: 317-325.

The behaviors of juvenile reared and wild Atlantic cod were compared in relation to a potential predator. The cod were allowed to swim and feed freely in a tank, separated from a predator (a large cod) by a transparent wall. The reared cod remained further from the predator than the wild cod did, and were slower to approach the predator.

Opstad, I., B. Strand, I. Huse, and O. Garatun-Tjeldstø. 1989. Laboratory studies on the use of rotifers (*Brachionus plicatilis* O.F. Müller) as start-feed for cod larvae (*Gadus morhua* L.). Aquaculture 79: 345-351.

Rotifers (*Brachionus plicatilis*), without enrichment or enriched with different types of dry feed for different times, were tested as first foods for cod larvae. Rotifers fed a dry diet containing Atlantic cod roe meal for more than four hours gave the best growth. Increasing water temperature increased the growth rate.

Palsson, W.A. 1990. Pacific cod (*Gadus macrocephalus*) in Puget Sound and adjacent waters: Biology and Stock assessment. Washington State Department of Fisheries Technical Report No. 112, Olympia. 122 p.

The biology of Pacific cod was reviewed. Catches in the years leading up to the study were below the previous 10-year average of 1.1 million kg/year. Catch rates in most regions and fisheries were lower in the 1980s than in the 1970s. Recreational catch rates for the southern stock were higher during some years in the late 1970s and early 1980s than during later years. The causes of the decreased catch rates are not clear. Lower catch rates corresponded to changes in oceanographic conditions but also followed a period of increased fishing effort and increased marine mammal abundance.

Paul, A.J., J.M. Paul, and R.L. Smith. 1988. Respiratory energy requirements of the cod *Gadus macrocephalus* Tilesius relative to body size, food intake, and temperature. J. Exp. Mar. Biol. Ecol. 122: 83-89.

Rates of oxygen consumption for Pacific cod were similar to those reported previously for Atlantic cod. Increases in environmental temperature between 3.5 C and 7 C resulted in a linear increase in the rate of oxygen consumption. Between 7 C and 12 C, oxygen consumption rates were similar.

Paul, A.J., J.M. Paul, and R.L. Smith. 1990. Consumption, growth and evacuation in the Pacific cod, *Gadus macrocephalus*. J. Fish Biol. 37: 117-124.

Growth of Pacific cod was related to energy consumption (cal g^{-1} day^{-1}). Maintenance ration was 11 and 12 cal g^{-1} day^{-1} at 4.5 C and 6.5 C, respectively. Cod between 200g and 5kg had similar growth rates when growth was expressed as a function of consumption (cal g^{-1} day^{-1}). Laboratory consumption of food averaged 0.9% and 1.3% body weight/day day at 4.5 C and 6.5 C. Measured consumption and growth rates were similar to those of Atlantic cod, *Gadus morhua.*

Sakurai, Y., H. Yoshida, and T. Nishiyama. 1993. Artificial propagation of Pacific cod and walleye pollock in Japan. In: Danielssen, D.S., Moksness, E., conveners. Programme and Abstracts. International Symposium Sea Ranching of Cod and Other Marine Species; June 15-18; Arendal, Norway. p. 41.

Pacific cod lay demersal eggs with the female releasing all the eggs in a single batch on the sea bottom. Cod seem to have some advantages over pollock in terms of ease of culture.

Smedstad, O.M. 1991. An introduction to the programme: enhancement of cod in a fjord, Masfjorden. ICES Mar. Sci. Symp. 192: 137-138.

A project to investigate the possibility of increasing the cod stock in a fjord by releasing large numbers of reared juveniles is described. Tagging studies demonstrated that cod remain stationary during the first years of their lives and migrate more extensively when they mature. They may spawn several times a year. They mature at about 3 years.

Initially, cod eat primarily crustaceans but the abundance of fish in their diet increases as the cod grow. Cannibalism was observed. Large pollock appear to be the most important predator on cod, and small pollock may be the most important competitor of cod.

Smith, R.L., A.J. Paul, and J.M. Paul. 1990. Seasonal changes in energy and the energy cost of spawning of Alaska Pacific cod. J. Fish Biol. 36: 307-316.

Pacific cod is similar to Atlantic cod in terms of energy cycling, maximum gonad sizes, energy expended during spawning and gonadal contribution to energy expenditure. Pacific cod differs from walleye pollock with respect to gonad index (13% and 20% vs. 20% and 8% for females and males), spawning weight loss (25% vs. 38%), liver energy loss during spawning (71% vs. 55%), and energy cost of spawning.

Svåsand, T. 1990. Cod enhancement experiments in Norway. In: Saunders, R.L. editor. Proc. Canada-Norway Finfish Aquaculture Workshop, September 11-14., Can. Tech. Rep. Fish. Aquat. Sci. 1761. p. 143-151.

Objectives of the studies were to compare reared and wild cod and to investigate if the release of reared cod can increase the yield from coastal cod populations. Results revealed only minor differences between wild and reared cod. Loss of rare alleles in the broodstock compared with the natural cod population and differences in behavior of newly released cod have been reported. Reared cod moved little after release. Natural mortality of reared cod after release was high and the fishing mortality low before recruiting to the local fishery at age 2.

Tilseth, S., G. Blom, and K. Naas. 1992. Recent progress in research and development of marine cold water species for aquaculture production in Norway. J. World Aquacult. Soc. 23: 277-285.

Recent progress in larviculture by Norwegian scientists of Atlantic cod and Atlantic halibut in enclosed seawater systems was reviewed. More than 240,000 cod juveniles had been produced in a

270,000 m^3 seawater pond. Promising production results of cod also have been achieved in plastic enclosures of volumes exceeding 100 m^3.

Tokranov, A.M., and A.B. Vinnikov. 1991. Diet of the Pacific cod, *Gadus morhua macrocephalus*, and its position in the food chain in Kamchatkan coastal waters. J. Ichthyol. 31: 84-98.

The diet of Pacific cod occurring on the east and west coasts of Kamchatka and in the southwestern part of the Bering Sea was studied. Cod consumed about 180 different items, but the primary prey (86%-96%) consisted of fishes and decapods. As the cod grew, crustaceans were replaced in the ration by fishes.

Van der Meeren, T. 1991. Algae as first food for cod larvae (*Gadus morhua* L.): Experimental data and field observations on larvae reared in mesocosms. ICES Mar. Sci. Symp. 192: 190.

Growth and survival rates of cod larvae reared in mesocosms are higher during larval stages than cod larvae reared on live food in laboratory systems. The appearance of green material (probably algal cells) in the gut of mesocosm larvae shortly after their release is a major difference between those reared in extensive and intensive systems. The research indicated that algal cells probably entered the larval gut through (1) zooplankton which feed on algae, (2) ingestion of fecal pellets from copepods and (3) direct ingestion by means of filtering. Young larvae probably filter-feed for the first exogenous feeding, which begins immediately after the mouth opens 1 to 2 days post-hatch. Larvae gradually shift to visual feeding on zooplankton. The change in size distribution of algae and algal fragments in the larval gut indicates that older larvae obtain algal material primarily through the gut contents of zooplankton.

Van der Meeren, T. 1992. Algae as first food for cod larvae, *Gadus morhua* L.: Filter feeding or ingestion by accident? J. Fish Biol. 39: 225-237.

Cod larvae, 2 to 6 days posthatch, were fed different species of algae in order to evaluate rates and mechanisms of ingestion. Small algae (*Nannochloris atomus*), entered the larval gut in conjunction with drinking. In contrast, the cod larvae concentrated larger algae (*Dunaliella salina*) in the gut at rates from 492 to 7,251 times the drinking rate. The cod larvae appeared to be active filter feeders during early larval stages.

Von Der Decken, A. 1989. Ration size in the feeding of cod (*Gadus morhua*): Effect of skeletal muscle proteins, with special reference to myosin heavy chain. Aquaculture 79: 47-52.

Cod of 80g body weight were maintained at 8 C. The fish were fed *ad libitum* for 70 days or at 75%, 50% or 25% of the *ad libitum* rate. Growth was retarded with decreasing ration size.

Westrheim, S.J., and W.R. Harling. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (*Gadus macrocephalus*), rock sole (*Lepidopsetta bilineata*), and petrale sole (*Eopsetta jordani*) landed in British Columbia. Can. Manuscr. Rep. Fish. Aqaut. Sci. No. 1681. 42 p.

Prey incidence of Pacific cod, rock sole, and petrale sole caught off British Columbia during 1950 through 1980 were determined. Principal prey species were sand lance (*Ammodytes hexzapterus*), herring (*Clupea harengus pallasi*), assorted crustaceans and sablefish (in Pacific cod stomachs). Sand lance was an important prey species for all three predators.

Westrheim, S.J., and G. Miller. 1987. A partial bibliography of Pacific cod (*Gadus macrocephalus*) in the North Pacific Ocean, through December 1985. Can. Tech. Rep. Fish. Aquat. Sci. No. 1518. 59 p.

The bibliography lists published reports through December, 1985 on Pacific cod in the north Pacific Ocean. General subjects included were management (37 individual subject codes; 391 individual references). Excluded were (1) unpublished reports, (2) reports in a foreign language which lacked an English abstract or summary, and (3) reports containing trivial references to Pacific cod.

Yamamura, O., K. Watanabe, and K. Shimazaki. 1993. Feeding habits of Pacific cod, *Gadus macrocephalus*, off eastern Hokkaido, North Japan. Proc. Nipr. Symp. Polar Biol. 6: 44-54.

Examination of stomach contents of Pacific cod captured off Hokkaido, Japan, revealed that fishes (mainly walleye pollock) and decapod crustaceans (mainly crangonid shrimps) were major dietary items. Shrimp (*Neocrangon communis* and *Argis lar*) and myctophid fishes dominated in cod less than 300mm. Food habits changed abruptly to walleye pollock and other fishes (e.g. *Sardinops melanostictus*, *Laemonema longipes*, stichaeid and cottid fishes) and octopus, *Paroctopus* spp. in larger cod. The cod showed an obvious feeding periodicity with a peak from 0600 to 1200 hours.

Yoseda, K. 1993. Recent progress in research on mass seed production of the Pacific cod in Japan. In: Danielssen, D.S., Moksness, E., conveners. Programme and Abstracts. International Symposium Sea Ranching of Cod and Other Marine Species, 15-18 June, Arendal, Norway. p. 57.

Developments of external morphology and digestive function of larval Pacific cod were studied to determine the cause of high mortality around 9mm TL under intensive culture. Teeth of both jaws and the stomach gland differentiated, and the digestive enzymes began to develop at about 9mm TL, which corresponded with the occurrence of high mortality. Experiments were initiated with enriched rotifers (*Brachionus plicatilis*) that resulted in survivals to 35 days (about 10mm TL) as high as 97.2%. A total of 95,000 cod juveniles were produced in 50m^3 tanks during 1991 and 1992.

FAMILY ANOPLOPOMATIDAE

Sablefish, *Anoplopoma fimbria*

Alderdice, D.F., J.O.T. Jensen, and F.P.J. Velsen. 1988. Incubation of sablefish (*Anoplopoma fimbria*) in a system designed for culture of fragile marine teleost eggs. Aquaculture, 71: 271-283.

An incubation system designed for fragile marine fish eggs was described. It was developed in conjunction with the hatching of sablefish eggs. Slowly rotating (2rpm) cylinders of 8L useful capacity, canted at an angle so the rotational pattern was cone-shaped, were employed. Filtered and UV sterilized seawater at 5.5 C o 6.0 C was continuously supplied from a head tank through flow regulators and was then recirculated. Maximum survival to hatching was 24%.

Alderdice, D.F., J.O.T. Jensen, and F.P.J. Velsen. 1988. Preliminary trials on incubation of sablefish eggs (*Anoplopoma fimbria*). Aquaculture 69: 271-290.

Gametes from adult sablefish were transported to the laboratory at 3 C to 4 C before fertilization was attempted. Egg fertilization dropped to 50% following immersion of the eggs in 35ppt seawater for 36 minutes. The motility of sperm dropped by 50% after only one minute in seawater. Sperm remained motile for from 300 to 500 hours if stored dry at 3 C to 6 C. A protocol was developed which resulted in from 85% to 90% fertilization. About 220ml of unfertilized eggs (about 150 egg/ml) were added to a dry 4L beaker and 1ml of milt was added to 20ml of 35ppt seawater and mixed for two to three seconds. The milt:seawater mixture was immediately added to the eggs and an additional 3L of seawater at 6 C was then added. A second portion of milt and seawater (1:20ml) was added and the solution was gently mixed. The process was repeated a third time after which the fertilized eggs were allowed to stand for five minutes. Floating eggs were removed, then the viable eggs were rinsed and placed in incubators.

The eggs of sablefish are extremely fragile. Survival to hatching in 20ppt to 35ppt salinity water of 2.1 C to 8.0 C ranged from 0.0% to 12.9%. Maximum survival to hatching occurred at 34ppt to 35ppt and 4.0 C to 6.6 C.

Boehlert, G.W., and M.M. Yoklavich. 1985. Larval and juvenile growth of sablefish, *Anoplopoma fimbria*, as determined from otolith increments. Fish. Bull. 83: 475-481.

Otoliths were examined from 105 larval and juvenile sablefish to determine growth rates.

Bowden, D.G., E.P. Groot, and J.O.I. Jensen. 1990. Tests on short-term storage of Pacific halibut (*Hippoglossus stenolepis*) sperm and salinity tolerance of Pacific halibut and sablefish (*Anoplopoma fimbria*) sperm. Can. Tech. Rep. Fish. Aquat. Sci. No. 1725. 23 p.

Salinity tolerance in sablefish sperm was determined by mixing fresh milt in various seawater concentrations (10ppt to 60ppt) and examining the duration of forward mobility of the spermatozoa.

Clarke, W.C. 1993. Temperature conditioning of marine broodstocks. In: Danielssen, D.S., Moksness, E., conveners. Programme and Abstracts. International Symposium on Sea Ranching of Cod and Other Marine Species, 15-18 June, Arendal, Norway. p. 14.

Sablefish held in captivity either did not mature or developed gametes of poor quality. The reason appeared to be associated with water temperatures, which were 3 C to 5 C higher in the laboratory than in the deep waters in which the species spawns. To test that hypothesis, two 3.7m diameter tanks were stocked with adult sablefish in late summer and then supplied with chilled seawater. During the following winter, five of the eight females held at 6 C to 7.5 C ovulated as compared with only one out of eight females held at ambient temperature (8.5 C to 9.7 C). All six males held in chilled water spermiated, while none of three males held at ambient temperature matured.

Fujiwara, S., and D.G. Hankin. 1988. Sex ratio, spawning period, and size and age at maturity of sablefish *Anoplopoma frimbria* off northern California. Bull. Jpn. Soc. Sci. Fish. 54: 1333-1338.

Sablefish were collected at depths from 100 to 900 meters off northern California. Sex ratios appeared to be 1:1 among immature fish at all depths, but significantly departed from 1:1 among mature fish during many months and at many depths, without any clear pattern. Data indicated that spawning occurred from late January through March with a probable peak during early February.

Grover, J.J., and B.L. Olla. 1987. Effects of an El Niño event on the food habits of larval sablefish, *Anoplopoma fimbria*, off Oregon and Washington. Fish. Bull. 85: 71-79.

The food habits of larval sablefish were examined during the 1983 El Niño event off Oregon and Washington and compared with a normal year (1980). The most notable difference between the two years was that during 1983 the larval sablefish consumed significantly more small copepods than during 1980.

Grover, J.J., and B.L. Olla. 1986. Morphological evidence for starvation and prey size selection of sea caught larval sablefish, *Anoplopoma fimbria* (Passas) 1811. Copeia 1986: 268-270.

The size of food consumed by larval sablefish varies with fish size. An analysis of larvae collected off Washington and Oregon showed three size classes: ≤12.5mm, 12.6-20.5mm and 20.6-28.5mm SL. Copepod nauplii were the most abundant food item in the stomachs of the smallest larvae. Nauplii were also consumed by the middle group, but not the largest group of sablefish larvae. Larger larvae consumed copepods of increasing size.

Grover, J.J., and B.L. Olla. 1990. Food habits of larval sablefish *Anoplopoma fimbria* from the Bering Sea. Fish. Bull. 88: 811-814.

Copepod nauplii and the copepod *Pseudocalanus* sp. were the primary food of larvae 12mm to 15mm. Larger sablefish larvae (16mm to 23mm) consumed primarily *Pseudocalanus* sp. adults. Unidentified copepods, amphipods, *Acartia longiremis*, and copepod nauplii were of less importance.

Hunter, J.R., B.J. Macewicz, and C.A. Kimbrell. 1989. Fecundity and other aspects of the reproduction of sablefish, *Anoplopoma fimbria*, in central California waters. Rep. CCOFI, 30: 61-72.

Sablefish in spawning condition off central California were found from October through early February. Fifty percent of the females over 60cm were sexually mature. The potential annual fecundity of a 2.5kg sablefish was 107 oocytes per gram of female. Batch fecundity averaged 24 hydrated oocytes per gram female for the last spawn, and 41 for earlier spawnings. Sablefish would have to spawn about three times to fully utilize their potential annual fecundity.

Jensen, J.O.I., W.C. Clarke, J.N.C. Whyte, and W. Damon. 1992. Incubation and larval rearing of sablefish (*Anoplopoma fimbria*) and Pacific halibut (*Hippoglossus stenolepis*). Bull. Aquacult. Assoc. Can. 92(3): 49-51.

Embryonic and larval development rates, temperature and salinity tolerance and effects of changes in salinity on neutral buoyancy have been determined for sablefish (and Pacific halibut). Conical upwelling incubators for egg incubation and yolk sac larval development have been designed and constructed. A computer-based control and monitoring system maintains critical water temperatures and flows in the larval fish laboratory at Nanaimo.

Kendall, A. W., Jr., and A. C. Matarese. 1987. Biology of eggs, larvae, and epipelagic juveniles of sablefish, *Anoplopoma fimbria*, in relation to their potential use in management. Mar. Fish. Rev. 49(1): 1-13.

This paper reviews studies that had previously been conducted on sablefish egg and larval development, feeding and occurrence. Sablefish are winter spawners that broadcast pelagic eggs near the edge of the continental shelf. Developing eggs are found floating at depths in excess of 200 meters and may require from two to three weeks to develop. The larvae apparently swim to the water surface shortly after hatching, and demonstrate growth rates as high as 2mm/day. Young-of-the-year appear in inshore waters near the surface by summer.

Maeda, R., and D. Hankin. 1983. Age and growth of sablefish landed in Eureka, California: A comparison of conventional surface age assignments with sectioned otolith assignments. In: Proceedings of the International Sablefish Symposium, 1983 March 29-31, Anchorage, AK. Alaska Sea Grant College Program Report No. 83-8. University of Alaska, Fairbanks. p. 81-94.

The theory is presented that the fishery based in Eureka, Calif. may harvest more than one sablefish stock and that a migratory slower-growing stock may enter the fishery in late fall.

Mason, J.C. 1984. On the fecundity of the sablefish (*Anoplopoma fimbria*) in Canadian waters. Can. Tech. Rep. Fish. Aquat. Sci. No. 1290. 20 p.

The fecundity of 55 mature female sablefish from 57cm to 110cm FL captured in Canadian waters during early February was determined. The ovaries contained a bimodal frequency distribution of oocyte diameters with peaks at 100µm and between 1,000µm and 1,200µm. Fecundity of individual females ranged from 58,200 to 977,000 advanced eggs. Fecundity was related to female length, not age.

Mason, J. C., R. J. Beamish, and G. A. McFarlane. 1983. Sexual maturity, fecundity, and early life history of sablefish (*Anoplopoma fimbria*) off the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 40: 2126-2134.

Sablefish spawn along the coast of British Columbia from January through April. Peak spawning is in February. Spawning occurs at depths in excess of 300 meters along the continental shelf slope. Half of the fish of both sexes initially spawn at approximately five years of age and are 58cm (females) and 52cm (males) in length at first spawning. Eggs hatch in March and April. Postlarvae migrate into surface waters and are found more than 180 kilometers offshore in late March. Juveniles appear in coastal waters in July and August. They reach 9cm by early August. Juveniles remain in nearshore waters until maturity, then migrate offshore.

McFarlane, G.A. 1988. Preliminary evidence for starvation and prey size selection of sea-caught larval sablefish, *Anoplopoma fimbria*. In: Proceedings Aquaculture International Congress, 1988 September 6-9, Vancouver, British Columbia. p. 33.

A multidisciplinary study aimed at developing the technology required for establishing a successful sablefish culture industry is described. Studies underway at the time were directed at determining optimal physical and nutrition conditions to carry larval sablefish through the post yolk-sac stage.

McFarlane, G.A., and R.J. Beamish. 1983. Biology of adult sablefish (*Anoplopoma fimbria*) in waters off western Canada. In: International Sablefish Symposium. Alaska Sea Grant College Program Report No. 83-8. University of Alaska, Fairbanks. p. 59-80.

Studies off British Columbia demonstrated that sablefish were present along the coast at depths exceeding 200 meters. Highest abundance was at between 600 and 800 meters. Spawning appeared to occur at depths greater than 300 meters. There appeared to be no significant spawning migration. Females matured at five years of age, with 50% of them averaging about 58cm. Males matured at the same age, but at a smaller average size (52cm). Sablefish fed primarily on rockfish, Pacific herring and squid. Sablefish as old as 55 years were found in Canadian waters.

McFarlane, G.A., and R.J. Beamish. 1983. Preliminary observations on the juvenile biology of sablefish (*Anoplopoma fimbria*) in waters off the west coast of Canada. In: International Sablefish Symposium. Alaska Sea Grant College Program Report No. 83-8. University of Alaska, Fairbanks. p. 119-135.

Young-of-the-year sablefish appeared inshore in July averaging 5cm in length. By November the fish had reached 28cm. At the end of their second, third and fourth years, the fish had grown to 40cm, 45cm, and 50cm, respectively.

McFarlane, G.A., and W.D. Nagata. 1988. Overview of sablefish mariculture and its potential for industry. In: Keller, S., editor. Proceedings of the Fourth Alaska Aquaculture Conference, 1987 November 18-21, Sitka, AK. Alaska Sea Grant College Program Report No. 88-4, University of Alaska, Fairbanks. p. 105-120.

While information obtained up to the time of this report indicated that sablefish are amenable to culture in terms of hardiness and food conversion efficiency, viable commercial production would depend on the development of further information on such areas as induced spawning, egg incubation, larval and juvenile rearing and the development of cost-effective feeds. Information obtained during studies at the Pacific Biological Station, Nanaimo, British Columbia had been used to develop techniques for fertilization and the determination of optimal conditions for incubation of eggs and yolk-sac larvae. Laboratory studies on rearing of wild captive larvae and juveniles were conducted.

Shenker, J.M., and B.L. Olla. 1986. Laboratory feeding and growth of juvenile sablefish, *Anoplopoma fimbria.* Can. J. Fish. Aquat. Sci. 43: 930-937.

Juvenile sablefish were collected off the coast of Oregon and placed in the laboratory. Growth was determined weekly for up to eight weeks in groups of fish ranging in size from 35mm to 100mm SL and weighing 0.3g to 16.5g. The fish were fed either mysid shrimp or adult brine shrimp at rates of 10%, 20%, or 30% of body weight daily or *ad libitum.* Fish fed known rates of mysids grew more rapidly than those fed the same levels of brine shrimp. Growth of sablefish juveniles can be extremely rapid when sufficient amounts of food are available.

Solar, I.I., I.J. Baker, and E.M. Donaldson. 1987. Effect of salmon gonadotropin and a gonadotropin releasing hormone analogue on ovarian hydration and ovulation in captive sablefish (*Anoplopoma fimbria*). Aquaculture 62: 319-325.

Sablefish do not normally ovulate in captivity. Gonadal hydration and ovulation were induced in captive adult female sablefish during their normal breeding season by injection of partially purified salmon gonadotropin or a gonadotropin releasing hormone analogue. A single injection of salmon gonadotropin at 1.0mg/kg body weight induced ovulation at one week post-injection. A single injection of gonadotropin releasing hormone analogue at 0.2mg/kg body weight induced ovulation at 2 weeks post-injection. No non-injected fish ovulated. Males spermiated independently of treatment.

Solar, I.I., E. McLean, I.J. Baker, N.M. Sherwood, and E.M. Donaldson. 1990. Short communication: Induced ovulation of sablefish (*Anoplopoma fimbria*) following oral administration of des Gly^{10}-(D-Ala^{6})LH-RH ethylamide. Fish. Physiol. Biochem. 8: 497-499.

A known dose of LH-RHa was delivered to sablefish utilizing an intubation technique. Time-course of LH-RHa absorption was followed for eight hours .

Sullivan, K.M., and K.L. Smith, Jr. 1982. Energetics of sablefish, *Anoplopoma fimbria,* under laboratory conditions. Can. J. Fish. Aquat. Sci. 39: 1012-1020.

Respiration, growth, ingestion and excretion rates were measured for sablefish collected off southern California at 500 meters and maintained in the laboratory. Sablefish fed a large ration (14% of wet body weight) every 7 to 10 days showed growth rates two to three times higher than those known from fish in nature. On a reduced ration (4% of wet body weight), sablefish grew at rates similar to field fish, but white muscle composition varied significantly from field fish. Sablefish did not show signs of starvation stress with food deprivation up to six months in the laboratory.

Westrheim, S.J., and W.R. Harling. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (*Gadus macrocephalus*), rock sole (*Lepidopsetta bilineata*), and petrale sole (*Eopsetta jordani*) landed in British Columbia. Can. Manuscr. Rep. Fish. Aqaut. Sci. No. 1681. 42 p.

See abstract under Pacific cod.

Whyte, J.N.C., W.C. Clarke, N.G. Ginther, J.O.I. Jensen, and L.U. Townsend. 1994. Influence of composition of *Brachionus plicatilis* and *Artemia* on growth of larval sablefish (*Anoplopoma fimbria* Pallas). Aquaculture 119: 47-61.

Larval sablefish were fed rotifers, and later brine shrimp reared on the microalgae *Nannochloropsis oculata*, *Isochrysis galbana* and *Chroomonas salina*. Diet composition influenced growth and time to 90% mortality of larvae. Survival was greatest for the group fed zooplankton reared on *N. oculata* and least in the group reared on *C. salina*. *B. plicatilis* contained 19% 20:5n-3 and 0.3% 22:6n-3 when reared on *N. oculata*, 3.3% 20:5n-3 and 5.2% 22:6n-3 when reared on *I.* galbana, and 5.6% 20:5n-3 and 3.0% 22:6n-3 when reared on *C. salina*. The failure to rear the larvae beyond day 60 from first feeding and the observed 50% n-3 HUFA in lipid of sablefish eggs and pelagic zooplankton, suggests that the dietary HUFA levels used to feed larvae in this study were too low to meet the apparent HUFA requirement.

FAMILY PLEURONECTIDAE

General

Becker, D.S., and K.K. Chew. 1987. Predation on *Capitella* spp. by small-mouthed pleuronectids in Puget Sound. Fish. Bull. 85: 471-479.

Predation by English sole, Dover sole and rex sole on polychaetes of the genus *Capitella* in disturbed soft-bottom sediments in Puget Sound, Wash., was studied. All three fishes exhibited some level of selective predation on the polychaetes. The polychaetes appeared to be more accessible to the fish at night. English sole appeared to alter their normal diurnal feeding behavior to forage successfully on the polychaetes at night.

Horton, H.F. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest). Dover and rock soles. U.S. Department of the Interior, Washington, D.C. 17 p.

Dover sole occur from northern Baja California to the Bering Sea. The species is abundant off the Columbia River and moderately abundant off northern Washington. Adults are rare in water of less than 36 meters and the species can be found to depths in excess of 1,000 meters. The species is commercially important from California to British Columbia. It has good shelf life and flesh quality. Females of 45cm TL and 11 years of age are all mature. Off northern California and Oregon all males reach maturity by 7 years and 39cm . Some individuals may mature when as small as 24cm. Spawning occurs in waters of from 80 meters to about 730 meters. Off Washington, Oregon, and California, the spawning season is from November through March. Fecundity ranges from 37,000 eggs for 36cm females to 265,800 for 57.5cm females. The eggs are buoyant and pelagic, averaging 2.3mm in diameter. Larvae are about 6.5mm SL at hatching. The larval stage continues until the fish reach about 50ml in SL. The larvae are found offshore, with juveniles of <18cm TL appearing over the continental shelf at depths of 55 meters to about 150 meters. The young fish are usually found between 55 and 90 meters during summer. Juveniles in nature reach nearly 11.5cm TL at age 2 and about 24cm at age 4. Four year old fish average 136g. At age 8 the fish reach 450g.

Dover sole feed primarily on benthic infaunal and epifaunal invertebrates. Primary foods are polychaetes, ophiuroids and molluscs. The fish have a preference for mud and silt substrates.

Hogue, E.W., and A.G. Carey, Jr. 1982. Feeding ecology 0-age flatfishes at a nursery ground on the Oregon coast. Fish. Bull. 80: 555-565.

The food habits of English sole, butter sole, speckled sanddab and sand sole were studied in a shallow nursery area on the Oregon coast. All but four of 422 fish from 17mm to 88mm SL studied had food in the gut. English sole and butter sole fed on benthic organisms including polychaete palps, juvenile bivalves, clam siphons, harpacticoid copepods, amphipods, cumaceans and juvenile decapods. Speckled sanddabs also fed on benthic organisms, taking primarily amphipods, cumaceans, decapods and mysids. Sand sole fed almost exclusively on mysids. The food habits of English sole varied with location of capture, season and fish length.

Molina Ureña, H. 1989. Distribution of the eggs and larvae of some flatfishes (Pleuronectiformes) off Washington, Oregon and northern California, 1980-1983. M.S. Thesis, Oregon State University, Corvallis. 192 p.

This paper describes larval development of eight species of flatfish collected between Cape Mendocino, Calif. and Juan de Fuca Strait, Wash. Species included were Pacific sanddab, speckled sanddab, rex sole, butter sole, slender sole, Dover sole, English sole and sand sole. Prolonged spawning seasons were reported for Pacific sanddab, speckled sanddab and English sole (fall spawners) as well as sand sole (spring spawner).

Pearcy, W.G., and D. Hancock. 1978. Feedings habits of Dover sole, *Microstomus pacificus*; rex sole, *Glyptocephalus zachirus*; slender sole, *Lyopsetta exilis*; and Pacific sanddab, *Citharichthys sordidus*, in a region of diverse sediments and bathymetry off Oregon. Fish. Bull. 76: 641-651.

Feeding habits of Dover sole, rex sole, slender sole and Pacific sanddab were examined at seven locations on the continental shelf off central Oregon. Dover sole fed on a large variety of infaunal and epifaunal invertebrates. Opportunistic feeding was indicated. Pelecypods were the most important prey on a weight basis at a location where they dominated the invertebrate macrofauna. Ophiuroids, sea pens, anemones and pelecypods were the most important prey on silty sand or sandy silt. Polychaetes comprised over 90% of the diet when the sediments were comprised of clayey silt or silty sand.

Small (<150mm SL) rex sole fed mainly in amphipods and other crustaceans. Large (150-450mm SL) rex sole preyed chiefly on polychaetes. The diet of rex sole was less diverse than that of Dover sole.

Both the Pacific sanddab and the slender sole preyed principally on pelagic crustaceans such as euphausiids, shrimp and amphipods. Molluscs, even when abundant, were not consumed by Pacific sanddab. Fish were occasionally considered to be important food for sanddab.

Petrale sole, *Eopsetta jordani*

Alderdice, D.F. and C.R. Forrester. 1971. Effects of salinity and temperature on embryonic development of the Petrale sole (*Eopsetta jordani*). J. Fish. Res. Bd. Can. 28: 727-744.

Earlier studies done by the authors showed that eggs of the Petrale sole were extremely fragile and suffered damage during incubation and handling. In this study, adults in spawning condition were collected off the west coast of Vancouver Island, British Columbia. Water samples taken at the spawning ground showed 33.2ppt salinity, 4.0 C temperature, and 0.93ppm dissolved oxygen.

Eggs were stripped and fertilized in the laboratory and placed in constant temperature and salinity incubators two hours after fertilization. Living fertilized eggs floated at the surface of the incubators. Neutral buoyancy was at 30.3ppt. Salinities from 20ppt - 35ppt were tested and temperatures were varied from 4 C to 8.5 C. A water velocity of 500cm/hr was adequate for minimizing mechanical damage and delivering proper concentrations of dissolved oxygen to the incubating eggs.

Temperature was the primary factor influencing egg development. Higher temperatures led to faster development. Salinity had little overall effect on development rate. Largest viable hatches occurred at 6.75 C to 7.25 C and 26.5ppt to 29.5ppt salinity. Larvae were very delicate after hatching.

Westrheim, S.J., and W.R. Harling. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (*Gadus macrocephalus*), rock sole (*Lepidopsetta bilineata*), and petrale sole (*Eopsetta jordani*) landed in British Columbia. Can. Manuscr. Rep. Fish. Aqaut. Sci. No. 1681. 42 p.

See abstract under Pacific cod.

Flathead sole, *Hippoglossoides elassodon*

Alderdice, D.F. and C.R. Forrester. 1974. Early development and distribution of the Flathead sole (*Hippoglossoides elassodon*). J. Fish. Res. Bd. Can. 31: 1899-1918.

Flathead sole were captured live in late March and early April off the coast of British Columbia. Eggs were stripped after three hours of captivity and fertilized in water ranging from 26.9ppt to 28.4ppt salinity. This study examined egg development under different salinity and temperature conditions.

Newly spawned eggs were buoyant in salinities of 25ppt to 27ppt or greater and newly hatched larvae were buoyant in salinities of 17ppt to 18ppt or greater. Temperature was the only significant factor in rate of egg development. Hatching times (fertilization to 50% hatched) ranged from 90 hours at 10.7 C to 190 hours at 2.4 C. Size at hatching increased with temperature, and was maximized at ≥6 C.

Total and viable hatch were greatest at salinities of 25ppt and temperatures of 6 C to 7 C. Larvae were mostly inactive and floated with yolk sac up but would swim rapidly if disturbed. Eventually, they became continuously active and swam with yolk sac down. Post-hatching development was limited by temperatures lower than 4.5 C. Maximum viable hatch occurred at or near 29.2ppt. The best salinity range for larval development was 28ppt to 32 ppt.

Miller, B.S. 1969. Life history observations on normal and tumor bearing flathead sole in East Sound, Orcas Island (Washington). Ph.D. Thesis. University of Washington, Seattle. 131 p.

The peak spawning months for flathead sole near Orcas Island in Puget Sound was in April, with some spawning occurring in March and May. Female fecundity ranged from 71,684 to 594,416 eggs and correlated with total length, age, eviscerated weight and ovary weight. Puget Sound is probably the southernmost portion of the flathead sole's range.

Artificial spawning of ripe females was carried out during April and May. Eggs were stripped by hand into 0.9L jars with seawater. Fertilized eggs were then decanted into 0.9L jar incubators and floated in an aquarium. Flowing seawater in the aquarium maintained temperatures at ambient levels. Water was exchanged daily and any debris or dead eggs were removed.

Hatching time was approximately nine days at 9.8 C and 30ppt salinity. Larval length at hatch ranged from 5.5mm to 6.3mm.

Rose, C.R. 1982. A study of the distribution and growth of flathead sole (*Hippoglossoides elassodon*). MS. Thesis. University of Washington, Seattle, Washington. 59 p.

This study primarily concerned the growth and distribution of flathead sole in the Kodiak Island and Bering Sea off Alaska. Comparisons are made to growth of the same species in the Orcas Island area of Puget Sound. Length at age was similar to the results obtained by Miller (1969).

Dover sole, *Microstomus pacificus*

Gabriel, W.L., and W.G. Pearcy. 1981. Feeding selectivity of Dover sole, *Mierostomus pacificus*, off Oregon. Fish. Bull. 79: 749-763.

This paper investigated the food habits and selectivity of Dover sole off the coast of Oregon. In midsummer, polychaetes were the primary food item, followed by a large proportion of ophiuroids. Molluscs were dominated as food items by *Macoma* spp. Crustaceans were represented by amphipods and cumaceans.

Hunter, J.R., B.J. Macewicz, N.C.H. Lo, and C.A. Kimbrell. 1992. Fecundity, spawning, and maturity of female Dover sole *Microstomus pacificus*, with an evaluation of assumptions and precision. Fish. Bull. 90: 101-128.

In this report the authors estimated annual fecundity, batch fecundity, rates of atresia, annual rates of spawning, length at 50% maturity and changes that occur in the female Dover sole as the spawning season progresses. The data were collected from samples taken off the Oregon and central California coasts. Calculated fecundity for a 1kg female was approximately 83,000 oocytes. A model predicted that a 1kg Dover sole with 83,000 advanced, yolked oocytes would spawn them in approximately nine batches. Length at 50% maturity was estimated to be approximately 332mm. Spawning season in Oregon and California waters extend for up to six months from December through May. Dover sole typically show a one to two month spawning season in more northern latitudes.

Markle, D.F., P.M. Harris, and C.L. Toole. 1992. Metamorphosis and an overview of early-life-history stages in Dover sole *Microstomus pacificus*. Fish. Bull. 90: 285-301.

Noting that there was little previous agreement on the sizes, duration and timing of the early life history stages of the Dover sole, the authors set out to describe them. They used five numbered stages to describe early development.

Pearcy, W.G., M.J. Hosie, and S.L. Richardson. 1977. Distribution and duration of pelagic life of larvae of Dover sole, *Microstomus pacificus*; rex sole, *Glyptocephalus zachirus*; and petrale sole, *Eopsetta jordani*, in waters off Oregon. Fish. Bull. 75: 173-183.

Dover sole spawn in water greater than 400 meters deep. Their larvae can reach an exceptionally large size and remain pelagic for extended periods. Large larvae (50mm to 65mm SL) can remain pelagic for over a year and few become benthic. They are most often found in the upper 50 meters of the water column in waters beyond the continental slope.

Yoklavich, M.M., and E.K. Pikitch. 1989. Reproductive status of Dover sole, *Microstomus pacificus*, off northern Oregon. Fish. Bull. 87: 988-995.

Fifty-seven mature female Dover sole from 345mm to 550mm TL were used to estimate fecundity. Fecundity ranged from 39,748 to 167,046 oocytes and increased with increasing fish length. The fish ranged from 11 to 34 years of age. Fecundity was more closely related to length and weight than to age.

English sole, *Parophrys vetulus*

Alderdice, D.F. and C.R. Forrester. 1968. Some effects of salinity and temperature on early development and survival of the English sole (*Parophrys vetulus*). J. Fish. Res. Bd. Can. 25: 495-521.

In southern British Columbia, English sole generally spawn over a four-month period ending in late March or early April. This study determined the effects of varying temperatures and salinities on egg and larval survival. Hatching ceased at temperatures between 2 C and 4 C. Two degrees was found to be lethal in all cases. Temperature had more influence on hatching development than salinity. A salinity of approximately 25ppt was best for hatching potential as well as size of larvae at hatch. Eight degrees C was optimum for total and viable hatches. The combination of 8 C and 25ppt was best for overall survival potential. Dissolved oxygen was maintained at a high enough level that it was not a factor in development and survivability. English sole eggs are considered to be euryhaline and develop normally over a wide range of salinities.

Becker, D.S. 1988. Relationship between sediment character and sex segregation in English sole, *Parophrys vetulus*. Fish. Bull. 86: 517-524.

English sole collected from Puget Sound, Wash., were segregated by sex and sediment type. The segregation existed with respect to the year samples were collected, season, depth and location. Fish age did not appear to influence sex segregation.

Boehlert, G.W., and B.C. Mundy. 1987. Recruitment dynamics of metamorphosing English sole, *Parophorys* [sic] *vetulus*, to Yaquina Bay, Oregon. Est. Coast. Shelf Sci. 25: 261-281.

English sole spawn in continental shelf waters off the west coast of North America and early development occurs in coastal waters. Near metamorphosis, larvae recruit to nearshore and estuarine nursery areas.

Burreson, E.M. 1977. *Oceanobdella pallida* N. sp. (Hirudinea: Piscicolidae) from the English sole, *Parophrys vetulus*, in Oregon. Trans. Am. Microsc. Soc. 96: 526-530.

A new marine leech, *Oceanobdella pallida*, is described. Recovered from the mouth of English sole, the parasite reaches a maximum length of 20mm. About 20% of English sole along the Oregon coast were parasitized.

Burreson, E.M. 1984. A new species of marine leech (Hirudinea: Piscicolidae) from the north-eastern Pacific Ocean, parasitic on the English sole, *Parophrys vetulus* Girard. Zool. J. Linn. Soc. 80: 297-301.

A leech, *Calliobdella knightjonesi*, found parasitic on English sole was described.

Casillas, E., L.L. Johnson, D. Misitano, T.K. Collier, J.E. Stein, McCain, B.B., and U. Varanasi. 1992. Inducibility of spawning, reproductive success, and egg production in flatfish species from urban and non-urban areas of Puget Sound, Washington. Mar. Envir. Res. 35: 227.

English sole were induced to spawn with injections of an analogue of LHRH. Ability to spawn, time of spawning and larval viability were related to sediment contaminant concentrations at sites of capture. Spawning and fertilization success were correlated with initial plasma estradiol and alkaline-labile protein-associated phosphate concentrations.

Casillas, E., D. Misitano, L.L. Johnson, L.D. Rhodes, T.K. Collier, J.E. Stein, B.B. McCain and U. Varanasi. 1991. Inducibility of spawning and reproductive success of female English sole (*Parophrys vetulus*) from urban and nonurban areas of Puget Sound, Washington. Mar. Envir. Res. 31: 99-122.

This paper's primary concern is the effects of sediment contaminants on the reproductive capability of English sole. Fish were captured in Puget Sound and transported to the laboratory where they were held in flow-through tanks at 10 C to 11 C. Verification of vitellogenic stage was made by measuring levels of plasma estradiol and alkaline-labile phosphate (ALP), also called vitellogenin. Required minimum levels for female English sole to have entered vitellogenesis are approximately 1000pg/ml for plasma estradiol and 10µg/ml for ALP.

Female English sole were induced to spawn using des Gly^{10} [D-Ala^{6}] luteinizing hormone releasing hormone ethylamide (LHRHa). Initial levels of plasma estradiol were excellent predictors of the success of using LHRHa. Females with plasma estradiol concentrations less than 2,500pg/ml showed a low probability of spawning while those with levels greater than 3,000pg/ml had a greater than 90% possibility of spawning with LHRHa.

Collier, T.K., J.E. Stein, H.R. Sanborn, T. Horn, M.S. Myers and U. Varanasi. 1993. A field study of the relationship between bioindicators of maternal contaminant exposure and egg and larval viability of English sole (*Parophrys vetulus*). Mar. Env. Res. 35: 171-175.

This study concerns egg and larval viability in fish which had reached maturation. Contaminant exposure of the mother was found to play only a minor role in egg and larval viability. However, the authors hypothesize that females that have been exposed to large amounts of the contaminants may, to some degree, be excluded from the spawning population.

Dygert, P.H. 1990. Seasonal changes in energy content and proximate composition associated with somatic growth and reproduction in a representative age-class of female English sole. Trans. Am. Fish. Soc. 119: 791-801.

A 386.7mm, 6-year-old female English sole gained 73g dry weight during the spring and summer and subsequently lost 61g of dry weight (36% of peak biomass) from October to March. The majority of the lost mass (33% of the 36%) was accounted for by increase in ovary mass. Movement of 55% of lost protein, 47% of ash and 5% of lipids was to the ovarian tissue.

Fargo, J., and T. Sexton. 1991. The ovarian histology of English sole (*Parophrys vetulus*). Can. Manusc. Rep. Fish. Aquat. Sci. No. 2133. 22 p.

Ovaries from mature English sole showed six distinct stages of oocytes, characterized by size and morphology, over an annual cycle. Photomicrographs of the stages are provided.

Foucher, R.P., A.V. Tyler, J. Fargo, and G.E. Gillespie. 1989. Reproductive biology of Pacific cod and English sole from the cruise of the FV *Blue Waters* to Hecate Strait, January 30 to February 11, 1989. Can. Man. Rep. Fish. Aquat. Sci. No. 2026. 85 p.

See abstract under Pacific cod.

Gunderson, D.R., D.A. Armstrong, Y-B. Shi, and R.A. McConnaughey. 1990. Patterns of estuarine use by juvenile English sole (*Parophrys vetulus*) and Dungeness crab (*Cancer magister*). Estuaries 13: 59-71.

English sole rely heavily on the Grays Harbor and Willapa Bay estuaries of Washington state as nursery areas. The larvae are released in coastal waters. Metamorphosis occurs both in coastal and estuarine areas. Most English sole migrate into the estuaries during their first year of life even if they initially become benthic while in coastal waters. Outmigration from estuaries begins when the fish are about 75mm long. Few remain in estuaries during their second year of life.

Johnson, L.L., and E. Casillas. 1991. The use of plasma parameters to predict ovarian maturation stage in English sole, *Parophrys vetulus*. J. Exp. Mar. Biol. Ecol. 151: 257-270.

Oocyte development in English sole was studied in relation to associated changes in condition factor and levels of estradiol, vitellogenin, calcium, magnesium, phosphate, total protein, triglycerides and glucose in plasma.

Johnson, L.L., E. Casillas, M.S. Myers, L.D. Rhodes, and O.P. Olson. 1991. Patterns of oocyte development and related changes in plasma 17-ß estradiol, vitellogenin, and plasma chemistry in English sole, *Parophrys vetulus* Girard. J. Exp. Mar. Biol. Ecol. 152: 161-185.

English sole were captured from two spawning locations in Puget Sound and the levels of estradiol, vitellogenin (estimated from alkali-labile protein-associated phosphate [ALP]), phosphate, calcium, magnesium, total protein, albumin, glucose and triglycerides were determined from blood samples. Plasma estradiol increased sharply at the onset of vitellogenesis and returned to normal following spawning. Vitellogenin ALP also increased during vitellogenesis but remained elevated after spawning. Albumin, total protein and calcium increased with vitellogenesis and decreased during or following spawning. Phosphate levels decreased during vitellogenesis and remained low following spawning. Magnesium levels decreased during vitellogenesis but increased after spawning. Plasma triglyceride levels decreased sharply following spawning as did glucose levels.

Two distinct clutches of oocytes were observed in the ovaries of prespawning females; a leading clutch of vitellogenic oocytes and another clutch of non-yolked oocytes in the primary growth phase. A high proportion of English sole females showed a tendency to resorb non-yolked oocytes.

Kruse, G.H. and A.V. Tyler. 1983. Simulation of temperature and upwelling effects on the English sole (*Parophrys vetulus*) spawning season. Can. J. Fish. Aquat. Sci. 40: 230-237.

Using spawning records and back-calculated spawning estimates, the authors mathematically modeled spawning of English sole. The authors concluded that spawning of English sole is primarily linked to the dynamics of bottom temperatures as they relate to upwelling.

Krygier, E.E., and W.G. Pearcy. 1986. The role of estuarine and offshore nursery areas for young English sole, *Parophrys vetulus* Girard, of Oregon. Fish. Bull. 84: 119-132.

The shallow waters along the open coast as well as in Oregon estuaries appear to be common nursery areas for 0-age English sole. Metamorphosing English sole enter Yaquina Bay, Ore., between November and June.

Laroche, W.A., and R.L. Holton. 1979. Occurrence of 0-age English sole, *Parophrys vetulus*, along the Oregon coast: An open coast nursery area? Northw. Sci. 53: 94-96.

This study found that in addition to estuaries, 0-age English sole also use nearshore areas along the Oregon coast as nursery areas.

Lycykowski-Laroche, J., S.L. Richardson, and A.A. Rosenberg. 1982. Age and growth of a pleuronectid, *Parophrys vetulus*, during the pelagic larval period in Oregon coastal waters. Fish. Bull. 80: 93-104.

Daily growth increments of both laboratory-raised and wild larval English sole were measured. Eggs were stripped and fertilized on board ship and then transported back to the laboratory in seawater-filled plastic bags. Water temperatures in the lab were maintained at 12 C to 13 C with a 14-hour photoperiod for hatching and larval rearing. Newly hatched larvae were moved into glass jars where they were maintained with a constant bloom of the green flagellate *Tetraselmis* sp. Four days after hatching the larvae were offered the dinoflagellate *Gymnodinium splendens* and the rotifer *Brachionus plicatilis*. One to two weeks later the *G. splendens* was discontinued. Rotifers were maintained in the jars for the duration of the study with *Artemia salina* nauplii and the harpacticoid copepod, *Tisbe* sp. offered as secondary food sources.

Based on otolith examination, growth in the laboratory was slower than growth in the wild once the yolk sacs were absorbed. The first growth increment ring was found in 5- to 6-day-old larvae which coincided with active swimming at the surface searching for food. By that time most of the yolk sac had been absorbed. Increment lines were found to be much more distinct in the wild caught larvae versus the laboratory larvae which, in some cases, were too faint to read.

Lycykowski-Laroche, J., and S.L. Richardson. 1979. Winter-spring abundance of larval English sole, *Parophrys vetulus*, between the Columbia River and Cape Blanco, Oregon during 1972-1975 with notes on occurrences of three other pleuronectids. Estuar. Cost. Mar. Sci. 8: 455-476.

Large variations in abundance, distribution and size composition of English sole were observed in late winter to early spring off the Oregon coast. The observed fluctuations may have been related to spawning time and differences in food availability.

Olson, R.E. 1978. Parasitology of the English sole, *Parophrys vetulus* Girard in Oregon, U.S.A. J. Fish Biol. 13: 237-248.

Nearly 900 juvenile English sole from Yaquina Bay estuary and nearly 750 juveniles and adults from the Pacific Ocean off Oregon were examined for parasites. Fifteen species of parasites were found in juvenile English sole in the estuary. An additional 14 species of parasites were found in offshore-dwelling fish.

Orsi, J.J. 1965. The embryology of *Parophrys vetulus*, the English sole. MS. Thesis. University of Washington, Seattle. 73 p.

This paper describes the development of English sole from fertilized egg to yolk sac absorption. Photomicrographs of egg cell cleavage, embryonic development and organ development are included.

Peterman, R.M., and M.J. Bradford. 1987. Density-dependent growth of age 1 English sole (*Parophrys vetulus*) in Oregon and Washington coastal waters. Can. J. Fish. Aquat. Sci. 44: 48-53.

This study found that there is a significant negative effect of cohort abundance on annual growth rate of age-1 English sole, but not on growth of fish from age-2 through age-7.

Rogers, C.W., D.R. Gunderson, and D.A. Armstrong. 1988. Utilization of a Washington estuary by juvenile English sole, *Parophrys vetulus*. Fish. Bull. 86: 823-831.

The relative density and abundance of 0-age English sole were compared in the Grays Harbor, Wash., estuary and the adjacent coastal zone. Timing of immigration and emigration from the estuary also was studied.

Rosenberg, A.A. 1982. Growth of juvenile English sole, *Parophrys vetulus*, in estuarine and open coastal nursery grounds. Fish. Bull. 80: 245-252.

Growth of English sole from estuarine and open coastal nursery grounds on the coast of Oregon is described in this paper. Growth was linear during the first year of life. Settlement of English sole larvae to the benthic habitat occurred over the winter and spring in the open coastal nursery area. In the estuary, settlement was concentrated in the early winter.

Sanborn, H.R., and D.A. Misitano. 1991. Hormonally induced spawning of English sole (*Parophrys vetulus* Girard). J. Appl. Ichthyol. 7: 15-25.

The effectiveness of carp pituitary and LHRH hormone analog to induce maturation in English sole was evaluated. Fish captured at various stages of development were treated with either daily injections of carp pituitary at 1mg/kg or LHRH at 0.15mg/kg body weight every four days. Both hormones induced gonadal maturation.

Toole, C.L. 1980. Intertidal recruitment and feeding in relation to optimal utilization of nursery areas by juvenile English sole (*Parophrys vetulus*: Pleuronectidae). Envir. Biol. Fish. 5: 383-390.

Juvenile English sole from 19mm to 102mm were collected from an intertidal flat in Humboldt Bay, Calif. Recently metamorphosed sole fed almost exclusively on harpacticoid copepods and other epibenthic crustaceans during spring and summer. Fish from 50mm to 65mm transitioned to infaunal polychaetes, which dominated the food habits of fish longer than 65mm. In early fall English sole left the intertidal zone at a size of 82mm.

Williams, S.F. and R.S. Caldwell. 1978. Growth, food conversion and survival of 0-group English sole (*Parophrys vetulus* Girard) at five temperatures and five rations. Aquaculture 15: 129-139.

Three 12-week experiments were conducted with wild-captured juvenile English sole. The fish were allowed to acclimate in the laboratory before studies on the effects of feeding rate and temperature on growth were initiated. Photoperiod was maintained at ambient with cool-white fluorescent lighting. Salinities were generally above 30ppt and always exceeded 21ppt.

Young fish were fed Oregon Moist Pellets, half in the morning and the remainder in the evening. Daily rations were calculated as a percent of body weight (dry weight food/dry weight fish). Fish were tested at 9.5, C 12 C, 15 C, 18 C and 21 C and fed rations of 4%, 8%, 12%, and 16% at all temperatures except 21 C which was only fed 8%, 12%, and 16%. Fish lost weight at all rations when held at 21 C. Feeding slowed at temperatures below 7 C and ceased altogether at 2 C to 3 C.

Best growth at all temperatures was associated with the 16% ration with best results occurring at 9.5 C. The most efficient growth was at 9.5 C and 8% daily ration. Mortalities in the experiments increased with increasing ration and temperature. Disease organisms found in conjunction with some of the mortalities including *Vibrio* bacteria, the microsporidian protozoan *Glugea* sp., and the monogenetic trematode *Gyrodactylus* sp.

Sand sole, *Psettichthys melanostictus*

Sommani, P. 1969. Growth and development of sand sole postlarvae (*Psettichthys melanostictus*). MS. Thesis, University of Washington, Seattle. 60 p.

This study examined the growth, development and characteristics of sand sole larvae after yolk sac absorption. Maximum recorded length is 62.9cm and the oldest recorded sand sole was 10 years old. Maturity is reached at age 2 in males and age 3 in females. It is possible that the sand sole has an extended spawning season ranging from January through July based on the findings of ripe females in the summer months. Peak spawning periods occur from March through April. Hatching time for eggs in Puget Sound is about five days when surface temperatures are 7 C to 9 C. Yolk sac absorption takes approximately 10 to 12 days.

FAMILY SCORPAENIDAE

General information on *Sebastes* spp.

Boehlert, G.W. 1980. Size composition, age composition, and growth of canary rockfish, *Sebastes pinniger*, and splitnose rockfish, *S. diploproa*, from the 1977 rockfish survey. Mar. Fish. Rev. 42: 57-63.

Canary rockfish are predominantly taken off the Oregon-Washington coast at depths of 91 meters to 272 meters. Recruitment is completed with fish from 14 to 15 years of age at 51cm for males and 55cm for females. Splitnose rockfish were taken at depths from 300 meters to 1560 meters. Recruitment was complete at ages 14 to 17.

Boehlert, G.W., and M.M. Yoklavich. 1986. Reproductive mode and energy costs of reproduction in the genus *Sebastes*. In: Proceedings of the International Rockfish Symposium, 1986 Oct. 20-22, Anchorage, AK. Alaska Sea Grant College Program Report No. 87-2, University of Alaska, Fairbanks. p. 143-152.

The genus *Sebastes* has historically been considered to be ovoviviparous, with all energy for embryonic development coming from the yolk present at fertilization. Studies have shown that embryos of two species receive nutrition in addition to that supplied in the yolk. Total energy required during embryo development was greater than that initially available in the egg.

Boehlert, G. W. and J. Yamada. 1991. Introduction to the symposium on rockfishes. Env. Biol. of Fish. 30: 9-13.

Worldwide decreases in rockfish stocks have spurred research in the U.S. and Japan on reproduction and early life history of the genus *Sebastes*. Japanese research has been approached somewhat differently than American research. The Japanese have been interested in starting an aquaculture industry to support coastal resources while the American approach has been to manage the existing stocks and count on natural production to renew the resource. Japan pioneered the use of aquaculture to enhance the declining natural stocks of kurosoi (*Sebastes schlegeli*). The results of that research will be valuable to any U.S. efforts to raise *Sebastes* spp. for aquaculture or enhancement purposes.

Boehlert, G. W., M. Kusakari, and J. Yamada. 1991. Oxygen consumption of gestating female *Sebastes schlegeli*: estimating the reproductive costs of livebearing. Env. Biol. Fish. 30: 81-89.

Pregnant female kurosoi, *Sebastes schlegeli*, showed significantly higher oxygen consumption compared to males and immature females of similar size and weight. A 1.5kg pregnant female was estimated to consume 68% more oxygen than a non-gestating fish during the gestation period (51.5 days).

Boehlert, G. W., M. M. Yoklavich, and D. B. Chelton. 1989. Time series of growth in the genus *Sebastes* from the northeast Pacific Ocean. Fish. Bull. 87: 791-806.

The otoliths of two species of rockfish, canary rockfish and splitnose rockfish, were studied to determine growth rates. The longevity of rockfish (over 80 years for many species) allows estimation of several decades of growth from older individuals.

Canino, M. and R. C. Francis. 1990. Rearing of *Sebastes* larvae (Scorpaenidae) in static culture. Fisheries Research Institute, University of Washington School of Fisheries Report FRI-UW-8917, Technical Report to NMFS Resource Assessment and Conservation Engineering Division. 8 p.

This report summarizes preliminary efforts to raise larvae from four species: copper rockfish, China rockfish, yelloweye rockfish and brown rockfish. The three latter species lived over 30 days in culture. The research represented the first rearing attempts for larvae of the China and yelloweye rockfish. Twenty-three brown rockfish juveniles were released after 62 days when they outgrew their food supply and required larger prey.

Larval rearing chambers were black 100L fiberglass or 20L polycarbonate tanks filled with 1.0μm filtered seawater. Temperature was maintained at 10.1 C ± 0.4 C. Constant illumination came from dim overhead fluorescent lighting. Initial stocking densities were estimated at 15 to 20 larvae/L. From 33% to 50% of the water was exchanged daily and circulated by minimal aeration in center of the tank. Bottoms were siphoned regularly.

Food organisms were the rotifer *Brachionus plicatilus* and field-caught zooplankton. Wild zooplankton consisted almost entirely of the early copepodite and naupliar stages of the copepod *Acartia clausi*. Newly extruded rockfish larvae were fed an approximate 2:1 mixture of rotifers and 35μm to 100μm zooplankton (early stage nauplii). Consumption of rotifers decreased while consumption of *Acartia* increased as the fish larvae grew. At 6mm SL the larvae were fed late copepodite and adult stage *Acartia*. Prey densities were maintained at approximately 10 prey per ml.

The authors recommended gathering broodstock during early gestation and holding them in darkened tanks until parturition to avoid premature extrusion which was the leading cause of early mortality. Catheterization can be used to determine if the fish are actually gravid. Larvae should be transported from brood tanks as soon as possible and as gently as possible. Culture tanks should be of dark, non-reflective colors although white colored bottoms have been used successfully and have been easier to clean along with facilitating enumeration of larvae. Illumination should be kept to minimal levels.

Larvae less than 6mm TL may be fed rotifers and wild plankton less than 200μm. Larger prey should be offered as larvae grow.

Conte, F. P., K. Takano, A. Takemura and G. W. Boehlert. 1991. Ontogeny of the sodium pump in embryos of rockfish of the genus *Sebastes*. Env. Biol. Fish. 30: 127-130.

Enzymatic levels of Na, K-ATPase were monitored in laboratory raised *Sebastes schlegeli* and *Sebastes taczanowskii*. Early larval stages contained no Na, K-ATPase while post-epiboly larvae did contain the enzyme. Maturation of the midgut, hindgut and intestinal tract, following epiboly, were concurrent with maximal levels of the enzymatic activity. The activity occurred within the ovaries of the *Sebastes* female and supported theories of embryonic feeding on ovarian fluid (matrotrophic viviparity).

Gunderson, D. R., and T. M. Sample. 1980. Distribution and abundance of rockfish off Washington, Oregon, and California during 1977. Mar. Fish. Rev. 42(3-4): 2-16.

Distribution and abundance data for several commercially important rockfish species and Pacific whiting are presented.

Gunderson, D. R., P. Callahan, and B. Goiney. 1980. Maturation and fecundity of four species of *Sebastes*. Mar. Fish. Rev. 42(3-4): 74-79.

Yellowtail rockfish, canary rockfish, bocaccio and chilipepper were studied. Predicted FL at 50% maturity for the four species were: Canary rockfish: males 39.5cm, females 49.2cm. Yellowtail rockfish: males 40.7cm, females 45.0cm. Chilipepper: males 26.1cm, females 37.0cm. Bocaccio: males 44.8cm, females 48.2cm.

Kendall, A. W., Jr. 1982. A catalog of information, primarily illustrative, on larval development of *Sebastes*. Northwest and Alaska Fisheries Center Proc. Report, 82-01. National Marine Fisheries Service, Seattle, Washington. 23p.

Emphasis in this report is on the known taxonomy of the genus *Sebastes* and the cataloging of all the available illustrations of larval and juvenile specimens. Larval illustrations are all referenced as to source.

Kendall, A. W., Jr. 1989. Additions to knowledge of *Sebastes* larvae through recent rearing. In: Northwest and Alaska Fisheries Center Proceedings. Report 89-21, National Marine Fisheries Service, Seattle, WA. 46p.

This report contains detailed descriptions and illustrations of the larval stages of 21 species of *Sebastes*. All larvae had been reared from adults caught in the northeast Pacific Ocean. The goal was to be able to identify field-caught larvae of the 40 or so species of *Sebastes* in the northeast Pacific by use of an illustrated catalog. Culture techniques for the various larvae are briefly described.

Kendall, A.W., Jr. 1991. Systematics and identification of larvae and juveniles of the genus *Sebastes*. Env. Biol. Fish. 30: 173-190.

This paper reviews information on the systematics and morphology of larval and juvenile rockfish species. Of the 102 species of *Sebastes* worldwide, 69 species had been illustrated as preflexion larvae, 35 as postflexion larvae, and 65 as pelagic juveniles.

Kendall, A. W., Jr., and W. H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. In: Proceedings of the International Rockfish Symposium, 1986 Oct. 20-22, Anchorage, AK. Alaska Sea Grant College Program Report No. 87-2, University of Alaska, Fairbanks. p. 99-128.

Though fecundity of rockfish ranges from about 10,000 to 1,000,000 eggs per female, the unusual reproductive patterns in rockfish cause their young to be dispersed differently from those which disperse planktonic eggs. Rockfish reproduction involves spermatogenesis, vitellogenesis, mating, ovulation, fertilization, embryonic development, hatching and larval extrusion. Mating may precede fertilization by several months, and males mature several months before females.

Embryos take 40 to 50 days to develop and hatch about one week before extrusion. Most species extrude young in the first six months of the year but some variation occurs.

Most juveniles have a pelagic stage followed by a benthic stage, though there is variability from species to species. Some restrict themselves to a limited home range while others may stay in estuarine areas for up to five years before migrating to deeper offshore areas. Many juveniles are associated with floating material and kelp beds in the early stages and may adjust their life cycles around those areas. Depth distribution of juveniles varies widely.

Kusakari, M. 1991. Mariculture of kurosoi, *Sebastes schlegeli*. Env. Biol. Fish. 30: 245-251.

The purpose of rearing *S. schlegeli* is for release of juveniles. Gravid females of 40cm to 46cm TL exhibit fecundities of 100,000 to 184,000 eggs. Larvae can be sequentially fed rotifers, *Artemia* nauplii, and young sand lance until they are 25mm long (about 35 days of age). Survival is 50%. Thereafter the fish should be graded to avoid cannibalism. Minced or chopped sand lance and commercial food can be provided until the stocking size of 100mm is attained. The growth of juvenile kurosoi from 25mm to 100mm requires 85 days, with a survival rate of 90%.

Larson, R. J. 1991. Seasonal cycles of reserves in relation to reproduction in *Sebastes*. Env. Biol. Fish. 30: 57-70.

From a review of the literature and the author's own observations it was suggested that northeast Pacific *Sebastes* spp. share common timing with respect to seasonal fat cycles. Fat is added during the food-rich summer months and catabolized during winter food shortages. The role of fat reserves in the reproductive cycle of *Sebastes* spp. is unclear. Most evidence indicates that reserves are used primarily for maintenance during the winter months. Better understanding of the role of fat reserves in reproduction can best be determined by feeding trials and observing the effects of varying the amounts of food.

Leaman, B.M. 1991. Reproductive styles and life history variables relative to exploitation and management of *Sebastes* stocks. Env. Biol. Fish. 30: 253-271.

This paper deals primarily with management. Of interest is the fact that rockfishes can be long-lived (50 to 100 years) and recruit at advanced ages (10 to 15 years).

Lenarz, W. H., and T. W. Echeverria. 1991. Sexual dimorphism in *Sebastes*. Env. Biol. Fish. 30: 71-80.

Sexual dimorphism in some species of rockfishes is evident in SL and morphometric differences in various features about the head. Females are usually longer than males of the same age while males may show longer upper jaws and larger orbits, interorbital widths, pectoral fins and first dorsal spines.

Love, M.S., M.H. Carr, and L.J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus *Sebastes*. Env. Biol. Fish. 30: 225-243.

In general, juvenile rockfish recruit to shallower depths than those occupied by conspecific adults. Habitat use by newly recruited rockfish differs markedly among species. While a few species recruit to shallow-dwelling macrophytes, others recruit to larger brown algae. A few deeper dwelling species recruit to low relief or soft substrata. Crustaceans are the major component in the diets of newly recruited *Sebastes*. Species which continue to forage in the water column shift to larger crustaceans (e.g. euphausiids) and fish as they grow.

Matthews, K. R. 1988. Habitat use and movement patterns of copper, quillback, and brown rockfishes in Puget Sound. Ph.D. dissertation, University of Washington, Seattle. 121p.

The copper rockfish, quillback rockfish and brown rockfish are solitary, demersal and inhabit shallow reefs. They differ in color but are morphologically similar. Though the copper and quillback rockfishes can be found throughout the Puget Sound region, the brown rockfish is limited in its distribution to central and south Puget Sound.

The author studied movements of the three rockfish species to determine home-range, migration between reefs, and whether homing occurred. Rockfishes maintained small home-ranges but did not defend them. Most displaced rockfish were able to successfully return to home sites when displaced from 50 meters to 8 kilometers.

The author found that high-relief reefs were suitable habitat for all three rockfish species while low-relief and sand/eelgrass sites were temporary habitats coinciding with summer algal and eelgrass growth. Artificial reefs were favorite sites for sub-adult quillback rockfish but not adults. Copper rockfish were found on artificial reefs where brown rockfish were rarely observed.

Matthews, K.R. 1990. A comparative study of habitat use by young-of-the-year, subadult, and adult rockfishes on four habitat types in central Puget Sound. Fish. Bull. 88: 223-239.

The hypothesis is presented that artificial reefs may have a negative impact on rockfish populations. Artificial reefs may not produce enough food for dense populations of rockfish whereas natural reefs are sufficiently productive. Many young fish were observed on the artificial reefs but few adults.

Moser, H.G., and G.W. Boehlert. 1991. Ecology of pelagic larvae and juveniles of the genus *Sebastes*. Env. Biol. Fish. 30: 203-224.

Pelagic larvae and juveniles of the genus *Sebastes* are widely distributed in continental shelf and slope waters of subarctic to temperate oceans, with greatest abundance in the Northern hemisphere. The ecology and distribution of the planktonic and micronektonic life stages were reviewed in relation to oceanographic conditions.

Nagahama, Y., A. Takemura, K. Takano, S. Adachi, and M. Kusakari. 1991. Serum steroid levels in relation to the reproductive cycle of *Sebastes taczanowskii* and *S. schlegeli*. Env. Biol. Fish. 30: 31-38.

The white-edged rockfish and the kurosoi are commercially important rockfishes found in the coastal waters of Japan. Serum steroid levels in females of the two species were measured during the annual reproductive cycle. Estradiol-17∂ (E_2) was at its lowest levels in August and highest levels in February at the end of vitellogenesis. Levels decreased rapidly after vitellogenesis.

The hormone 17∂,20ß-dihydroxy-4-pregnen-3-one (17∂,20ß-diOH prog) levels were high during gestation in May and low during vitellogenesis. Serum progesterone levels were at low levels for the duration of the reproductive cycle with temporal peaks coinciding with the highest levels of 17ß,20∂-diOH prog during gestation. The authors suggested that E_2 is the most important steroid involved in vitellogenesis and 17ß,20∂-diOH prog plays an important role in oocyte maturation and the gestation period.

Nakanishi, T. 1991. Ontogeny of the immune system in *Sebastiscus marmoratus*: histogenesis of the lymphoid organs and effects of thymectomy. Env. Biol. Fish. 30: 135-145.

The study suggests that the thymus plays an essential role in the development of the immune system and its functions continue into adult life in *Sebastiscus marmoratus*.

Phillips, J. B. 1964. Life history studies on ten species of rockfish (genus: *Sebastodes*). Cal. Dept. Fish and Game Fish Bull. No. 126. 70 p.

Life history data for 10 species of rockfish found off the coast of California are presented. The 10 species were: bocaccio, chilipepper, yellowtail rockfish, canary rockfish, vermilion rockfish, widow rockfish, dark-blotched rockfish, splitnose rockfish, stripetail rockfish and the short-belly rockfish.

Polovina, Jeffrey L. 1991. Evaluation of hatchery releases of juveniles to enhance rockfish stocks, with application to Pacific ocean perch *Sebastes alutus*. Fish. Bull. 89: 129-136.

Mathematical models were used to study the feasibility of raising 1-year-old Pacific ocean perch juveniles in hatcheries and using them to enhance the fishery. The Beaverton and Holt yield per recruit model was used to determine the effects of long-term introductions on the fishery. The Deviso-Schnute delay-difference age structure model was used to study short-term releases and a Ricker stock-recruitment model was used to determine the total recruitment of natural and hatchery raised rockfish, by weight, to the fishery. The models showed potential for more rapid recovery and higher yields of Pacific ocean perch with releases of up to five million juveniles annually.

The models used also showed similar potentials for augmenting natural stocks of yellowtail rockfish and canary rockfish. Because rockfish are slow growing and long lived, the stock recovery and/or enhancement efforts would, by necessity, be long-term projects.

Reilly, C. A., T. W. Echeverria, and S. Ralston, 1992. Interannual variation and overlap in the diets of pelagic juvenile rockfish (genus: *Sebastes*) off central California. Fish. Bull. 90: 505-515.

The authors determined diet overlap and annual variation of diet for five species of rockfish: the widow rockfish, yellowtail rockfish, chilipepper, short-belly rockfish and bocaccio. Primary food items were euphausiid eggs, copepod juveniles and copepods. Fish larvae were consumed only by the bocaccio juveniles. The data suggested opportunistic feeding by the juveniles.

Dietary overlap between species was studied to determine if competition existed. Latitude and depth effects on diet also were studied. Primary food items remained the same but were consumed in slightly different quantities as latitude changed. It could not be determined if any particular food item was limiting for juvenile rockfish.

Rosenthal, R. J., V. Moran-O'Connell, and M. C. Murphy. 1988. Feeding ecology of ten species of rockfishes (Scorpaenidae) from the Gulf of Alaska. Calif. Fish and Game, 74: 16-37.

The summer diets of 10 species of rockfish from southeast Alaska were presented and compared with rockfish food habits in other Pacific coastal regions. Fish were the primary food of black rockfish. Pacific sand lance was the primary fish consumed in southeast Alaskan waters. Herring and other small schooling fish species were the primary food for black rockfish in other Pacific coastal regions.

The yellowtail rockfish also consumed fish as a primary food. Pacific sand lance was the most commonly consumed fish in southeast Alaskan waters. Yellowtail rockfish also fed on numerous pelagic crustaceans and their larvae. Similar feeding habits have been observed off the coast of Washington.

The dusky rockfish was reported to feed on organisms suspended in the water column, especially crab larvae, copepods, amphipods and other crustaceans.

The widow rockfish consumed Pacific sand lance as its primary food. That species is not commonly seen in Puget Sound.

The Puget Sound rockfish, *S.emphaeus*, is a small, schooling rockfish that consumes copepods as its primary food.

Food for the china rockfish is usually obtained from the benthos. In southeast Alaska brittle stars were the primary food item while crustaceans were of secondary importance followed by fish.

The yelloweye rockfish is a large predatory reef fish that feeds close to the bottom. It is an opportunistic piscivore and was found to consume many other species of rockfish as well as herring, sand lance and lingcod. In southeast Alaska the primary fish eaten was the Puget Sound rockfish.

Quillback rockfish are also solitary reef-dwellers that stay close to the bottom. Crustaceans were the dominant food items with fish consumed when the opportunity arose.

The copper rockfish eats crustaceans and small fish that hover in the water column. Shrimp and sand lance were the dominant food items in southeast Alaska.

Caridean shrimp were the most important prey item for southeast Alaska tiger rockfish. Brachyuran crabs, gammarid amphipods and some small fish (herring and juvenile rockfish) also were consumed.

The success of rockfishes in the Pacific coastal zones from Baja California to Alaskan waters was attributed to their opportunistic foraging behavior. All species have shown a great deal of flexibility with respect to diet.

Seeb, L.W., and A.W. Kendall, Jr. 1991. Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus *Sebastes*. Env. Biol. Fish. 30: 191-201.

Allozyme polymorphisms were used in identifying rockfish larvae to species. Other DNA-level techniques will likely further increase the ability of researchers to identify rockfish larvae.

Shimizu, M., M. Kusakari, M.M. Yuoklavich, G.W. Boehlert, and J. Yamada. Ultrastructure of the epidermis and digestive tract in *Sebastes* embryos, with special reference to the uptake of exogenous nutrients. Env. Biol. Fish. 30: 155-163.

Ultrastructural features of the epidermis and rectum in *Sebastes schlegeli* and *S. melanops* during the late stages of embryonic development were studied to confirm uptake of maternal substances. The authors suggest that the embryonic epidermis is structurally loose and takes up low-weight molecules, while rectal cells, after the opening of the mouth, actively ingest exogenous, high-weight molecules.

Stahl-Johnson, K. L. 1984. Rearing and development of larval *Sebastes caurinus* (copper rockfish) and *S. auriculatus* (brown rockfish) from the Northeastern Pacific. M.S. Thesis, University of Washington, Seattle. 203 p.

Copper rockfish and brown rockfish were reared and described from birth to complete caudal fin formation. Fertilization for rockfish, in general, is internal with gestation usually lasting from three to six weeks. Active pelagic larvae are released at parturition. Peak insemination for copper rockfish appeared to be from January to February with peak insemination for brown rockfish in February and March. Peak parturition periods were from April to May for copper rockfish and from May to June for brown rockfish. Larvae have all been found in nature at temperatures between 9 C and 17.2 C.

Ripe females were held in circular flow-through tanks. Large rocks and/or bricks were added to the tanks to provide vertical relief and shelter for the fish. Sunshades also were provided.

Parturition of full-term embryos was only observed in conjunction with females that were kept separate in 600L tanks. Higher density caused premature abortion. The gestation period was from 41 to 44 days at 8.3 C to 9.1 C.

Temperature averaged 13.6 C ± 0.6 C. Dissolved oxygen concentration ranged from 6.3ppm to 7.9ppm and salinity from 28.0ppt to 30.2ppt. The pH was constant at 8.0. Light intensity, maintained by ambient daylight and fluorescent lighting over the tanks, was limited to 35 to 50 footcandles at the water surface.

Larval food consisted primarily of rotifers, *Brachionus plicatilus*, brine shrimp nauplii and assorted harpacticoid copepods. Phytoplankton was added to all larval rearing tanks to feed the zooplankton. Direct overhead lighting caused full-term larvae to dive to the bottom of the tanks. The larvae were mostly inactive in the absence of food but actively hunted and ate rotifers when the zooplankton were introduced. Brine shrimp nauplii were not as readily accepted. Larvae would preferentially feed on rotifers or the phytoplankton *Tetraselmis* spp. instead. The best diets for growth were combinations of rotifers, *Artemia* and copepods, but the rotifers were preferred. The author recommended stocking larvae at 2/L in a minimum volume of 100L with 500L being optimum.

Stein, D. and T.J. Hassler, 1989. Brown rockfish, copper rockfish and black rockfish. U.S. Dept. of the Interior, Fish and Wildlife Service, Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest). U.S. Fish and Wildlife Service, Washington, D.C. 15 p.

Most rockfish species are venomous. Poison glands are associated with all or some of the spines of the first dorsal, anal and pelvic fins. The venom is painful but not considered dangerous unless allergic symptoms or infection set in.

Brown rockfish are distinguished by a light brown body with darker brown mottling; pinkish caudal, pelvic and pectoral fin membranes; and a prominent dark brown blotch on the gill covers. Copper rockfish have a dark brown, olive, pink or orange-red back with patches of yellow or copper-pink. The white lateral line extends from below the first dorsal fin to the tail. The jaw has a smooth underside. Black rockfish have a black or blue-black body mottled with gray. The first dorsal fin has black spots and the upper jaw extends to behind the eye.

All rockfishes have internal fertilization and bear live young. The young receive nourishment from the mother by assimilating ovarian fluid. Insemination can take place during a month-long period and parturition can occur over a two-month period for any single species. Most rockfishes spawn once a year.

In Puget Sound, spawning occurs once a year for the brown rockfish. Eggs ripen and mature in the ovaries during winter and fertilization occurs directly after ovulation in March and April. Embryos develop and are released from April to July. Female brown rockfish of 311mm TL carry about 52,000 eggs and those of 477mm TL may contain as many as 339,000. Fecundity is directly related to TL of females.

Copper rockfish also spawn once a year in Puget Sound. The time of egg maturation has been estimated to vary from February to May in different studies. Fertilization is estimated to occur from March through May and parturition may occur as early as April. A 242mm female carried 15,600 eggs and a 474mm female carried 640,000 eggs.

Black rockfish probably spawn once a year. Eggs may develop as early as August. Parturition occurs off British Columbia from February to April and during January off the Oregon coast.

Black rockfish larvae are 5mm to 6mm at birth, as are copper rockfish larvae. Copper rockfish larvae are pelagic until they are 40mm to 50mm SL and have an ontogenetic migration. Black rockfish larvae are about 5.5mm at birth and are also pelagic until reaching about 40mm to 50mm SL.

Juveniles become benthic at 40mm to 50mm SL and may recruit to small reefs where they can hide in crevices. They can be associated with kelp, reefs, floating flotsam, piers and tide pools.

Distribution of adult brown rockfish in California shows a tendency for the older adults to migrate to deeper waters after spending up to five years in shallower nearshore areas. Adult copper rockfish are almost always found in association with the bottom in the rocky areas they frequent. They appear to remain close to their home location. In British Columbia black rockfish tend to form mixed-sex schools from June through September. They are found higher in the water column during upwelling periods. Larger adults may migrate from kelp beds during day and return before dusk. Smaller adults and juveniles stay more closely associated with kelp or other cover.

Sexual maturity in brown rockfish males is reached by 225mm in Puget Sound. All black rockfish males are mature by age 10 (430mm) and some may mature by age 3 (250mm). Copper rockfish females are all mature by age 7 or when they reach 410mm TL. Maximum recorded length is 55cm for the brown rockfish, 57cm for the copper rockfish and 60cm for the black rockfish. Growth rates for the copper rockfish are greatest up to age 3 in Puget Sound. Growth was found to be fastest during summer months reflecting high feeding rates.

Brown rockfish feed on crabs, small fish, shrimp, isopods and polychaetes. Copper rockfish feed mainly on benthic organisms; primarily crustaceans, fish and molluscs. Smaller copper rockfish (<45mm SL) feed primarily on calanoid copepods. At 110mm to 155mm they eat small crustaceans like amphipods, shrimp, caprellids and isopods. One to 3-year-olds eat juvenile Dungeness crabs and anchovies. Large copper rockfish are aggressive feeders known to eat spiny dogfish in Puget Sound. Black rockfish eat primarily fish and zooplankton like salps, mysids and crab megalops.

Of the three species discussed in this report, the brown rockfish has the widest range of environmental tolerance. Temperatures vary from 10 C to 17 C in their natural habitat (they live primarily above the thermocline) and the species can tolerate at least 22 C. Salinity tolerance is also judged as broad because the brown rockfish exists in estuarine and oceanic environments. No specific temperature information is presented for copper or black rockfish adults. Juvenile black rockfish occur at temperatures from 8 C to 18 C.

Brown rockfish are found to depths of 128 meters, the copper rockfish from shallow depths to 183 meters, and the black rockfish from the surface to depths of 366 meters. Brown rockfish are closely associated with rocky substrates and kelp beds. Copper rockfish are primarily found on rocky reef or rock-sand bottoms and black rockfish are usually found in mid-water in kelp or around cover such as piers, although some are found in open water as well.

Washington, P. M., R. Gowan, and D.H. Ito. 1978. A biological report on eight species of rockfish (*Sebastes* spp.) from Puget Sound, Washington. Northwest and Alaska Fisheries Centers Proc. Report. National Marine Fisheries Service, Seattle, Washington. 50 p.

Of the 21 species of rockfish that occur in Puget Sound, eight are commonly taken by sport and commercial fishermen. Those were the focus of this study. Several stomachs were examined from each species, and with the exception of bocaccio, sufficient data were obtained to provide a good indication of food habits.

Crustaceans and fish, in that order, were the most frequently observed foods in stomachs of copper rockfish. Of the crustaceans, 37% were crabs and 20% were shrimp (primarily *Pandalus danae*). Fish consumed included blennioids, some spiny dogfish and embiotocids. The copper rockfish appears to be an opportunistic carnivore.

Quillback rockfish appeared to use the same food items as the copper rockfish but in different proportions. Quillbacks consumed far less fish and crabs.

In stomachs of brown rockfish, crustaceans comprised 52% of the occurrences and fish 33%. Shrimp were the primary crustaceans, followed by crabs. Pacific sand lance and embiotocids were identified.

Black rockfish stomachs revealed that fish were the primary food followed by crustaceans and some jellyfish. Pacific herring, Pacific sand lance, and crab larvae were the most commonly occurring food organisms.

Fish were the primary food of yellowtail rockfish, followed by crustaceans. Pacific herring, Pacific sand lance and crab larvae were the most commonly found food items.

Fish appeared to be the primary food of yelloweye rockfish. Species recovered from yelloweye rockfish stomachs included walleye pollock, Pacific cod, Pacific hake and poacher.

The tentative age at first maturation was determined to be 3 years for copper and brown rockfish. Fifty percent of the eight species were mature by age 4 and all were mature by age 7. Most of the males begin maturation in December and are spent by April. Most females are ripe by January and spent by March. There was no indication of multiple spawning.

Wilkins, M.E. 1980. Size composition, age composition, and growth of chilipepper, *Sebastes goodei*, and bocaccio, *S. paucispinis*, from the 1977 rockfish survey. Mar. Fish. Rev. 42: 48-53.

Size and age compositions were compiled from length measurements and otolith samples of chilipepper and bocaccio from trawl catches off California. Similar growth patterns were observed in the two species. Females grew faster than males after the mean length at maturity had been reached.

Woodbury, D., and S. Ralston. 1991. Interannual variation in growth rates and back-calculated birthdate distributions of pelagic juvenile rockfishes (*Sebastes* spp.) off the central California coast. Fish. Bull. 89: 523-533.

Growth rates and back-calculated birthdates for five species of rockfish (short-belly rockfish, bocaccio, chilipepper, widow rockfish and yellowtail rockfish) were examined. Age estimates of the young-of-the-year rockfishes were made by looking at daily otolith increments.

Wourms, J. P. 1991. Reproduction and development of *Sebastes* in the context of the evolution of piscine viviparity. Env. Biol. Fish. 30: 111-126.

The evolutionary connotations of viviparity in *Sebastes* were discussed. The author hypothesized that vertebrate viviparity first evolved in fishes and was retained by vertebrates due to selective advantages. Rockfishes seem to be a transitional group in that they are in the first stages of changing from oviparity to full matrotrophic viviparity.

Yamada, J., and M. Kusakari. 1991. Staging and the time course of embryonic development in kurosoi, *Sebastes schlegeli*. Env. Biol. Fish. 30: 103-110.

Intraovarian development of embryos in *Sebastes schlegeli* was described in detail. Development was not much different than in oviparous fishes. Gestation period for *S. schlegeli* was estimated to be 48 days at 9.8 C.

Brown rockfish, *Sebastes auriculatus*

The following information is summarized from some of the papers listed in this bibliography that deal with multiple species of rockfishes.

Habitat Preferences

Adults: primarily found in high-relief reefs, known to move to low-relief and sand/eelgrass areas in summer. Not found on artificial reefs (Mathews 1988).

Juveniles: high-relief reefs primarily. Prefer kelp for cover. Become primarily demersal by September or October

Larvae: born pelagic feeders. Seem to prefer surface cover (e.g.,.kelp mats). Congregate in low current areas

Environmental Requirements

Temperature: 7 C o 13 C

Salinity range: Ambient range found in Puget Sound

Current velocity: strong

Behavior

Feeding: crustaceans (crabs and shrimp) and small fish

Schooling: not reported

Spawning: peak insemination period is January and February. Peak parturition period is May and June.

Previous Culture Attempts: Stahl-Johnson (1984) was able to rear the fish from wild broodstock to the time when caudal fin formation was complete.

Copper rockfish, *Sebastes caurinus*

The following information is summarized from some of the papers listed in this bibliography that deal with multiple species of rockfishes.

Habitat Preferences

Adults: bottom dwellers that prefer high-relief reefs (usually >30 meters deep). Are known to seek shallower low-relief and sand/eelgrass areas in summer (Mathews 1990).

Juveniles: seem to prefer low-relief reefs and sand/eelgrass areas. Often associated with heavy kelp cover near reefs. Become demersal at about four months.

Larvae: Born pelagic feeders. Associated with heavy surface cover (e.g., kelp mats). Tend to accumulate in low current areas.

Environmental Requirements

Temperature: 7 C to 13 C

Salinity range: ambient range found in Puget Sound

Current velocity: stronger current areas preferred as the fish grow larger

Cover: often associated with cover. Like to be in caves or rock crevices during winter and spring when they are mostly inactive.

Behavior

Feeding: primarily crustaceans and small fish

Schooling: appears to be generally solitary

Spawning: peak insemination period is January and February. Peak parturition period is April and May.

Previous Culture Attempts: Stahl-Johnson (1984) was able to rear the fish from wild broodstock to the time when caudal fin formation was complete.

Dygert, P.H., and D.R. Gunderson. 1991. Energy utilization by embryos during gestation in viviparous copper rockfish, *Sebastes caurinus*. Env. Biol. Fish. 30: 165-171.

The energy utilized by developing copper rockfish embryos was measured through direct respirometry and compared with the change in energy content of embryos from fertilization to birth. The difference between the energy consumed and energy lost during gestation indicates that 11.5% of the energy utilized during gestation is contributed by the mother after fertilization.

Gunderson, D.R., and P.H. Dygert. 1988. Maternal contribution of energy to embryos during gestation in the viviparous copper rockfish, *Sebastes caurinus* (Richardson). Fisheries Research Institute, Publ. FRI-UW-8718. University of Washington, Seattle. 8 p.

The energy requirements for developing copper rockfish embryos were measured through direct respirometry. This was compared with the energy obtained from the egg alone. The difference was ascribed to direct maternal inputs of energy during the development period. The results suggested that copper rockfish are matrotrophic with 11.5% of the energy consumed during gestation being contributed by the mother.

Haldorson, L., and L.J. Richards. 1986. Post-larval copper rockfish in the Strait of Georgia: Habitat use, feeding, and growth in the first year. In: Proceedings of the International Rockfish Symposium, 1986 Oct. 20-22, Anchorage, AK. Alaska Sea Grant Report No. 87-2, University of Alaska, Fairbanks. p. 129-141.

In August, young-of-the-year copper rockfish densities were highest in kelp beds, somewhat lower in eelgrass and *Agarum* slope, and lowest in sand habitats. By September, densities in kelp and sand had declined to near zero but eelgrass and *Agarum* slope population levels remained high. The trend continued in October.

Recently settled copper rockfish juveniles fed on planktonic zooplankton, epi-benthic crustaceans, and invertebrates associated with the benthos or macrophytes. Harpacticoid copepods, gammarid amphipods, caprellid amphipods, mysids and shrimp were important prey items.

Yellowtail rockfish, *Sebastes flavidus*

The following information is summarized from some of the papers listed in this bibliography that deal with multiple species of rockfishes.

Habitat Preferences

Adults: semi-demersal. Form large groups off the bottom during the day and may retreat to rocks at night. Found in Puget Sound at depths generally <24 meters.

Juveniles: initially pelagic but become more benthic when they are 40mm to 50mm long.

Larvae: pelagic

Environmental Requirements

Temperature: 7 C to 13 C may be suitable; not known with precision

Salinity range: Puget Sound and coastal waters of Washington seem appropriate

Behavior

Feeding: herring, sand lance, crab larvae, and euphausiids

Schooling: yes

Spawning: peak insemination in January. Peak parturition period is April and May.

Bowers, M.J. 1992. Annual reproductive cycle of oocytes and embryos of yellowtail rockfish *Sebastes flavidus* (family Scorpaenidae). Fish. Bull. 90: 231-242.

Female yellowtail rockfish were caught from Cordell Bank, Calif., to determine annual reproductive cycle. Gestation required about 30 days with parturition occurring between January and March. Mature oocytes were also collected in March, suggesting the Cordell Bank yellowtail population has a prolonged reproductive season extending into April.

Carlson, H.R., and R.E. Haight. 1972. Evidence of a home site and homing of adult yellowtail rockfish, *Sebastes flavidus*. J. Fish. Res. Bd. Can. 29: 1011-1014.

Existence of a home site and homing ability was established for adult yellowtail rockfish. Fish returned to the home site from as far as 22.5 kilometers, some after displacement to other schools of the species and some after three months in captivity. Stretches of deep open water appeared to pose a hindrance to homing. Intensive fishing of a localized adult stock could cause a long-term decline in its abundance.

Eldridge, M.B., J.A. Whipple, M.J. Bowers, B.M. Jarvis, and J. Gold. 1991. Reproductive performance of yellowtail rockfish, *Sebastes flavidus*. Env. Biol. Fish. 30: 91-102.

Reproduction of the yellowtail rockfish from Cordell Bank, Calif., was characterized in this study. Findings included reversal of the sex ratios and male-female ages and sizes at age throughout the annual cycle, heavier and longer females at age than males after sexual maturation, maturation of females at 6 and males at 8 years, long reproductive lifespans, distinct male and female gonadosomatic index patterns over the annual cycle, age- and size-specific fecundity, no difference between potential and realized fecundity, and seasonal changes associated with gonadogenesis.

Fraidenburg, M.E. 1980. Yellowtail rockfish, *Sebastes flavidus*, length and age composition off California, Oregon, and Washington in 1977. Mar. Fish. Rev. 42: 54-56.

Yellowtail rockfish length and age samples from a survey of rockfishes off California, Oregon and Washington were analyzed to produce length and age composition data for the area from lat. 35°30'N to 48°30'N. There was evidence of a north to south cline of decreasing size and age.

Laroche, W.A., and S.L. Richardson. 1980. Development and occurrence of larvae and juveniles of the rockfishes *Sebastes flavidus* and *Sebastes melanops* (Scorpaenidae) off Oregon. Fish. Bull. 77: 901-923.

See abstract under "Black Rockfish"

MacFarlane, R.B., E.C. Norton, and M.J. Bowers. 1993. Lipid dynamics in relation to the annual reproductive cycle in yellowtail rockfish (*Sebastes faavidus*). Can. J. Fish. Aquat. Sci. 50: 391-401.

In yellowtail rockfish, lipids that accumulated in the mesenteries and liver during the summer and early fall upwelling were subsequently translocated to developing ovaries during late fall and winter.

Pearcy, W.G. 1992. Movements of acoustically-tagged yellowtail rockfish *Sebastes falvidus* on Heceta Bank, Oregon. Fish. Bull. 90: 726-735.

Movements of 25 yellowtail rockfish on Heceta Bank, off Oregon, were studied by acoustical tagging and tracking. Some fish remained at the capture site after release or returned after displacement to a different release site. Tagged yellowtail rockfish usually remained at midwater depths of 25 to 35 meters, well above the sea floor depth of about 75 meters. No obvious diel vertical or horizontal migrations were detected.

Quillback rockfish, *Sebastes maliger*

The following information is summarized from some of the papers listed in this bibliography that deal with multiple species of rockfishes.

Habitat Preferences

Adults: demersal. Prefer high-relief reefs through most of the year, but low-relief in summer. Not seen in eelgrass areas (Mathews 1988).

Juveniles: seem to prefer artificial and low-relief reefs

Larvae: pelagic and often associated with floating kelp

Environmental Requirements

Temperature: 7 C to 13 C

Salinity range: ambient Puget Sound range

Behavior

Cover: prefer rocky areas

Feeding: molluscs, polychaetes, crustaceans and small fishes

Schooling: none. Species is solitary.

Spawning: peak insemination in January. Peak parturition period is April and May.

Culture attempts: Canino (1987) hatched them and maintained them to 1 day of age.

Black rockfish, *Sebastes melanops*

Boehlert, G.W., and M.M. Yoklavich. 1983. Effects of temperature, ration, and fish size on growth of juvenile black rockfish, *Sebastes melanops*. Env. Biol. Fish. 8: 17-28.

Young *Sebastes melanops* live as pelagic larvae and juveniles in offshore waters, recruiting to the nearshore environment at approximately 6 months of age. During the summer upwelling season, juveniles may be captured in tidepools and shallow coastal waters, where temperatures may be as low as 8 C, or in shallow estuarine habitats where temperatures reach 18 C.

The study described in this paper was conducted to determine the effects of temperature, ration, and fish size on growth. Growth in length ranged from -0.023mm to 0.314mm per day, relative growth in weight ranged from 0.689% to 1.495% body weight per day, and gross conversion efficiencies ranged from -13% to 21% among treatments. At rations expressed as percent maximum at a given temperature, growth increased with increasing temperature. Maximum relative ration (% body weight per day), however, decreased with decreasing temperature. At equivalent relative rations, growth did not differ significantly among temperatures. The results suggest that the thermal environment has an important effect on first year growth of black rockfish.

Boehlert, G.W., and M.M. Yoklavich. 1984. Reproduction, embryonic energetics, and the maternal-fetal relationship in the viviparous genus *Sebastes* (Pisces: Scorpaenidae). Biol. Bull. 167: 354-370.

In the black rockfish, egg size is small (0.8mm), but the gestation period is 37 days and larvae at birth are well developed, with a remnant of yolk and the ability to initiate feeding. A bioenergetic study demonstrated that approximately 70% of the catabolic energy used during gestation is contributed by the maternal system.

Laroche, W.A., and S.L. Richardson. 1980. Development and occurrence of larvae and juveniles of the rockfishes *Sebastes flavidus* and *Sebastes melanops* (Scorpaenidae) off Oregon. Fish. Bull. 77: 901-923.

Developmental series of larvae and juveniles *Sebastes flavidus* and *S. melanops* are described and illustrated.

Yoklavich, M.M., and G.W. Boehlert. 1991. Uptake and utilization of ^{14}C-glycine by embryos of *Sebastes malanops*. Env. Biol. Fish. 30: 147-153.

The ability of embryos of black rockfish to take up nutrients from an exogenous substrate was demonstrated by incubating embryos at various stages of development (18 to 30 days after fertilization) in ^{14}C-labeled glycine for 24 hours. Uptake was highest for embryos at the latest stages (28-30 days) and increased at a linear rate during the incubation period.

EMBIOTOCIDAE

General

Fritzsche, R.A., and T.J. Hassler. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific southwest). Pile perch, striped seaperch, and rubberlip seaperch. U.S. Dept. of the Interior, Biological Report 82 (11.103) TR EL-82-4. Washington, D.C. 15 p.

The literature on the life histories of pile perch, striped seaperch and rubberlip seaperch is reviewed in this paper.

Webb, P.W., and J.R. Brett. 1972. Respiratory adaptations of prenatal young in the ovary of two species of viviparous seaperch, *Rhacochilus vacca* and *Embiotoca lateralis*. J. Fish. Res. Bd. Can. 29: 1525-1542.

The structure of the ovary and embryos of embiotocids was reviewed in relation to factors that would affect the exchange of materials between ovarian and embryonic blood streams. It was concluded that convection of the ovarian fluid must occur as a necessary mechanism for efficient exchange of materials with increasing brood/ovary weight ratio. It was further concluded that the supply of materials to the brood would be limited by ovarian blood-flow characteristics rather than structural considerations, except immediately prior to parturition.

Webb, P.W., and J.R. Brett. 1972. Oxygen consumption of embryos and parents, and oxygen transfer characteristics within the ovary of two species of viviparous seaperch, *Rhacochilus vacca* and *Embiotoca lateralis*. J. Fish. Res. Bd. Can. 29: 1543-1553.

Oxygen tension and content of intraovarian fluid were measured. Oxygen tension decreased with increasing demands of the brood. Oxygen consumption of two pregnant striped seaperch, *Embiotoca lateralis*, was fairly constant at 70mg O_2/kg/hr early in gestation, increasing later to approximately 107mg O_2/kg/hr at parturition.

Pile perch, *Rhacochilus vacca*

Wares, P.G. 1971. Biology of the pile perch, *Rhacochilus vacca* in Yaquina Bay, Oregon. Tech. Papers Bur. Sport Fish. Wildl. No. 57. Washington, D.C. 21 p.

Growth, reproduction, food habits and parasites of pile perch were investigated in Yaquina Bay, Ore. Fish live at least 10 years. Males and females of given ages are close to the same size up to age 4, after which females are increasingly larger than males. Males and females approach average ultimate sizes of 1,120g at 430mm and 2,000g at 490mm TL. Some females mature in their second year; 90% mature at age 3. Some males also mature in their second year. Mating occurs in the fall; there is a delay of about three months before fertilization. The gestation period is about 6.5 months. Most young are born between late June and early August. Pile perch are carnivorous, obtaining food from the bottom or protruding surfaces in the littoral zone. The diet varies between seasons and localities. Principal foods are barnacles, mussels, bay clams, crabs, mud shrimp and a tube-dwelling amphipod.

Striped seaperch, *Embiotoca lateralis*

Haldorson, L., and M. Moser. 1979. Geographic patterns of prey utilization in two species of surfperch (Embiotocidae). Copeia, 1979: 567-572.

The diet of striped seaperch was examined from Puget Sound, Wash. to Santo Tomas, Baja California, Mexico. The species consistently consumed amphipods and bryozoans.